CHARACTERISATION OF COMMUNAL RANGELAND DEGRADATION AND EVALUATION OF VEGETATION RESTORATION TECHNIQUES IN THE EASTERN CAPE, SOUTH AFRICA

A Thesis submitted in fulfilment for the degree of

DOCTOR OF PHILOSOPHY IN PASTURE SCIENCE

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'Mota Samuel Lesoli December 2011

ACRONYMS

AET – Actual Evapotranspiration

APS – Atmosphere-Plant-Soil

ARC – Agricultural Research Council

ARC - SCW – Agricultural Research Council – Institute for Soil, Climate, and Water

ARDRI – Agricultural Research and Rural Development Institute

ATA – Amakhuze Tribal Authority

AU – Animal Units

ANOVA - Analysis of Variance

CAM – Crassulacean Acid Metabolism

CBNRM - Community Based Natural Resource Management

CC - Carrying Capacity

CEC – Cation Exchange Capacity

CSIR – Council for Scientific and Industrial Research

DSS - Decision Support System

EC – Electrical Conductivity

ET - Evapotranspiration

GIS – Geographic Information System

GLM – Generalized Linear model

GMRDC – Govan Mbeki Research and Development Centre

GPS – Global Positioning System

HCZ – Homogeneous Climate Zone

HRM - Holistic Range Management

IPCC – Intergovernmental Panel on Climate Change

IWM –Integrated Watershed Management

IWUE – Intrinsic Water Use Efficiency

LAI – Leaf Area Index

LU - Livestock Units

LSD – Least Significant Difference

LSF - Linear Structure and Function Model

LWP – Livestock Water Productivity

NEP - Non-Equilibrium Persistent

RC - Range Condition Model

RMA – Rangeland Management Associations

RUE – Rain Use Efficiency

RWH - Rainwater Harvesting

SAS – Statistical Analysis System

SE – Standard Error

SAWGA - South African Wool Growers Association

SAWS – South African Weather Service

SWC - Soil and Water Conservation

SWR – Soil Water Repellency

UCS - Unconfined Compressive Strength

USAID – United States Agency for International Development

WUE – Water Use Efficiency

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DEDICATION

This thesis is dedicated to my daughter **SEAPEI EVELYN LESOLI**.

ABSTRACT

This study assessed the social factors influencing poor communal rangeland management, which are assumed to result in rangeland degradation. This was followed by, examination of biophysical characteristics of rangeland degradation in communal areas. To relate social factors featuring in communal rangeland management with rangeland degradation, biophysical factors influencing livestock grazing distribution patterns were studied. To establish the solution to communal rangeland degradation, rangeland restoration techniques were evaluated. The study was conducted at Amakhuze Tribal Authority (ATA) (S32^o 38´, E26^{o}56, 763 - 1500 m.a.s.l) composed of six villages and Phandulwazi Agricultural High School (S32^o 39´ and E26^o 55´, 747 m.a.s.l). Focus group discussions were conducted in six villages and questionnaire surveys in four randomly selected villages to assess social factors influencing communal rangeland degradation. Communal rangeland degradation biophysical characteristics were assessed. Biophysical factors affecting livestock grazing distribution pattern were examined through direct field observations for 12 months. Restoration techniques were evaluated on 26 plots.

The social factors influencing communal rangeland management include lack of skills on rangeland management for farmers, lack of individual/community obligation on grazing management, lack of effective policies and/or poor enforcement accompanied by lack of effective institutions governing rangeland utilisation and management. Communal rangelands were more (χ^2 = 2612.07, df = 26, p < 0.01) degraded compared with controlled grazing areas. Within the communal rangelands, land degradation was higher at the low-lying areas, compared to foothills, midslopes, and mountaintop (crest). Rangeland degradation in communal areas was characterised by poor forage productivity and poor vegetation cover , higher soil unconfined compressive strength (UCS) (4.5 kg/cm^2) with low hydraulic conductivity (5.21 x 10^{-3}) and physical soil loss characteristics such presence of terracettes, pedestals, rills and gullies. Grazing distribution was higher at valley bottom ($r^2 = 0.404$, $p < 0.001$), low altitude ($r^2 = -0.007$, $p < 0.001$), closer to water points ($r^2 = -0.001$, $p < 0.001$), and on grassland vegetation ($r^2 = 0.620$, $p < 0.001$). Introduction of seedlings with microcatchment combined with brushpack promoted ($p < 0.05$) higher number of tillers (13), leaves (42) and reduced seedling mortality (10.4%). *T. triandra* produced higher ($p < 0.05$) number of tillers (12) and leaves (39) but low number of inflorescence (0.7) with higher mortality rates (25.3%) compared to *P. dilatatum*. Where plant propagules were introduced as seeds, use of microcatchment promoted higher seed germination ($F = 38.84$, $p < 0.05$) and maintained higher plant density ($F = 37.43$, $p < 0.05$). *E. curvula* seeds attained higher germination rate and maintained higher plant density compared to *D. eriantha* and *P. Maximum*. Use of microcatchment, brushpack, and water spreading system promoted soil water retention.

It is important that any interventions aimed at improving communal rangeland management, controlling rangeland degradation in the communal areas, or restoring degraded rangelands to consider the social factors driving rangeland management and biophysical factors influencing grazing distribution pattern. Rangeland restoration techniques for communal areas should be centred on their ability to collect and retain water to promote restoration performance of introduced plant propagules.

Key words: grazing distribution, communal rangelands, rangeland degradation, rangeland restoration

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1. INTRODUCTION

1.1. Background

[1] A communal area can be defined as an area where rangelands are held under communal (for or by a group rather than individuals) tenure, while individuals or households have some other form of individual right to arable land (Abel 1997). Everson and Hatch (1999) further defined communal rangelands as those areas where agriculture is largely subsistence-based and where rangelands are generally communally owned and managed as opposed to private or individual ownership. The key feature defining communal rangelands is that these systems are held and administered as a common property, or common pool resource (Toulmin *et al*. 2004). The two most important characteristics of common property resources are that exclusion of users of these resources is difficult and that each user is capable of subtracting from the welfare of others (Berkes *et al*. 1989; Ostrom *et al*. 1999). However, some of communal rangelands are open-access in nature than being managed as common property, hence a waning commitment to their management (Ainslie 1998).

In South Africa, communal areas were established under the Natives Land Acts of 1913 and 1936 under which indigenous South African people were resettled in specific areas formally referred to as homelands (Wessels *et al*. 2007). Black people engaged in crop-livestock production, mainly for subsistence, predominantly populate these areas (Wessels *et al*. 2004). These areas are characterized by high human and livestock populations, overgrazing, soil erosion, and loss of more acceptable grazable species (Hoffman and Todd 2000). The communal rangeland tenure system is such that all members of the community have rights to the rangeland resources (Hahn *et al.* 2005).

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Communal rangelands are used primarily as a source of feed for livestock. They, however, provide other secondary resources such as firewood, wild foods, medicinal plants, and water. Land degradation is the major challenge in the communal rangelands of Eastern Cape (Palmer *et al*. 1997), because it reduces primary productivity and soil protection. Abel and Behnke (1996) defined rangeland degradation as an effectively permanent decline in the rate at which land produces forage for a given input of rainfall under a given system of management. While, Hahn *et al*. (2005) defined land degradation as the reduction or loss of biological and economic productivity arising from inappropriate land use practices.

Land degradation results in declining functional capacity, increased poverty, and food insecurity (Cohen *et al*. 2006). Major changes in rangeland surface morphology and soil characteristics have a drastic effect on the primary productivity of the rangeland ecosystem, and in turn on livestock production (Payton *et al*. 1992). This suggests a need for interventions to halt degradation and improve the functional capacity of communal rangelands. Understanding of the causes, level, and nature of degradation should precede the intervention. There are a number of factors responsible for degradation; among others are climate, grazing (Arnalds and Barkarson 2003), soil quality, and landform and its influence on rangeland ecosystem hydrology (Garcia-Aguirre *et al.* 2007).

Degraded ecosystems characterized by low productivity, low diversity or both are often trapped in stable states, showing little or no improvement over time. Restoration can improve their utility. The interventions required to restore productivity are often not clear (Cummings *et al*. 2007). Identification of putative abiotic and biotic barriers to the natural regeneration of more desirable vegetation can lead to the implementation of appropriate restoration treatments (Whisenant 1999). The potential for ecosystem restoration can be optimised if the functional status of ecosystems is defined beforehand and the relationship between ecosystem structure and functioning can be established (Cortina *et al*. 2006).

In communal areas, community members influence management of rangelands; therefore, there is a need to engage them in the identification of degradation as a problem, vegetation restoration, and proper rangeland management as a solution and identification of a desirable state. Local communities and other stakeholders such as policy makers and researchers must play an important part in the process if sustainable rehabilitation is to be achieved (Everson *et al*. 2007). Community based natural resource management (CBNRM) is regarded as the best approach to encourage better resource management with the full participation of resource users in decision-making activities and the incorporation of local institutions, customary practices and knowledge systems in the management process (Armitage 2005). Kavana *et al*. (2005) suggest that there should be complementarities of modern scientific knowledge and traditional natural resource management for sustainable livestock productivity, biodiversity, and soil conservation in traditional agricultural systems. A scientific view might promote restoration goals derived from geomorphological and ecological imperatives (Kondolf 1998). However, restoration is more of a process of modifying the biophysical environment and captures the interaction between scientific definitions and the goals of society as a whole (McDonald *et al*. 2004).

This study aimed to assess the perceptions of land users on rangeland degradation and restoration techniques; assess communal rangeland degradation characteristics and evaluate restoration techniques in the communal rangelands of Amakhuze Tribal Authority in the Eastern Cape Province of South Africa.

1.2. Objective

To identify the key characteristics of rangeland degradation and evaluate restoration techniques in communal areas of the Eastern Cape Province, South Africa.

1.2.1. Specific objectives

1. To investigate social factors influencing poor management of communal rangelands and drivers of communal rangeland degradation.

2. To compare the occurrence of land degradation between rangeland management practices, between landscapes, and identify rangeland degradation characteristics in communal areas of Eastern Cape.

3. To examine factors influencing livestock grazing distribution pattern in the communal rangelands of Eastern Cape.

4. To evaluate water collection and storage effects of restoration techniques on performance of introduced plant propagules on degraded rangelands.

1.2.2. Hypotheses

1. The null hypothesis was that communal farmers have skills in rangeland management, take livestock grazing management as their individual and community obligation, and have effective policies and institutions governing utilisation of rangeland resources and that has lead to good rangeland management practices, hence, no rangeland degradation. This is based on the assumption that, if the farmers have skills for livestock-rangeland management, take grazing management as individual/community obligation, and have effective policies and institutions to regulate access and utilisation of rangelands; there would be proper grazing management and there will be no rangeland degradation. Furthermore, if the farmers have

rangeland management skills, they would understand rangeland management practices and their rationale. That would lead to farmers comprehending the reasons for responsibility in livestock movement control.

2. The null hypothesis was that communal rangeland degradation occurrence is not different compared to the controlled grazing areas, land degradation does not vary with landscapes within communal rangelands, is not characterised by poor forage production and vegetation cover, high soil compaction with low infiltration and soil loss. This hypothesis is based on the premise that grazing intensity and frequency are not controlled in the communal areas and that this leads to rangeland degradation. Rangeland degradation could be indicated by the dominance of grass species such as increaser II category and poor vegetation cover. In addition, occurrence of physical rangeland degradation indicators such as pedestals, terracettes, rills, and gullies would be high on communal rangelands due to high runoff rates preceded by poor soil cover. In the communal areas, because of poor grazing management control, rangeland degradation would vary between the landscapes, thus, areas receiving high utilisation would be more degraded than areas with low utilisation intensity.

3. The null hypothesis was that grazing distribution pattern in communal areas is not affected by landscape, vegetation type, land use practices, seasonal climatic changes and grazing distance from drinking points; thus, grazing pressure is distributed evenly, and therefore, rangeland degradation cannot be associated with grazing distribution. This is based on the premise that areas subjected to higher grazing intensity and frequency are susceptible to land degradation due to reduced species composition and soil cover resulting from over-utilisation. Poor soil cover exposes the soil to high runoff rates that successively washes away the soil particles and simultaneously increases the rate of water loss from the rangelands. The spatial factors could include landscape and altitude variation, land use practices, vegetation types,

and distribution of water bodies. Temporal factors on the other hand could include seasonal variations, which are responsible for change in rainfall and temperature.

4. The null hypothesis was that rangeland restoration is not dependent upon water availability in the soil and therefore, could not be improved by restoration techniques that promote collection and retention of water and introduction of plant propagules. This hypothesis is based on the conception that there are barriers of vegetation natural recovery or artificial restoration success. These barriers include low soil moisture content, low soil temperature, poor sunlight-leaf interception, low soil seedbank, and high grazing disturbance. Therefore, restoration techniques should aim at addressing these natural vegetation recovery barriers. Development of microcatchments and use of brushpacks would improve soil moisture storage. That is through collection of runoff water and reduction of soil moisture loss. These are achieved through improved infiltration rates resulting from digging and reduced evaporative loss by shading effect of brushpack. Introduction of plant propagules (seeds and seedlings) would address the low soil seedbank barrier. The higher water collection and retention levels promote germination of seeds, establishment, and growth of seedlings. Furthermore, use of water collection and retention practices such as water spreading systems, use of brushpack, and microcatchment where the plant propagules are not introduced could support germination from the seedbank and regrowth from the remaining tufts.

2. LITERATURE REVIEW

2.1. Causes and extent of degradation in communal rangeland

2.1.1. Livestock grazing patterns and location in different seasons within the rangelands

Cattle naturally form a herd when they are grazed in rangelands and the distance between individuals may be influenced by various factors. The spatial pattern formed by a cattle herd is usually aggregated and the area occupied by the herd does not infinitely increase (Shiyomi 1995). The area occupied reaches equilibrium and attraction activities (desire to be in a group) are balanced in the herd, although the area they occupy is elastic within the grazing land (Shiyomi and Tsuiki 1999).

Animals exhibit certain foraging mechanisms during grazing; these mechanisms were divided into non-cognitive, cognitive, and foraging models based on rules and optimal foraging theory (Bailey *et al*. 1996). The non-cognitive mechanisms do not require herbivores to use memory during foraging and they require little judgement from animal. These include (i) foraging velocity – the rate at which herbivores transit different portions of the landscape could affect aggregate grazing patterns. Slower movement through areas of greater nutrient abundance would ensure that herbivores spend proportionally more time in nutrient-rich areas (Bailey *et al*. 1996); (ii) Turning frequency and angles – if animals turn more often during grazing in nutrient-rich patches or feeding sites, their twisting grazing pathway would result in proportionally more time spent in the nutrient-rich area (Bailey *et al*. 1996). (iii) Intake rate – there is an indirect relationship between intake rate and forage availability and that can explain the grazing pattern (Forbes 1988). (iv) Neck angle – Changes in neck angle may provide a stimulus to initiate small-scale movements between feeding stations (Jiang and

Hudson 1993). (v) Slope – slope gradient is an important determinant of grazing distribution of herbivores (Bailey *et al*. 1996).

Cognitive mechanisms may affect behaviour that occurs at small and large scales. Learning and memory affect diet selection and may be important in selecting feeding sites (Bailey *et al*. 1996). The cognitive mechanisms of animal grazing patterns are based on learning and memory. These include (i) learning model of diet selection – thus diets selected by herbivores are affected by post-ingestion feedback from nutrients and toxins (Provenza 1995). (ii) Momentary maximisation – diet selection is maximised at each moment along the grazing pathway (Senft *et al*. 1987), momentary maximisation assumes that animals select the best available alternative at any given time (Provenza and Cincotta 1993). (iii) Frequency of patch and feeding site selection – herbivores may return to nutrient-rich productive patches and feeding sites. Bailey (1995) reported that cattle in a heterogeneous grazing area did not return to a feeding site with lower forage quality for 21 consecutive days and alternated between the remaining two feeding sites with higher quality forage.

Rule-based model – grazing mechanisms in some foraging models assume that the search for patches is random while other models use simplistic rules for locating patches and feeding sites within the animals' habitat (Bailey *et al*. 1996). Suitability, distance from other patches, presence of other animals and the time since the last visit were four rules to direct herbivore movements in a spatially explicit foraging model (Hyman *et al*. 1991). Optimal foraging theory provides a functional approach for examining grazing behaviour, foraging behaviours are heritable, and that a currency (e.g. energy, protein) can be identified to link foraging behaviour with fitness (Pyke 1984).

Sustainable use of rangelands for grazing depends on an understanding of how grazing interacts with the underlying environmental variables and ecological processes of these ecosystems (Solomon *et al*. 2006). Herbivores can influence or regulate forage quality and availability through influence on changes in production, plant species composition, and rates and pathways of nutrient cycling (Person *et al*. 2003). Grazing can increase palatability of forages by increasing nitrogen content of aboveground biomass or by shifting demographics of plants toward younger and more mitotically active individuals (Ritchie *et al.* 1998). The condition of the grazing area is influenced principally by herbivore species, densities and landscape structure (Person *et al*. 2003).

Population densities of grazing animals and intensity of their foraging can determine some rangeland dynamics. It determines whether herbivory increases nutrient cycling and plant productivity or affects plant communities by driving changes in successional pathways, decreasing nutrient cycling, and influencing biodiversity of those communities (Kieland *et al*. 1997; Pastor and Cohen 1997; Olff and Ritchie 1998; Harrison and Bardgett 2004). When herbivores exhibit density-dependent reductions in physical condition and fecundity with increasing population size, a corresponding negative effect on the plant community is expected with reductions in plant productivity and nutrient cycling (Stewart *et al*. 2006). Such effects drive changes in successional pathways or lead to degradation of plant communities (Pastor and Cohen 1997; Person *et al*. 2003).

Most of the rangelands in the Eastern Cape Province consist of a mixture of uplands and lowlands. The lowlands are generally 5 to 30 m lower and are grazed approximately three times more intensely than associated uplands due to easy access by animals (Senft *et al.* 1985). Because rangelands occur at heterogeneous topography, any activity on rangelands requires a spatial knowledge of soil physico-chemical properties (Corwin and Lesch 2005). Severe grazing reduces litter cover and increases bare ground portion of land through reduced plant density and vigour; and this in turn reduces plant basal cover and exposes land to soil erosion (Milchunas *et al*. 1989).

Long term grazing can have effects on soil water and nutrient cycling dynamics (McNaughton *et al*. 1988). Furthermore, long term grazing intensity can alter litter, plant basal and canopy cover characteristics, which can also affect soil water dynamics by altering microclimate and soil temperature (Day and Detling 1994). Soil moisture, soil temperature, and soil organic matter are believed to be among the most important soil physicochemical properties influencing population dynamics, activity, and ecology of soil microbiota (Varnamkhasti *et al*. 1995).

Overgrazing of rangelands has often been mentioned as one of the major causes of land degradation and desertification (Verburg and van Keulen 1999). Grazing impacts on watershed properties vary naturally from area to area and over time due to the normal variability of climate, vegetation, intensity, and duration of livestock use (Blackburn 1983). Many concerns with livestock grazing in arid rangelands are the results of uneven grazing distribution (Bailey 2004). Typically, cattle graze areas with gentle terrain and near water more heavily than rugged terrain or areas far from water. Physiographically diverse rangelands will have areas of over utilization adjacent to areas with under utilization because the negative interaction between slope and distance to water promotes over concentration of use on areas adjacent to water sources (Pinchak *et al.* 1991). Livestock affect plant species composition directly by grazing and trampling; although impacts vary with animal density and distribution (Belsky and Blumenthal 1997).

There is an increasing awareness of the importance of grazing and grazing animals in the dynamics of ecological systems. There is also an increasing interest in the role played by large herbivores in shaping and maintaining vegetation formations (Pratt *et al*. 1986; Moleele and Perkins 1998; Schuman *et al.* 2002; Oztas *et al*. 2003; Maki *et al*. 2007). The inter-relationships between herbivores and vegetation are more complex than many models recognize. They are influenced as much by the behaviour and ecology of the herbivores as by ecological responses of different plant species to trampling or defoliation.

It is generally perceived that rangeland degradation in communal areas is caused by overgrazing (Varnamkhasti *et al*. 1995; Verburg and van Keulen 1999). The main objective of grazing management practices is to achieve an equitable distribution of livestock use among areas and plant communities within a pasture (Pinchak *et al*. 1991). Grazing-induced degradation often intensifies natural ecosystem change patterns and may largely subsume simple radial effects (Pickup 1998). While grazing has been reported to be one of the factors causing degradation, especially species change, species loss has also been observed to occur in rangeland areas where there has never been domestic animals grazing (Curry and Hacker 1990). This makes it difficult to separate the impact of natural declining land condition and biodiversity from that of introduced herbivory (Pickup 1998). Livestock reduce plant cover and compact the soil, increasing the volume of overland water flow (Blasky and Blumenthal 1997).

Animal grazing density and intensity is influenced by drinking water distribution within rangelands. The degree of water dependency is determined by the ability of an animal to absorb water from faecal material during passage through the large intestines and by mechanisms of thermoregulation (Owen-Smith 1999). Animals spend most of the grazing time around drinking points and that subjects the grazing areas adjacent to water points to severe grazing and subsequently to soil erosion. Van Rooyen *et al*. (1994), and Friedel (1997), suggested that the reasons for vegetation change along a distance gradient from livestock watering points, and in relation to land use are complex and dependent on the interaction of rainfall, landscape characteristics, and grazing.

The effects of herbivore grazing pressure on plant species distribution patterns in the broader landscape are distinct from those affecting the environment of the heavily trampled sacrifice area immediately around a water-point (Friedel *et al*. 2003). Large mammalian herbivore density declines with increasing distance to drinking points. Water-points provide a focus for niche separation amongst grazing herbivores when forage is limited in quantity and quality (Fensham and Fairfax 2008). Animal species vary with water dependency, browsing, and highly mobile animal species are the least dependent on water (Smit *et al*. 2007).

2.1.2. Climate change: impacts, vulnerability and adaptations on rangeland degradation

Major effects of climate change on rangelands could be on vegetation biodiversity, land degradation, and water dynamics. Climate change and biodiversity loss are global problems, their causes are complex, frequently local and vary from one part of the world to another (Pickup 1998). Climate change and climate variability have affected, and are projected to continue to affect, individuals, populations, species and ecosystem composition and function (Gitay 2004). Climate change affects land degradation through changes in vegetation, soils, and the hydrological cycle. Grazing with domestic livestock is the major land use in the communal rangelands in Southern Africa. As the rangelands are affected by climate change, vegetation properties, soil properties, and rangeland water dynamics will change. That will lead to the farming and grazing systems, particularly in the arid, semi-arid, and sub-humid areas being altered as a response to higher rainfall variability, and to changes in the frequency and intensity of droughts and floods (Gitay 2004).

Climate change has been identified as a major current issue for the world's rangelands (Harle *et al*. 2007; Henry *et al*. 2007; Howden *et al*. 2008, Wei *et al.* 2008). Multiple environmental changes will have positive or negative consequences for global vegetation. The consequences will vary in different areas, thus some areas will benefit from an increased rainfall while other areas suffer. This will affect crop and pasture yields and forest productivity (Reilly *et al*. 2007). It is further expected to bring about major change in freshwater availability, the productive capacity of soils, and in patterns of human settlement (Raleigh and Urdal 2007). As the impacts of climate change intensify, this may have substantial impacts on rangeland ecosystems, agricultural crops, water resources, and in turn affect human health and livelihood (Lioubimtseva and Henebry 2009).

Increasing temperatures, precipitation anomalities, and extreme weather are expected to aggravate the processes of resource degradation that are already underway (Hormer-Dixon and Blitt 1998). Meier *et al*. (2007) reported that decreased vegetation is associated with an escalation of pastoral conflict in the Horn of Africa. It is important to consider the potential impact of changing climates, especially with respect to rainfall distribution and quantity (Meadows and Hoffman 2003). Although degradation is the result of interaction between natural and social dynamics, it is closely, but differently related to the spatial pattern of human activities (van der Leeuw and Archaeomedes Research Team 2005). Climate change is likely to influence food-producing capacity in many areas. Thus, some areas may experience a reduction in production while other places are likely to benefit (Raleigh and Urdal 2007).

An increase in temperature of a few degrees is projected to increase crop yield in temperate areas. However, in tropical areas, where dry land agriculture dominates, even a minimal increase in temperature may be detrimental to food production (IPCC 2001).

Climate change affects land degradation through changes in vegetation and soils, and through changes to the hydrological cycle. Degradation of soil and water resources is likely to be intensified by adverse changes in temperature and precipitation, although adaptive behaviour has the potential to mitigate these impacts as land use and management have been shown to have greater impact on soil conditions than the indirect effect of climate change (IPCC 2001; Raleigh and Urdal 2007).

Higher water temperatures are likely to lead to a degradation of water quality; however, non-climatic factors may influence freshwater availability and quality to a larger degree than climate change. Thus, water management may significantly reduce vulnerability (IPCC 2001). Climate change also alters farming and grazing systems as a response to higher rainfall variability and to the shortening of fallow periods. Climate change presents multiple stresses to the rangeland ecosystems; these include low temperatures, high wind speeds, short growing seasons, low nutrient availability, and soil moisture. These may limit plant growth and primary production in rangelands (Walker *et al*. 1994)

Rainfall variability and uncertainty surrounding its annual reliability have prompted dryland communities to adapt to dynamic climatic, environmental, and weather conditions throughout history (Stringer *et al*. 2009). However, the speed of current climate change is feared to exceed the limits of adaptation in many parts of the world (Adger and Vincent 2005). The African continent has low adaptive capacity and it is sensitive to many of the projected changes and therefore, highlighted as particularly vulnerable in the future (IPCC 2007). Vulnerability of the African continent to land degradation due to the rapid climate change will be more emphasised in communal areas. A combination of rainfall and geomorphological factors coupled with the historical and political circumstances is likely to render the communal areas more susceptible to future intensification of the land degradation problem especially under the rapidly changing climatic conditions predicted under most global warming scenarios (Meadows and Hoffman 2003).

Adaptation is a process of deliberate change, often in response to multiple pressures and changes that affect people's lives. The actions that decrease vulnerability and increase resilience, in response to a range of immediate needs, risks, and aspirations could be viewed as the characteristics of successful adaptations (van Aalst *et al.* 2008). Vulnerability depends on the degree to which a system is exposed to a perturbation, its sensitivity to that perturbation, its adaptive capacity, and its resilience (Kasperson *et al*. 1995). The physical aspects of vulnerability include land degradation, changes in agricultural productivity (Mizina *et al*. 1999; Smit and Skinner 2002), and the availability of water resources (Arnell 2004).

There are complexities brought about by climate change on the different biophysical processes as well as how they influence, and are affected by, human land use (Behnke *et al*. 1993). There have been important shifts in ecological thinking, and the present understanding of the ecological dynamics of semi-arid lands. Arid and semi-arid savannas were thought to be stable but fragile, i.e. ecosystems, which, if left undisturbed, would remain in a state of equilibrium but which were sensitive to human disturbance. Now they are viewed as non-equilibrium systems, i.e. variable but resilient ecosystems and the influence of drastic events, cyclic variation over time, and spatial heterogeneity, is stressed more than before (Walker 1993). Variation in rainfall and episodic events such as drought explain most of the observed environmental change, usually overriding effects of different management strategies (Dahlberg 2000).

2.1.3. The extent of communal rangeland degradation

The sustainable use of communal rangelands depends on the understanding of the extent of the rangelands deterioration, and how can these grazing areas be restored (Solomon *et al*. 2006). Most of the people working in communal areas have underestimated the degradation problems (Meadows and Hoffman 2003). The biophysical and climatic environment appears crucial for any model of land degradation (Hoffman and Todd 2000). Rangeland degradation is not a spatially uniform process; there are substantial off-site effects. Some landscapes are more prone to degradation than others because they have erodible soils and palatable species, which attract more grazing activity or both (Pickup 1998).

Land degradation has affected two billion hectares (22.5%) of world agricultural land, rangeland, forest, and woodland (Al Dousari *et al*. 2000). Severe degradation is blamed for the disappearance of about 5-10 million ha of agricultural land annually. Dryland areas are environmentally fragile, and thus especially susceptible to degradation (Gao and Liu 2010). The major land degradation features associated with deterioration of soil and vegetation conditions reveals several key areas of degradation in South Africa.

Hoffman and Todd (2000) categorised land degradation in South Africa into soil and rangeland degradation. The extent of land degradation when soil and rangeland degradation indices were combined was found greater on the steeply sloping environments along the eastern escarpment incorporating the communal areas of the former Ciskei, Transkei and Kwazulu, which emerged as some of the most degraded areas in South Africa (Hoffman and Todd 2000).

The extent of land degradation varies with the management history of the farming areas. There are severely degraded districts and these have a common history, i.e. they are characterised by a communal land tenure system and formed part of the former “homelands” of the apartheid state of South Africa (Meadows and Hoffman 2003). Furthermore, the magnitude of land degradation varies with land ownership and management. Thus, if soil and rangeland degradation are the main assessment criteria, largely communally farmed areas of South Africa are perceived to be significantly more degraded than commercial areas (Hoffman *et al*. 1999, Hoffman and Todd 2000). However, while there are the identification of a structural, socio-political foundation to the land degradation problem; the role of physical environmental factors on degradation should not be underestimated.

Hoffman *et al*. (1999) highlighted that the distribution of communal and commercial agricultural land in South Africa, is itself underpinned by physical environmental circumstances. The commercial farms are likely to be found in areas characterised by greater aridity and gentler slopes than the communal system. On the other hand, rural South Africa dominated by communal land is subject to higher levels of land degradation susceptibility because it is characterised by higher rainfall and steeper slopes (Meadows and Hoffman 2003).

Land degradation has also been reported from other parts of Africa and the world. The extent varies with different areas being affected by a number of biophysical and socio-economical factors. Land degradation affects primary productivity of rangelands and in turn affects ecosystem biological and economic function. In Ethiopia, soil losses through sheet and rill erosion were reported to have reached the alarming levels of up to 100 – 200 Mt ha^{-1} yr^{-1} (Herweg and Stillhardt 1999). Hakkeling (1989) reported in the same area that at this level of soil loss 50% of agricultural areas were affected.

While there are general concerns about the impact of land degradation, especially with regard to ecosystem structure and function, Dahlberg (2000) highlighted that there is a debate on environmental change in the semi-arid regions of Africa especially when linked to issues of land degradation and sustainability. The major disagreement is on the magnitude, severity, causes, and effects of observed changes. The main areas of contradiction relate to how findings may be spatially and temporally generalised and extrapolated, how perceptions of the environment are recognised and analysed, and how value-judgement terms are defined and used.

2.2. Rangeland degradation characteristics

Climate and soil quality represent the most important factors affecting land vulnerability to degradation (Basso *et al*. 2000). Environmental degradation as the antithesis of sustainability has drawn increasing attention from researchers, land users, and policy makers (Johnson and Lewis 2007). The perception of desertification as a simplistic, linear degradation pattern has been gradually replaced by that of a dynamic, non-equilibrium, spatial-heterogeneity process (Westoby *et al*. 1989; Milton *et al*. 1994; Dougill *et al*. 1999; Illius and O'Connor 1999, Gillson and Hoffman 2007). According to Hoffman and Ashwell (2001), desertification may only manifest itself in rural areas but food security, poverty, rural – urban migration are all associated processes that act on metropolitan and rural areas alike. This shift in ecological thinking emphasizes the importance of a place-based approach to desertification to understand the causal relationships within specific physical and social circumstances (Warren 2002; Reynolds *et al*. 2007).

Land degradation is reflected in a decline of land productivity that has because of cyclical causes and effects resulted in a depletion of the plant cover, soil exposure to erosion, reduction of soil organic matter and nutrient content, and the deterioration of soil structure (Sanchez *et al*. 2002). Gullies are some of the land degradation characteristics that indicate soil loss. Gullies are considered small catchment basins with a surface area of less than 1ha (Burylo *et al*. 2007). They are generally V-shaped and are composed of a bed and sides with steep slopes generally around 40^{o} (Rey 2003). As a result, the bedrock is overlaid with a regolith layer made of sediment accumulations that heavy rainfall events transport to the gully outlet and then to the valley.

Soil properties such as soil surface stability, aggregate stability, infiltration, compaction, and organic matter content affect soil erosion and can change with management. Soil organic matter enhances rangeland sustainability because it binds soil particles together into stable aggregates that in turn improve porosity, infiltration and root penetration reducing runoff and erosion (Chrisholm and Dumsday 1987). Soil organic matter enhances soil fertility and plant productivity by improving the ability of the soil to store and supply nutrients, water and air.

Soil compaction is detected when soil particles are physically compressed, eliminating the air spaces, or pores between the soil particles. Soil compaction is problematic because the increased soil density and decreased pore space limits water infiltration, percolation, and storage and limits plant growth and nutrient cycling. Stable soil aggregates are critical to erosion resistance, water availability, and root growth. Soils with stable aggregates at the surface are more resistant to water and wind erosion than other soils. There have been intense debates about the causes of soil erosion and especially the role of grazing (Arnalds and Barkarson 2003).

2.3. Rangeland vegetation, soil, and soil seed bank condition

2.3.1. Vegetation condition

Plant species differ in environmental requirements and tolerance and therefore, vegetation distribution varies along environmental gradients (Swaine 1996). Species composition is one of the means of studying ecological changes in the development of a rangeland (Malan and Van Niekerk 2005). This is a reflection of many factors, including past management (Whalley and Hardy 2000). Any change in grazing practice will cause a change in species composition (Abel 1997; Hayes and Holl 2003). Grazing pressure causes changes in vegetation structure, composition, and productivity (Moleele and Perkins 1998; Oztas *et al*. 2003; Maki *et al*. 2007). Sisay and Baars (2002) indicate that a long-term increase or relaxation of grazing pressure changes a plant community. Under heavy grazing pressure, decreaser species disappear and are replaced by increaser and/or invader species (Sisay and Baars 2002). Coronato and Bertiller (1996), Svejcar *et al*. (1999), Laughlin, and Abella (2007), however, indicated that the composition change is determined more by rainfall than by grazing pressure. Structural characteristics of the community such as greater cover can affect efficiencies of water use and offset or complement physiological response to defoliation (Milchunas *et al*. 1989). Species composition is an indicator of rangeland condition because species vary significantly in their acceptability and response to impacts of herbivores (Abule *et al*. 2007).

The impacts of herbivores such as grazing and trampling are intensified directly around rangeland resources. Herbivores directly affect rangeland ecosystems through defoliation of vegetation and trampling. Animals physically damage plants by cutting, bruising, and debarking; certain plants may be dislodged or uprooted during grazing. These physical damages to plants result in injury to growing points, changes in plant moisture relations and changes in physical strength and flexibility of plant parts. Trampling causes a change in species composition, thus certain species are more resistant while others are vulnerable to trampling. Furthermore, animal movement affects soil properties through compaction and mechanical breakdown of soil aggregates. However, there are positive effects of herbivores on vegetation such as plant distribution, promotion of seed germination and seed dispersal, and soil nutrient cycling through excretion (Schuman *et al*. 2002). Grazing stimulates aboveground biomass production, increases tillering and rhizome production, and root respiration. These effects of animals on rangeland ecosystem necessitate proper rangeland utilisation practices. Uncontrolled grazing may result in poor basal cover, change in species composition and low biomass production, which in turn lead to rangeland degradation (Smet and Ward 2005).

Herbivory affects vegetation dynamics, thus, over utilisation of vegetation changes rangelands from being dominated by perennial grasses to being dominated by annual grasses. Selective grazing and/or under utilisation of rangeland vegetation leads the rangeland to be dominated by unacceptable or species with less preference to animals. The individual plant species, which make up the grassland communities, vary in their adaptive mechanisms and tolerance to grazing (Abel 1997; Illius and O'Connor 1999; Hayes and Holl 2003; and Smet and Ward 2005). The composition of the plant communities will shift over time in response to different grazing intensities (Tainton 1999).

Certain plant species characterize different successional stages during grassland retrogression and they can be used as indicators of rangeland condition (Malan and Van Niekerk 2005). High intensity grazing leads to excessive removal of the most palatable species, which are usually perennial grasses (Todd and Hoffman 1999; Anderson and Hoffman 2006). This opens the way for less palatable and faster establishing annual grasses and forbs to take hold (Nsinamwa *et al*. 2005). Constant diminishing of the highly desirable species (Malan and Van Niekerk 2005) can result in rangeland deterioration. On the other hand, heavy grazing depletes foliage of the palatable species, which results in reduced plant vigour (Morris and Kotze 2006).

Single animal species grazing systems can have dramatic, negative effects on vegetation composition due to selective grazing (Smet and Ward 2005). Different animal species have different preferences for grazing material; this preference could be on plant species, plant parts, and on grazing location within the rangeland. Cattle prefer tall grass and their grazing behaviour has a limited degree of selection, however, in the presence of many species; cattle will select certain species over others for grazing. Sheep prefer shorter grass and there is a higher degree of selection on softer plant parts with higher level of nutrition. Goats are generally browsers and they select softer leaves and twigs of the trees. The animals have some level of grazing and/or browsing selectivity, the most common in rangeland utilisation is species and area selection. Because of area and/or species selective grazing, certain parts of the grazing area and some species will be utilised more than others. That will exert more grazing pressure on the preferred areas and species while others are not utilised.

Vegetation species composition and cover vary between different vegetation types (O'Farrell *et al*. 2007). Species composition can be strongly filtered by abiotic factors such as total nitrogen in the soil (Laughlin and Abella 2007). The nutritive value of range forage is dependent among other factors on species composition, soil fertility, and physiological stages of grasses. Annual grasses and forbs are seldom considered as favourably as their perennial counterparts are (Arzani *et al*. 2006). Species and chemical composition of feed and season of growth affect digestibility of grasses (Dohme *et al*. 2006). Grass species vary with feed chemical composition, thus some grasses have higher fibre content, and that renders them less digestible than species with less fibre content. The fibre content of grass species varies with their stages of growth; the younger fresh grass has less fibre and that makes it more digestible than mature grass. The composition of the dry matter of a rangeland varies depending on the physiological stage of the grass, dominant species, and soil nutritional status (McDonald *et al*. 1987). The growth of the grass plant is generally divided into vegetative and reproductive (flowering), the nutrient distribution within the plant is higher in the leaves and stems during vegetative growth and when reproductive growth commences the nutrients are utilised by the plant for flowering. The soil fertility status also affects the nutritional quality of the grasses, thus grasses growing on the soil with higher fertility status have higher nutritional quality that grass growing on poor soil.

Rangeland forage quality has spatial and temporal variation (Arzani *et al*. 2006; Laughlin and Abella 2007). Forage quality varies with different spaces or locations within the rangeland; this is because of, among other factors, different soil quality, soil moisture regime, microclimate, and landscape. Certain grass species grow well on the deeper soils with high fertility status and a specific range of soil pH, and will possess different forage quality characteristics to those growing on poor and shallow soils. Rangelands have different soil moisture regimes at different locations, thus some areas have a high soil moisture content compared to others, and this is due to reasons such as rangeland water recharge, storage, and discharge as affected by soil quality, landscape, and microclimate.

Furthermore, rangeland forage quality varies with time of the year. This is because factors such as climate and physiological stages of grasses change at different times of the year. Generally, grasses germinate or regrow in spring and become dormant in winter. The major translocation of nutrients occurs in autumn in preparation for dormancy, the translocation process stores nutrients as reserves that will help during spring regrowth. These rangelands usually supply livestock with high quality food during spring and early summer and forage quality declines in autumn and winter (Laughlin and Abella 2007).

However, the temporal nature of forage quality varies with ecological zones as affected by different climate, parent material, and soil nutrients. There are areas with higher rainfall and parent material with low base status, while there are other areas with low rainfall where parent material gives rise to soils with a high base status (Hardy *et al*. 1999). The aspects of the environment that promote carbon assimilation (water supply and temperature) in relation to nutrient supply also determine forage quality of rangelands. In the higher rainfall areas, carbon assimilation is high relative to nutrient supply and in low rainfall areas; nutrient supply is high relative to carbon assimilation. Interaction of soil moisture and fertility in rangelands affect forage quality and quantity. Thus, rangelands with higher soil fertility status and low moisture content result in low biomass and high forage quality, while those with high soil moisture content and low soil fertility produce high biomass with low forage quality.

Rangelands that are properly managed normally have more of acceptable species and higher biomass production (Sisay and Baars 2002). Forage yield or biomass commonly refers to above ground herbaceous material. It is expressed as dry matter weight (Abule *et al*. 2007). Biomass production is used to determine the amount of available forage for animals, to measure the effects of management on vegetation and to assess the rangeland condition (Abule *et al*. 2007).

Forage yield in rangeland may be described in terms of quality and biomass production of the dominant grass species (Peden 2005). Quality is influenced by factors such as type and amount of nutrients, fibre content, unpalatable chemical substances, and percentage moisture, and varies with species. Palatable species occur naturally in rangeland that is well managed, and decreases with poor management such as overgrazing (Morris and Kotze 2006). Biomass production of natural grassland systems varies considerably according to available moisture (Noellemeyer *et al*. 2006).

Acceptable grasses lose their vigour because of repeated removal of leaves and constant draining of their nutrient reserves (Malan and Van Niekerk 2005). When a plant is unable to replenish the stored resources, it will fail to produce new leaves and will eventually have reduced photosynthetic power (Morris and Kotze 2006). As the desirable plants become weaker and die off, the number of roots in the upper layer of the soil decreases. This reduces the competitive ability of grasses (Sisay and Baars 2002). Defoliation removes plant biomass, which changes the light regime in a plant stand (Tomlinson and O'Connor 2005) and this result in low photosynthetic rate of plants, which in turn reduces rangeland productivity.

The bare areas between grasses become larger as the grass species are exhausted, causing a decline in the effective use of rainfall in the area. These are ideal conditions for woody plant establishment (Stuart-Hill and Tainton 1989). According to Tainton (1996), environmental conditions play a role in changes in grass species composition. Perennial grasses produce more foliage than annual grass and thus provide more of forage yield than annuals (Peden 2005).

Perennial grasses have extensive root systems and protect the soil from erosion more effectively than annual species. Annual species replace perennial species as the grazing intensity increases (Maki *et al*. 2007). The dominance of perennial grass species locally indicates that the rangeland has good protection against soil erosion (Morris and Kotze 2006). When annual grasses die, the ground remains bare for a long time becoming susceptible to erosion (Malan and Van Niekerk 2005). The excessive removal of perennial grass species reduces ground cover (Eccard *et al*. 2000; Nsinamwa *et al*. 2005). Annual grasses can only germinate in bare patches during limited periods when water is available. Their seeds can survive in the soil during long periods of drought (Malan and Van Niekerk 2005).

The stage of rangeland retrogression in grassland is characterized by increased rates of runoff (Svejcar *et al*. 1999). Water inputs may be intercepted by plants, infiltrate the soil, or runoff the surface depending on, among other factors, soil characteristics, topography and vegetation cover (Morris and Kotze 2006). The most important single factor affecting water run-off is the amount and type of vegetative cover (Malan and Van Niekerk 2005). Soil cover provided by vegetation to soil may be in basal or aerial terms. The base of a rooted plant provides the basal cover; it depends on the thickness of the tufts and plant density. The higher the basal cover, the lower the run off rate and the lower the basal cover the higher the run-off rate. Run-off rate is one of the factors responsible for soil particle transportation. The leaves provide the aerial cover and stems of the plants. The run-off rate depends on the spread of leaves and stems; it reduces raindrop impact on the soil, which normally causes soil particle detachment.

Herbaceous plants provide more soil protection against raindrop impact and run-off than non-herbaceous ones (Tainton 1999). This is because grasses provide a complex network of roots immediately below the ground surface, which hold the soil particles together unlike deep-rooted trees. Stands of perennial species are more stable than stands of annual species; and provide stable soil cover. Influence of basal cover and bare ground on grass yield was reported to be higher on forage biomass production i.e. higher proportion of basal cover leads to a higher forage yield (Fahnestock and Detling 2000). Baars *et al*. (1997) indicated that, under proper rangeland management practices, basal cover of excellent vegetation is expected to be greater than 12%. The basal cover decreases as the condition of the rangeland declines (Sisay and Baars 2002). Bare ground is a good indicator of over utilization and degree of degradation of the vegetation (Abule *et al*. 2007).

Varnamkhasti *et al*. (1995) indicated that long term grazing can select for genotypes that are more tolerant to current year defoliations and basal cover of plants can increase with grazing. Potential for compensatory regrowth of plants after defoliation is often centred on resource conservation or utilization efficiency mechanisms. Rain use efficiency of plant communities may be at least as much a function of grazing management influence on vegetation condition and aridity (Varnamkhasti *et al*. 1995). At low rainfall, relatively more water is lost through evaporation, leaving less water available to plants, and so the rain use efficiency is reduced. However, at high rainfall levels rain use efficiency decreases because ecosystem productivity becomes limited by nutrients rather than water (Hein 2006). In arid areas, herbaceous plant production is linearly related to rainfall amount, distribution, and season of rainfall, and drought affects plant production by influencing soil moisture and, therefore, water efficiency (Oba *et al*. 2000).

2.3.2. Rangeland soil quality

Soil forms the basis for all vegetation growth and plays a key role in the hydrological, carbon and nutrient cycles of ecosystems (Li *et al*. 2007). Soil organic matter has been identified as an indicator of soil fertility based on the rationale that it contributes significantly to soil physical, chemical, and biological properties that affect vital ecosystem processes of rangelands (Hopmans *et al*. 2005).

Soil aggregate stability is widely recognized as a key indicator of soil and rangeland health (Herrick *et al*. 2001). It is related to a number of ecosystem properties, processes, and functions, including the quantity and composition of organic matter, soil biotic activity, infiltration capacity, and resistance to erosion. Soil aggregation has potential benefits on soil moisture status, nutrient dynamics, tilth maintenance, and erosion reduction (Sainju 2006).

Soil aggregate stability is a good indicator of organic matter content (Li *et al*. 2007), biological activity, and nutrient cycling in the soil (Amezketa 1999). The amount of organic matter increases after the decomposition of litter and dead roots. Stable aggregates result from this process because soil biota produces material that binds particles together (Shrestha *et al*. 2007). Changes in aggregate stability may serve as early indicators of recovery or degradation of ecosystems (Amezketa 1999).

Soil aggregate stability indicates the ability of the soil to be detached by light rainfall (slow wetting), torrential rainfall (fast wetting) and mechanical disaggregation. Soil aggregate stability is one of the main factors controlling top soil hydrology, crustability, and erodibility (Caravaca *et al*. 2002). Stability of soil aggregates and pores between them affect the movement and storage of water, aeration, and soil erosion (Amezketa 1999).

Disturbance of the soil surface by grazing animals has both beneficial and detrimental effects on aggregate stability. It incorporates litter and standing dead vegetation into the soil, increasing the content of organic matter. However, it also breaks the soil apart, exposing the organic matter glues to degradation and loss by erosion (Caravaca *et al*. 2002). Heavy grazing that significantly reduces plant production disrupts the formation of aggregates by reducing the inputs of organic matter. Grazing is more likely to increase aggregate stability in areas where an unusually large amount of standing dead material is on the soil surface and the risk of erosion is not increased by removal of plant material and disturbance of the soil surface (Shrestha *et al*. 2007).

Soil quality is defined as the capacity of a soil to function, within ecosystem and land use boundaries, to sustain biological productivity, maintain environmental quality, and promote plant and animal health (Corwin *et al*. 2003). Salinity and especially alkalinity can have major impacts on plant production. Extreme values of soil pH, which affect the solubility of most of the elements necessary for plant growth, is an insidious problem in some regions. Soil pH affects the solubility of nutrients and uptake by plants (Rezaei and Gilkes 2005). Soil pH often affects plant community composition because plants differ in nutrient requirements and soil acidity or basicity tolerance. Soil pH is influenced by elevation. Soil parent materials of higher pH occur at lower elevation (Laughlin and Abella 2007).

Salinity is a dynamic soil property; it varies temporally and spatially with depth and across the landscape. Salinity varies primarily due to the process of leaching with topographic effects contributing to this variation (Corwin *et al*. 2003). Surface topography plays a significant role in influencing spatial EC variation. The difference in CEC of the soils is influenced by organic carbon and clay content. The CEC values indicate the capacity of soil to retain nutrient cations against leaching (Ludwig *et al*. 2001).

There is a positive relationship between soil organic carbon and the capacity of the soil to supply essential plant nutrients including nitrogen, phosphorus, and potassium (Rezaei and Gilkes 2005). Soil nitrogen (N) content follows soil carbon content in grassland soils (Conant and Paustial 1998). The relationship between organic carbon and landscape attributes, as well as the positive relationship between organic carbon and nutrient elements, indicates the usefulness of organic carbon as a reliable and sensitive indicator of rangeland health (Rezaei and Gilkes 2005).

The soil under rangeland management contains a high level of organic carbon and almost all organic constituents (Lu *et al*. 1998). Li *et al*. (2007) indicated that soil organic carbon plays an important role in improving soil physical, chemical, and biological properties for sustained plant growth. The soil carbon balance is maintained by plant litter inputs, which enter the soil as particulate organic carbon. Rangeland sustainability is related to soil carbon and nutrient balance and the capability to maintain adequate soil conditions for water availability and root development (Noellemeyer *et al*. 2006).

Soil under shade such as tree canopy, accumulates more soil organic carbon due to the influence of the tree canopy on the soil temperature regime. The different carbon dynamics are the result of a high proportion of woody debris under shade and different removal rates of aboveground biomass by grazing in the open communities (Simion *et al*. 2003).

Changes in soil carbon can occur in response to a wide range of management and environmental factors (Schuman *et al*. 2002). Rotational grazing management provides enough time between occupation periods and in turn stimulates growth of herbaceous species and improves nutrient cycling in grassland ecosystems (Schuman *et al*. 2002). Disturbance of rangelands has a negative impact on soil structural properties and water holding capacity, which are related to losses of soil organic carbon pools (Li *et al*. 2007). Deterioration of soil structural properties decreases soil infiltration and water retention; and accelerates soil erosion.

Soil texture is a fundamental property which largely determines the water balance and the potential biomass carbon production and in turn carbon input and stabilization. Soil moisture availability is determined by soil texture, which can influence the composition of the plant community (Laughlin and Abella 2007). Soil texture also has a strong effect on biomass production and soil organic carbon in rangeland soils (Scholes and Archer 1997). There is a positive relationship between texture and soil organic carbon. This could be attributed to the stabilization of organic compounds by clay particles and the influence of texture on the water availability for biological activities (Noellemeyer *et al*. 2006).

Standing biomass is lower in soils dominated by sand and not different in silt and clay dominated soils (Laughlin and Abella 2007). Plant cover change and removal of biomass can decrease organic matter in soil, reduce important soil physical parameters, and, consequently, increase soil erosion (Li *et al*. 2007). Soils that are dominated by sand are highly limited in nutrient and water retention. Soil productivity is reduced also by the large proportion of gravel and stones in the soil due to limited root growth (Salako *et al*. 2006).

2.3.3. Rangeland soil seed bank

Plants establish themselves by the expansion and subsequent fragmentation of vegetative parts such as tillers, rhizomes, or runners, or by the successful establishment of a soil seed bank (Freedman *et al*. 1982). Seeds may have been introduced to the seed bank during the current or previous years and are removed through germination, predation, senescence, and pathogens (Solomon *et al*. 2006). The balance between these processes determines the turnover rate of the seed bank in a location. Soil seed banks are important in grassland and savanna ecosystems where grasses form a large part of the vegetation. The soil seed bank is a potential pool of propagules for regeneration of grasses after disturbance (Bekker *et al*. 1997). It reduces the probability of population extinction of plants and it is further likely to be the major source in establishing aboveground plant communities following environmental changes (Du Preez and Snyman 1993).

The recruitment of the seed bank is restricted to periods with favourable conditions of those soil parameters that may control seed germination; these include soil water, pH, and temperature and light (Solomon *et al*. 2006). Drought and heavy grazing adversely affect the size and composition of grasses in the seed bank, both spatially and temporally (Bekker *et al*. 1997; Solomon *et al*. 2006). The evaluation of soil seed banks can therefore give an idea of the recovery potential of degraded rangelands (Bekker *et al*. 1997; Tongway *et al*. 2003).

Soil seed bank provides an indication of the potential vegetation recruitment rate of plant seedlings through germination. However, Tormo *et al*. (2006) suggested that the soil seed bank is not the reason for lack of vegetation in disturbed areas. Although soil seed bank in the degraded areas is generally low, the major factor determining vegetation germination is soil moisture. The main factors driving plant colonization could be the very short duration of available water in soil and high regolith salinity which play an important role during the germination stage or chemical variables such as pH, organic carbon or the soil phosphate concentration (García-Fayos *et al*. 2000; Wiegleb and Felinks 2001).

2.4. Hydrological and biogeochemical dynamics of arid and semi-arid rangeland areas.

2.4.1. Significance of water in arid and semi-arid rangelands

In arid and semi-arid ecosystems, water is the major limiting factor (Chen *et al*. 2007). Performance of landscape functions relies heavily on the availability of water (Vohland and Barry 2009). In Southern Africa, a number of studies in rangeland ecology have been conducted; however, most of them have been limited to traditional disciplines such as grazing management, and fire ecology and vegetation characteristics. The rangeland environment generally consists of abiotic components such as soil and climate parameters, and a biotic community including plants and animals. Processes such as photosynthesis, the hydrological cycle, respiration and many others explain the interaction between the biotic and abiotic components of ecosystems. Therefore, there is a need for a full understanding of the complex nature of the rangeland environment and of the various interactions and feedbacks between the different processes.

An understanding of the relationship between soil water dynamics and vegetation density is helpful for recommendations on soil erosion control and vegetation development in semi-arid and arid areas (Braud *et al*. 2001). Water covers almost three quarters of the earth's surface as rivers, lakes and oceans, but only 3% of the planet's water is fresh, and two thirds of this is ice. Plants, animals, and soils contain a small (0.003%) but very important amount of water while about 0.6% percent is in the earth's underground aquifers. Water is a transient resource, in continual motion; any stasis in time or space is a fleeting phase (Morse 1996), therefore, there should be an understanding of factors that influence its stasis and dynamism within the rangelands. Such comprehension will provide a background on improving rangeland management and utilization with consideration of water movement within rangelands.

Soil moisture is one of the most limiting environmental factors influencing plant production (Noy-Meir 1973; Bennie *et al*. 1997; O'Connor *et al*. 2001) and plant survival in arid and semi-arid climates (Chen *et al*. 2007; Snyman 2004). The availability of water is relatively limited in the arid and semiarid areas, and in turn sustainable animal production in these areas is in danger, therefore, the combined effects of plant water requirements and influence of defoliation on vegetation should be realised (Snyman 1999). Understanding rangeland water dynamics and WUE is of particular importance due to low water availability in arid areas (Yu *et al*. 2005).

One of the most important principles in sustainable utilisation of arid and semi-arid rangelands is efficient soil-water management (Snyman 1998) and therefore it is essential to know how water use efficiency is affected by degradation (Snyman and Fouche 1993) and soil conditions over the short and long term (Emmerich and Heitschmidt 2002). Understanding the effects of vegetation on soil water dynamics will provide background for understanding the mechanism of water shortage and in addressing the problem of poor long-term vegetation recovery (Chen *et al*. 2007). Soil water absorption, storage, and transpiration are the basic process controlling interactions of precipitation with plant. Water temporarily stored on plant tissues is transpired through the stomata and evaporated from the leaf surface (Keim *et al*. 2006). Keim *et al*. (2006) concluded that storage of water in plants varies with rainfall intensity and suggests that morphological characteristics of vegetation play a role in the process.

In order to improve our understanding of soil water-vegetation interactions it is necessary to integrate hydrological and biogeochemical processes to estimate, not only water dynamics, but also its influence on vegetation density (Xia and Shao 2008). Soil water carrying capacity is defined as a maximum vegetation density that an arid or semi-arid area will support without soil water experiencing decreases in the ability to support future generations during plant growth periods, given desired climatic conditions, soil texture and management program (Xia and Shao 2008).

2.4.2. Relationship between soil properties and rangeland water dynamics

In water-limited ecosystems, water stored in the soil layer occupied by roots influences vegetation dynamics. The timing of rainfall influences the water availability in soil, and thus water fluxes between soil and plants, and vegetation growth (De Michele *et al*. 2008). Water-limited ecosystems offer a particularly rich example of space-time species dynamics due to the complex temporal variability present in interannual precipitation (Fernandez-Illescas and Rodriguez-Iturbe 2004). Soils influence hydrological processes by providing the medium for the capture, storage, and release of water (Whisenant 1999). The flow of soil and water through rangeland ecosystems is related, because flow of water can cause soil erosion. Soil and water are two critical resources for agricultural production. There is, therefore, an urgent and ongoing need for research to devise ways to mange soil and water resources in a sustainable manner especially in rangelands (Sarangi *et al*. 2004).

The long-term difference between actual evapotranspiration (AET) and precipitation (P) is particularly relevant because it indicates to what extent water is retained and used for primary production. In the case where P is greater than AET, water losses through runoff or deep drainage are likely to be important, land condition can be expected to be poor, and associated processes such as soil erosion may be active. However, where P is less than AET, water inputs by overland or sub-surface flow can be expected to outweigh the losses by runoff and deep drainage (Domingo *et al*. 2001).

Soil water repellency (SWR) is affected by various biotic and abiotic factors. Some of the biotic factors are the presence of hydrophobic organic compounds released by roots and plant tissues, fungal activity, or the mineralization/humification rates (Doerr *et al*. 1998; Jex *et al*. 1985; McGhie and Posner 1981). Abiotic factors that affect soil water repellency include wild fires, soil texture, temperature and soil moisture (Doerr *et al*. 2000). Some of the consequences of SWR are reduced soil infiltration rates, enhanced overland flow, soil erosion and non-uniform wetting fronts with fingered flow (Ritsema *et al*. 1993; Jordán *et al*. 2008).

2.4.3. Grazing practices and water dynamics in rangelands

In arid and semi-arid areas, shallow groundwater circulates within a system and is replenished by high intensity precipitation events, this serves as the main source of water for grazing and daily nomadic life (Tsujimura *et al*. 2006). Grazing activities affect the surface condition and should have a large influence on the surface-atmosphere interactions (Sugita *et al*. 2007). Grazing activities reduce surface vegetation cover and thus make the soil more vulnerable to erosion.

Forage production that determines animal production is controlled primarily by precipitation (Diaz-Solis *et al*. 2006). According to the livestock water productivity (LWP) framework, there are nine strategies to increase LWP (Descheemaeker *et al*. 2010). These include water management, feed type selection, improving feed quality, improving feed water productivity, grazing management, increasing animal productivity, improving animal health, supportive institutions, and enabling policies (Descheemaeker *et al*. 2010). The strategies directed at the biophysical components of the farming systems are grouped into three categories related to feed management, water management and animal management (increasing animal productivity, improving animal health) (Descheemaeker *et al*. 2010).

Livestock keeping and feeding are important components of agricultural water use in sub-Saharan Africa and other parts of the world (Harrington *et al*. 2009). Livestock convert water resources into high value goods and services. Animals derive their water from different sources (Sileshi *et al*. 2003; McGregor 2004), such as water directly consumed by drinking and water consumption through feed intake. The amount of drinking water used varies from 20 l to 50 l day per Tropical Livestock Unit (TLU, 250 kg body mass), and depends on various factors related to animal, feed and environmental conditions (Gigar-Reverdin and Gihad 1991).

Livestock keeping has important impacts on water resources at the watershed and landscape scales (Ameda *et al*. 2009). Livestock grazing affects the hydrological response of pastures and rangelands and may result in soil and vegetation degradation (Descheemaeker *et al*. 2006). Grazing pressure on vegetation and the trampling effect of livestock are especially notable around watering points, where land degradation can be severe (Brits *et al*. 2002). The importance of precipitation is highlighted by the suggestion of water-use efficiency as a unifying concept in the ecology of semi-arid areas (Le Houerou 1984). Water use efficiency is related to infiltration, runoff, and soil storage (Fischer and Turner 1978).

Water productivity generally is defined as the ratio of agricultural outputs to the amount of water consumed. It provides a robust measure of the ability of agricultural systems to convert water into food (Kijne *et al*. 2003). Livestock water productivity (LWP) is the ratio of net livestock-related benefits, including both products and services, to the water depleted and degraded in producing these (Peden *et al*. 2007). Livestock outputs comprise many different products varying from food items such as meat, fibre, and milk, and secondary product such as manure, draught power, and transport, and services such as nutrient cycling, risks spreading and socio-cultural roles (Descheemaeker *et al*. 2010).

2.4.4. Managing rangelands for water conservation

Soil and water are the two critical resources for agricultural production and there is an urgent and ongoing need for research to devise ways to manage soil and water resources in a more sustainable manner (National Research Council 1992). In the context of agricultural production in drylands, soil and water conservation (SWC) practices such as rainwater harvesting (RWH) provide an opportunity to stabilise agricultural landscapes in semi-arid regions and make them more productive (Wallace 2000). Stabilization of an agricultural landscape includes the restoration of degraded cultivated and /or natural grazing lands (Vohland and Barry 2009). Many marginal water sources could be used more efficiently such as road and land runoffs that are normally lost through erosion processes (Prinz and Malik 2002). Rainwater harvesting (RWH) practices refer to all practices whereby rainwater is collected artificially to make it available for cropping or domestic purposes (Ngigi 2003). *In situ* RWH practices refer to micro-catchments at field level (Prinz and Malik 2002). These practices mainly help to overcome dry spells, as the soil, which is the main storage site of *in situ* RWH practices, serves only some days to weeks as a storage system (Falkenmark *et al*. 2001).

Integrated watershed management (IWM) is a vital approach for sustainable development as the watershed is the hydro-geological unit that harbours the natural resources. IWM can be defined as a multidisciplinary, holistic way of protecting and managing a watershed's natural resources to enhance biomass production in an eco-friendly manner (Sarangi *et al*. 2004). The watershed is viewed as a hydro-geological complex and dynamic ecosystem in which natural and anthropogenic processes occur and interact, which gives rise to runoff at the watershed outlet.

In practice, several factors need to be taken into account for the water-saving agricultural system viz (i) the quantity, quality, spatial and temporal distribution of water resources. (ii) The establishment of cultivation practices aimed at reducing water consumption because of shaping the existing farming structure and cropping system in line with the current distribution pattern of water resources. (iii) Sufficient work force and equipment for research, development, production, supply, and maintenance of water saving materials, spare parts, instruments, and facilities. (iv) Relevant laws and statutes concerning water management to be enacted, formulated, and perfected and a special campaign to enhance the public's water-saving awareness (Deng *et al*. 2003).

Water utilisation rate and water use efficiency through maximisation of rainfall use efficiency is one the challenges in that rangeland management research should solve (Deng *et al*. 2006). The main purpose of water saving in agriculture is to increase the water use efficiency (WUE) of the system. This could be achieved by maximizing the soil-stored water content/precipitation volume; water consumption/soil storage of water; transpiration/water consumption; biomass yield/transpiration and economic benefits/biomass yield. The improvement of these hydro-pedological and plant parameters are the key issues to be solved (Deng *et al*. 2006).

Most interventions in water management merely modify the flow so that this scarce resource can be channelled towards the desired target, which may be people, livestock, or crops. Water harvesting techniques can be divided into five basic methods: (1) vegetation management, (2) natural impervious surface, (3) land alteration (4) chemical treatment of soil and (5) ground cover. These methods have a wide range of costs, performance and durability, which can limit the potential applicability of a treatment (Frasier 1975).

Shan (2002) defined water saving agricultural system as integrated farming practices that are able to sufficiently use natural rainfall and irrigation facilities for improved water use efficiency. Deng *et al*. (2006) described the scientific measures in a water-saving agricultural system; these include spatial and temporal adjustment of water resources, effective use of natural rainfall, rational use of irrigation water and increased plant WUE. Several factors are of importance in agricultural practices viz. the quantity, quality, spatial and temporal distribution of water resources.

2.4.5. Rangeland vegetation restoration and water recharge, storage and discharge

In arid and semi arid regions, vegetation dynamics depend on soil water availability, which, in turn, results from a number of complex and mutually interacting hydrological processes (Porporato *et al*. 2002). Vegetation restoration, therefore, requires considering the soil water dynamics in both time and space. Soil water dynamics are affected by a number of factors such as topography, soil properties, land cover, water routing processes, depth to water table and/or meteorological conditions (Beate and Haberlandt 2002). The relationship between vegetation and soil moisture varies with region (Domingo *et al*. 2001; Kerkhoff *et al*. 2004). Choosing suitable species in respect to soil water balance is crucial for vegetation restoration where water shortage is a limiting factor. There are a number of factors controlling plant growth, these include temperature and nutrient availability, however, when temperature and nutrient availability are not the controlling factors, soil moisture becomes the key controlling variable (Daly *et al*. 2004). Vegetation restoration in the arid and semi-arid regions has to consider that rainfall is the only source of water recharge to sustain plant growth (Chen *et al*. 2007).

Chen *et al*. (2007) discovered that semi-natural grassland has moret soil moisture compared to sloping cropland. They, however, noted that average soil moisture varied between vegetation types and periods of observation. Such temporal dynamics are pronounced in water-limited ecosystems (Tinley 1982). Chen *et al*. (2007) attributed this result to the difference in transpiration of plants at different periods and the difference of soil moisture among different vegetation types decreases with increasing soil depth.

2.5. Rangeland vegetation restoration

2.5.1. Role of management in rangeland restoration

Natural ecosystems have been severely destroyed because of anthropogenic disturbances, unreasonable utilisation, and neglect of protection and restoration (Hai *et al*. 2007). These disturbed or degraded ecosystems are confronted with poor soil fertility, shortage of water and deteriorated microenvironment, which would severely restrict their productivity. How to comprehensively restore and harness the degraded ecosystem is a key issue in increasing productivity, improving environmental conditions and achieving sustainable development. When the disturbance is removed, the degraded ecosystems will initiate a succession to the primitive community, and restoration process is considered as the progressive succession (Peng 2003).

Management of land degradation can be divided into preventative and restoration measures. Answers to preventative measures can often be found within the causes of land degradation. In view of the massive scale of land degradation that has already occurred in parts of southern Africa's communal rangelands, restoration is of significant importance to land owners. The fast rate at which intact natural ecosystems are degraded and decline, has emphasised the importance of ecological restoration to maintain the earth's natural capital (Young 2000). In order to restore degraded ecosystems, it is crucial to identify which ecosystem functions should be restored first. It is therefore, important to define the functional status of the ecosystem beforehand. It is also important to establish the relationship between ecosystem structure and functioning, and to assess the potential for ecosystem restoration (Cortina *et al*. 2006).

2.5.2. Theories, Paradigms, and Models describing rangeland dynamics

There are a large number of conceptual models that have been developed by restoration ecologists to describe how ecosystem structure and functioning are related (Cortina *et al*. 2006). Bradshaw (1984) developed a model for the reclamation of derelict land, which later was termed Linear structure and Function model (LSF). This model assumes a linear increase in ecosystem function with an increase in complexity of its structure (Cortina *et al*. 2006). According to this model, restoration is defined as the simultaneous increase in structure and function promoted by human intervention, paralleling changes occurring during secondary succession. Although the LSF model has a strong heuristic value and has successfully captured the essence of ecological restoration, it fails to reflect many real situations, and it may lead to excessively narrow definitions of reference ecosystems, and to erroneous estimations of the effort needed to restore degraded ecosystems (Cortina *et al*. 2006).

The major assumption of the LSF model is the linear and positive relationship between ecosystem structure and function, however, Hooper *et al*. (2005), suggested the relationship between community composition and ecosystem functioning does not form a straightforward universal relationship between both sets. A negative relationship between biodiversity and productivity (Bakker and Berendse 1999) can serve as an example of the inconsistency of the LSF model. Furthermore, the arrival of a new species does not always translate into measurable changes in ecosystem function (Cortina *et al*. 2006). Species differ in their impact on ecosystem function and the effect of a particular species on ecosystem function may be low (Hulbert 1997). In the same vein, species loss does not always directly relate to functional decline (Smith and Knapp 2003). The LSF model is implicit in that the notion of linear trajectory and a single final ecosystem state follow Clementsian successional trajectories (Cortina *et al*. 2006).

Hobbs and Norton (1996) reported the alternative meta-stable states in the structure-function space, and this was the basis for state and transition models. State and transition models recognise that multiple successional trajectories are possible, and that alternative meta-stable states can exist under the same environment (Hobbs and Norton 1996). Different states represent areas of higher probability in the structure-function space and may result from gradual or sudden changes in ecosystem structure and function. Alternative states can be targeted as reference ecosystems for restoration, if a particular combination of both sets of variables suits society interest (Hobbs and Norton 1996).

State and transition models can help define feasible transitions and those that are not, and may help to identify restoration techniques needed to bring an ecosystem to a desired state (Cortina *et al*. 2006). The existence of irreversible transitions and dynamics has major consequences for ecological restoration. When aggradative and degradative trajectories differ, restoration may need to use bypasses to reach a particular reference ecosystem, and thus additional efforts may be required (Cortina *et al*. 2006). Restoration may not need to follow the entire sequence of degradation stages to reach the target ecosystem, but may 'jump' over partially degraded ones.

Walker (1980) defined three concepts that have to do with system dynamics, viz. stability, resilience, and a system's domain of attraction. He describes a stable system as one which when subjected to outside stress (e.g. drought or grazing) changes little in composition and production. A resilient system may or may not be stable, but remains attracted towards its equilibrium. A domain of attraction is described as that region of a system's state-space within which the system is attracted towards equilibrium.

According to Walker (1980), in a resilient system the domain of attraction is usually large. If a stable system changes to such an extent that it falls outside the domain of attraction, the amounts of the variables will then either change to a different equilibrium, or they will go to zero (extinction). The state and transition model and its derivative, the rangeland health model, can be used to characterize the conditions of different vegetation states (Westoby *et al*. 1989), which feature high vegetation cover turnover (Noy-Meir 1973).

Equilibrium (based on range succession) and non-equilibrium grazing models (such as state and transition, rangeland health, climate-plant-herbivory models) have influenced rangeland policy and management (Oba *et al*. 2000). Fenandez-Gimenez and Allen-Diaz (1999) also attested that the two equilibrium based ecological models have dominated conventional range science and management. However, they are both founded on the clementsian successional model of vegetation change (Clements 1916; Ellison 1960) and the classical model of plant-herbivore population dynamics (Caughley 1979). Equilibrium and non-equilibrium models differ in their characterisation of range ecology, grazing systems and development (Oba *et al*. 2000). Furthermore, equilibrium model posits tightly coupled relationships between the abundance of herbivores and the productivity, and species composition of plants and non-equilibrium does not (Fenanadez-Gimenez and Allen-Diaz 1999).

The range condition (RC) model of vegetation dynamics has been established based on a presumed relationship between grazing intensity and vegetation (Dyksterhuis 1949). The RC model predicts that as herbivore number increases, plant biomass and cover decline and species composition shifts from dominance by perennial grasses and forbs towards dominance by unpalatable forbs and weedy annuals (Oba *et al*. 2000). When grazing is reduced or stopped, biomass and cover are predicted to increase, and species composition shifts back towards late-successional stages. The classical rangeland theory has portrayed traditional, communal rangeland management as an unproductive and unsustainable form of land use, invariably leading to irreversible rangeland degradation (Abel 1993). However, the compatibility of traditional pastoral systems with the prevailing uncertainty of the physical, social, and economic climate under which they operate has been highlighted (Ellis *et al*. 1993). Equilibrium-based theoretical models and the resource management measures based on them are purported to have failed to predict successfully the behaviour of complex natural systems (May 1977; Connell and Sousa 1983).

There are a number of alternative models proposed for addressing rangeland dynamics; these include the state and transition (Walker and Noy Meir 1989; Allen-Diaz and Bartolome 1998), threshold (Friedel 1991; Laycock 1991) and catastrophe (Lockwood and Lockwood 1993) models. These models are closely related and they focus on describing quasi-stable vegetation states, predicting the circumstances that trigger transitions to specific different states, and modelling these changes. They emphasize the non-linearity of vegetation responses to grazing and other environmental perturbations (Fernandez-Gimenez and Allen-Diaz 1999).

The non-equilibrium persistent (NEP) model of rangeland dynamics (Ellis and Swift 1988, Behnke and Scoones 1993) focuses on the effects of abiotic factors on plant community and herbivore population dynamics. Ellis and Swift (1988) proposed that many rangeland ecosystems are dominated by density independent and abiotic factors, rather than density dependent and biological interactions. Furthermore, Oba *et al*. (2000) highlighted some ecological characteristics of a non-equilibrium system, which are generally inverse to the characteristics of an equilibrium system viz, climatic variability; variability of primary productivity, livestock population is controlled by density independent factors and livestock track unpredictable forage production. Vegetation cover and plant productivity in the arid and semi-arid rangelands may be regulated by rainfall variability rather than by herbivore density (Ellis and Swift 1988).

The NEP model predicts that in arid and highly variable ecosystems abiotic factors such as precipitation have a greater influence on vegetation biomass and species composition than grazing (Fernandez-Gimenez and Allen-Diaz 1999). The model also predicts that in moist and constant environments, grazing plays a greater role in regulating vegetation productivity and composition.

The climate-plant-herbivore interactive model is one of the new models in rangeland management. This model contributes to the improved understanding of the dynamics of sub-Saharan rangelands. Most importantly, this model provides an opportunity to interpret more effectively the causes of land degradation in arid zones (Oba *et al*. 2000). The linkages between climate, plants, and herbivory serve as ecological drivers that influence the dynamics of sub-Saharan African rangelands (Oba *et al*. 2000). The principal driver is the climate with its variability having a direct impact on the variability of plant cover and biomass. However, herbivory influences biomass, species diversity and the efficiency with which plants use rainwater. Pickup (1994), Rietkerk *et al*. (1997) and O'Connor (1994) indicated that in the arid zones vegetation growth depends on soil moisture, structure, and water storage capacity, rainfall patterns over several years, amounts of effective rainfall released and duration of rainfall and season (Ellis and Swift 1988).

Noy-Meir (1973) explained the two synergistic effects of rainfall and grazing on plant production. Firstly, rainfall, by increasing plant growth, increases food availability to herbivores. Second, moderately intense herbivory promotes productivity that is higher than in the absence of grazing. Understanding the interaction among climate, plants, and grazing rather than trying to separate their effects would improve understanding of the dynamics of rangelands (Oba *et al*. 2000). The climate-plant-herbivory interactive model has the components that describe responses of the rangelands to climate and grazing, it addresses linkages between components that describe the functions of grazing ecosystems, and the components are linked through complex, interactive ecological and physiological processes that serve as diagnostic parameters for measuring and monitoring responses of plants to rainfall and grazing.

Carrying capacity (CC) has been used as a tool for rangeland management purposes and it is usually expressed as the number of standardized livestock units (LU) of 250 kg that can be held per unit of land area. The major flaw with this concept is that it assumes that a unique population of livestock is directly associated with a defined grazing area of homogeneous forage growth and quality (Hary *et al*. 1996). The validity of the CC is based on the premise that grazing systems behave as density-dependent systems, thus rangeland productivity decreases with increasing stocking rates and vice-versa. The amount of forage produced mainly varies according to the amount of rainfall, whereas forage quality on offer is also affected by the length of the growing period. It is best at the peak of the growing season and declines rapidly until the beginning of the dry season (Hary *et al*. 1996).

2.5.3. Role of vegetation in restoration of degraded rangelands

Vegetation plays an important role in erosion control; it efficiently mitigates erosion by active and passive protection (Rey *et al*. 2004). Active protection against erosive agents consists of raindrop interception (Woo *et al*. 1997), and increase in water infiltration in soil, thermal regulation and soil fixation by root systems (Gyssels and Poesen 2003). Vegetation also has a passive action by trapping and retaining sediments inside the catchment due to its aerial parts (Abu-Zreig 2001).

A protective soil cover can be installed efficiently on eroded lands using bioengineering works based on common practices of ecological engineering. These structures favour artificial and natural vegetation dynamics so the vegetation predominates over erosive dynamics and controls it. The long-term goal of the degradation interventions is to restore ecosystems, in accordance with recent considerations about ecological engineering concepts and techniques (Gattie *et al*. 2003; Odum and Odum 2003). Restoration is commonly considered as accelerated succession (Hilderbrand *et al*. 2005).

Planting vegetation as a restoration measure for degraded rangelands is preferred over structural measures since concrete, masonry, wood or any other building materials are subject to decay and liable to be bypassed (Sarangi *et al*. 2004). Vegetation grows through different stages while it is improving the function of the ecosystem by providing physical soil protection against erosion by reducing the velocity of runoff and its decomposition contributes to nutrient cycling (Schwab *et al*. 1993).

2.5.4. Rangeland restoration techniques

In rangelands that have become degraded to the point that ecosystem functions cannot recover solely through-improved management strategies within practice-relevant time spans, active rehabilitation techniques are sought (Dregne 2002). Most of these techniques aim at the improvement of soil water status by increasing infiltration or decreasing evaporative loss (Thurow 2000). These restoration techniques include introducing transplants, application of brush packs or organic mulch and developing microcatchments to capture runoff (Anderson *et al*. 2004; Simons and Allsopp 2007; Visser *et al*. 2004; Li *et al*. 2005).

Revegetation and improvement of degraded land is practiced after development of better techniques of seedbed preparation and planting methods (Gebremeskel and Pieterse 2008). Seed germination and establishment in natural and artificial revegetation is a result of the number of seeds in favourable microsites or 'safe sites' in the seedbed rather than the total number of available seeds (Harper *et al*. 1965). Various techniques to improve microsites for sown seeds and to increase the seed germination rate and establishment have been introduced in the rangeland revegetation process (Gebremeskel and Pieterse 2008).

Some methods used for rangeland restoration consist of biological and mechanical approaches. The biological approach includes planting methods of seeds using manure, gravel, and straw. The mechanical approach includes use of farm implements to disturb the soil (van der Merwe 1997). The use of organic mulch to improve establishment of oversown grass seeds in degraded rangelands has been emphasised (Ricket 1970; Winkel *et al*. 1991; and Jordaan and Rautenbach 1996).

The objective of the various methods of vegetation restoration among others is to create favourable microsites to enable seeds to germinate and establish more successfully (Gebremeskel and Pieterse 2008). These revegetation techniques are normally practiced when insufficient desirable forage plants have remained on the rangelands (Vallentine 1989) and when sound rangeland management practices cannot restore it to its original grazing potential (West *et al*. 1989; Jordaan 1997). Hyder *et al*. (1971) and Stoddart *et al*. (1975) further indicated that natural revegetation of perennial grasses is slow in many areas and therefore, species adapted to sowing are often desirable.

2.6. Post restoration management of communal rangelands

Animal production systems in semi-arid rangelands are complex; these production systems include a myriad of important variables such as climate, soils, and vegetation (Diaz-

Solis *et al*. 2006). Range productivity, stocking rate and market conditions influence management decisions, however, the principal decision is determination of the stocking rate (Redmon 1999). Behnke and Scoones (1993) indicated that stocking rate affects the balance between the domestic animal population and available forage. The establishment of fixed stocking rates for semi-arid rangelands is inexpedient due to climatic variability (Behnke and Scoones 1993; Illius *et al*. 1998; Diaz-Solis *et al*. 2009). Alternative management strategies might include increasing or decreasing stocking rate based on the current condition of the rangeland, season of the year, as well as direction and rate of change in animal condition.

There are a number of principles proposed for rangeland management, these include the principle of adaptive management (Walters and Hillborn 1978), Savory's holistic range management (HRM) (Savory 1988) and integrated watershed management (IWM) (Sarangi *et al*. 2004). Adaptive management entails *a priori* construction of a series of management-related hypotheses, implementation of the relevant management actions, monitoring of the outcome of such actions, and evaluation of the results obtained against expectations (Grossman *et al*. 1999). On the other hand, HRM puts more emphasis on record keeping; its guidelines include proformas for keeping records of finance, livestock performance, rangeland productivity, and condition of resource. However, unless effective use can be made of such records, there is no justification for keeping them (Hardy *et al*. 1999). IWM is defined as a multidisciplinary, holistic way of protecting and managing a watershed's natural resources to enhance biomass production in an eco-friendly manner.

The watershed acts as a social, economic, and political unit for planning and management purposes. Therefore, the watershed manager and policy makers consider all technical, social, economic, environmental, legal, and institutional aspects of watershed planning processes (Sarangi *et al*. 2004). Development of a decision support system (DSS) to address specific issues of watershed management assumes importance and holds the promise of making watershed management simpler and more effective. DSSs show great promise in the strategic planning of soil conservation efforts and can aid in selection of appropriate soil conservation practices for agricultural watersheds (Montas and Madramootoo 1992).

Land use is governed by economics, technology, social issues, and environmental considerations, and is influenced by state, national, and international policies. However, the outcome is largely determined by the ways in which land managers respond to the policies (Teague 1996). Management of rangeland ecosystems must be based on ecological theory; rangeland management planning should focus on developing an understanding of basic ecological processes, and answering specific ecological questions pertinent to management problems (Walker *et al*. 1978). Teague (1996) highlighted that the challenge is to understand how management influences ecosystem structure and function; and what management adjustments are required to achieve desired results of rangeland management. In coming up with the relevant rangeland management practices, the definition of the rangeland problems and priorities have to be provided in consideration of the three spheres viz, clientele objectives, research priorities, and extension roles. The definition of the ecosystem structure and conceptualization of ecosystem function will serve for the establishment of the key ecological and management questions (Figure 2.1).

Rangelands are a salient renewable resource and the primary land type in the world (Batabyal 2004). There are a number of important ecological functions such as nutrient cycling, decomposition of organic matter and infiltration performed by rangelands. Furthermore, a variety of goods and services including red meat, fibre, recreation, and wildlife viewing are provided by rangelands (Batabyal 2004). Although range managers have attempted to provide a sustainable rangeland management, they have little control over stochastic environmental events such as drought and fire. Batabyal (2004) further indicated that a range manager is unable to definitively determine the impacts of their actions on the condition of a rangeland. This is therefore, indicative of the fact that effective rangeland management is fundamentally an exercise in decision making under uncertainty.

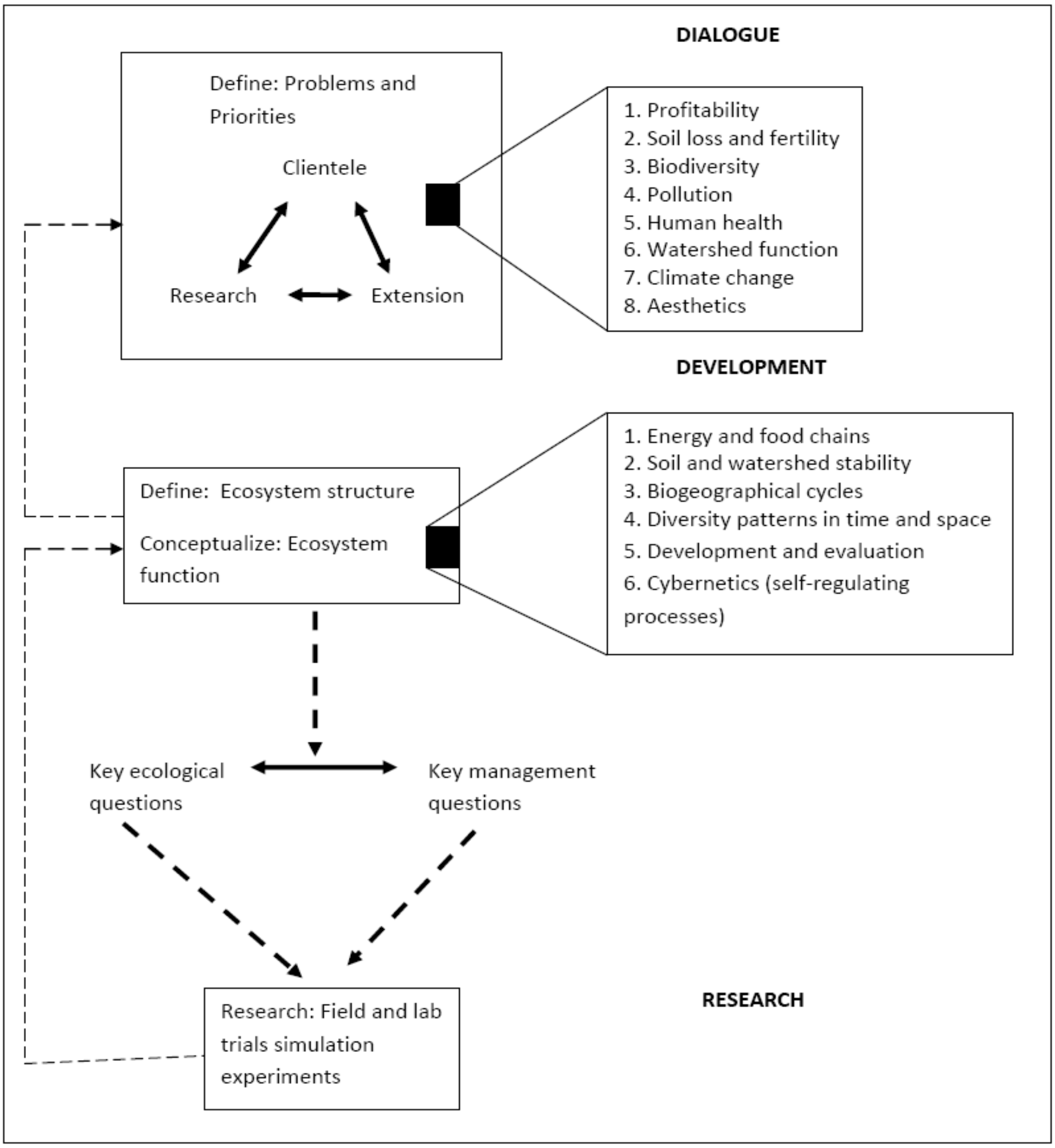

Figure 2.1: A framework for research: detail of issues pertinent in the dialogue phase and ecosystem functions to be considered when evaluating key ecological and management questions (Source: Teague 1996).

In the state and transition model, the objective of a range manager is to take opportunities and circumvent hazards (Batabyal 2004). This model puts more emphasis on timing and flexibility rather than on establishing a fixed policy (Westoby *et al*. 1989). Batabyal and Godfrey (2002) have shown that there are certain range states in which there is substantial scope for managerial actions, and there are states in which there is little or no role for managerial actions. However, Batabyal (2004) noted that whilst Batabyal and Godfrey (2002) acknowledge that some range states are likely to be undesirable, they do not account for the possibility that there may be a state of rangeland degradation, and that is effectively irreversible. Both their works emphasise the time factor in rangeland management. Thus Batabyal and Godfrey (2002) underline the amount of time a rangeland spends in the desirable and undesirable sets of states, whereas, Batabyal (2004) emphasised the amount of time a rangeland spends away from the irreversible state.

The question in providing a solution to rangeland degradation is driven from a point of view that overgrazing is the cause of rangeland degradation. Furthermore, the question would be, does over grazing depend on the number of animals or the time that the plants are exposed to herbivory or both? With regard to this uncertainty, Savory and Butterfield (1999) have argued that overgrazing bears little relationship to the number of animals but rather to the time that plants are exposed to the animals. According to Trollope *et al*. (1990), overgrazing is defined as excessive defoliation of the grass sward by animals to the detriment of the condition of the rangeland. Excessive defoliation could be due to both higher animal densities and a longer period of utilisation of rangelands. In the same vein, Nelson (1997) has maintained that it is risky to oversimplify and argue merely that too many animals pursuing a limited grazing resource are destroying the dryland areas of the world.

To understand what is occurring in rangeland production-based systems, it is valuable to contextualise current land management practices in terms of their production paradigms (Richards and Lawrence 2009). This can be largely described as a productivist model; this mode of production is increasingly contested due to such things as food quality and security, and its impact upon the environment (Lang and Heasman 2004). Productivism is the term that has been given to a system of agricultural/grazing enterprise that is characterized by the application of productivity-raising technologies, the introduction of new, more efficient breeds of animals, the use of antibiotics and other pharmaceuticals, and abiding by market ‘signals’ in the allocation of resources (Friedmann 2005).

Lang and Heasman (2004) indicated that productivism tends to emphasize quantity over quality and as a wider system of food production, assumes that consumers will be advantaged by the maximization of food production. It is ideally characterized by production intensification and concentration, along with product specialization (Argent 2002). This system is based upon unstable ecosystems that are subjected to the vagaries of the global market (Friedmann 2005; Gray and Lawrance 2001). This system is facing increasing challenges from consumers who are demanding clean and green foods, thus natural foods derived from sustainable farming systems; this is because of environmental, food safety, and animal welfare concerns with the existing system (Lyons *et al*. 2004).

There have been some proposals for alternative models following the shortfalls of the industrialised food production model. Such alternatives are referred to as the ecologically integrated paradigm. In this system, the practices are grounded in the ecological and biological sciences, and philosophically geared toward working with the rhythms of nature, rather than against them (Lang and Heasman 2004). This system requires reduced inputs from agribusiness suppliers such as pesticides and promotes a more interactive approach to land management aimed at maintaining ecological integrity.

2.7. Perceptions of farmers in communal grazing areas on rangeland degradation

Soil erosion is an insidious process; therefore, farmers need to perceive its severity and the associated yield loss before they can consider implementing soil and water conservation (SWC) practices. Soil erosion induces loss of productivity and has an effect on reducing current and future yields that makes it a major threat to food security (Chizana *et al*. 2007). Yields are a product not only of soil erosion but also of past and current management practices, seed sources, climate, colonial history, pests and diseases, as well as other stochastic events in nature (Chizana *et al*. 2007). The farmer's perspective is often different from a researchers' scientific explanation. Thus, a farmer's perspective on soil erosion utilizes and integrates the view of the farmer who is the ultimate user of the soil (Murwira *et al*. 2006).

Farmers in communal areas are aware that soil degradation takes place in various forms and different forms of erosion are taking place in communal rangelands. The major indicators of degradation as identified by the farmers include rill and gully erosion, declining productivity, and reduction of soil fertility (Chizana *et al*. 2007). The challenge for addressing the problem of rangeland degradation in communal areas is the introduction of conservation measures and making people aware of the benefits through education (Everson *et al*. 2007). The reason for involving communities is that they are directly affected by degradation and benefit from land rehabilitation. Therefore, incorporation provides a greater chance of acceptance by the communities and establishes the conditions necessary for success of a traditional system of natural resource management (Fernandez-Gimenez 2000). It further provides opportunities for evaluating natural resources from the perspective of local management decisions associated with land degradation (Oba *et al*. 2008). Local communities have developed systematic methods of environmental assessment and monitoring. This is based on personal experiences of the physical and biological resources that often reflect social-cultural values of resource users (Oba *et al*. 2008).

Degradation of biological and physical rangeland resources has become a serious challenge, bearing negative influences for pastoral ecosystems, livestock production, and livelihoods thereof (Vetter 2005). The results include reduction in total vegetation cover and palatable plant species, increases in undesirable and unpalatable plants and depletion of soil quality and nutrients due to various forms of soil erosion (Haileslassie *et al*. 2005). Gemedo-Dalle (2004) and Vetter *et al*. (2006) indicated that policy makers, development planners, and researchers do not fully understand rangeland degradation. It is rather confused with desertification (Mortimore 2005), and influenced by biases of western intellectuals (Ellis and Swift 1988; Sandford 1983). All this has led to human perceptions being overlooked (Allsopp *et al*. 2007; Gemedo-Dalle *et al*. 2006), and the production system being considered as ecologically unfriendly and unsustainable (Lamprey 1983).

The importance of pastoralists' perceptions has not been fully appreciated by policy makers, government staff and nongovernmental personnel and the broader public (Azadi *et al*. 2007). Herskovitz (1926) hypothesised that pastoralists accumulate vast numbers of livestock mostly for reasons of social power and prestige. Hardin (1968) noted the concept of the tragedy of commons; this notion further illustrated the irrational and destructive nature of pastoral management. Nunow (2000) criticized pastoralists as irrational, ecologically destructive, and economically inefficient producers. As a result many scholars and officials in the international development community have widely accepted the belief that pastoral livestock management is irrational and inherently destructive (Sandford 1983). This has further resulted in pastoralists and their interests not being very high on national policy agendas. Furthermore, according to the diffusion of innovations theory (Roling *et al*. 1976), the farmers had to accept technologies recommended by scientists to change their irrational thoughts and behaviour (Roling 1979). The low level of knowledge, capacity, and resources from the farmers has prevented them from voicing their views and perceptions (Fratkin and Roth 2004).

3. GENERAL DESCRIPTION OF STUDY SITES

3.1. Study areas

3.1.1. Amakhuze Tribal Authority and Phandulwazi Agricultural High School

The study was conducted at Amakhuze Tribal Authority (ATA) and Phandulwazi Agricultural High School. Amakhuze Tribal Authority (ATA) is composed of six villages viz. Makuzeni, Gomro, Mpundu, Guquka, Sompondo, and Gilton. The Amakhuze Tribal Authority is situated at Nkonkobe Local Municipality in the central Eastern Cape. It is located at S32^{o} 38´, E26^{o}56´ with the altitude ranging from 763 m.a.s.l in lowlands to 1500 m.a.s.l at the summit of Amakhuze Tribal area boundaries. Phandulwazi Agricultural High School is located at S32^{o} 39´ and E26^{o} 55´ at an altitude of 747 m.a.s.l (Figure 3.1). Amakhuze Tribal area was established in the late 1890s, the villages within this tribal area share the rangelands of approximately 400 ha (Van Averbeke *et al*. 1998). Administratively, the ATA falls within the boundaries of Amatola District Municipality (Hebinck 2007). These villages were subjected to limited betterment planning during the early 1960s to the extent that rangeland and arable land were fenced off from the residential sections of the villages.

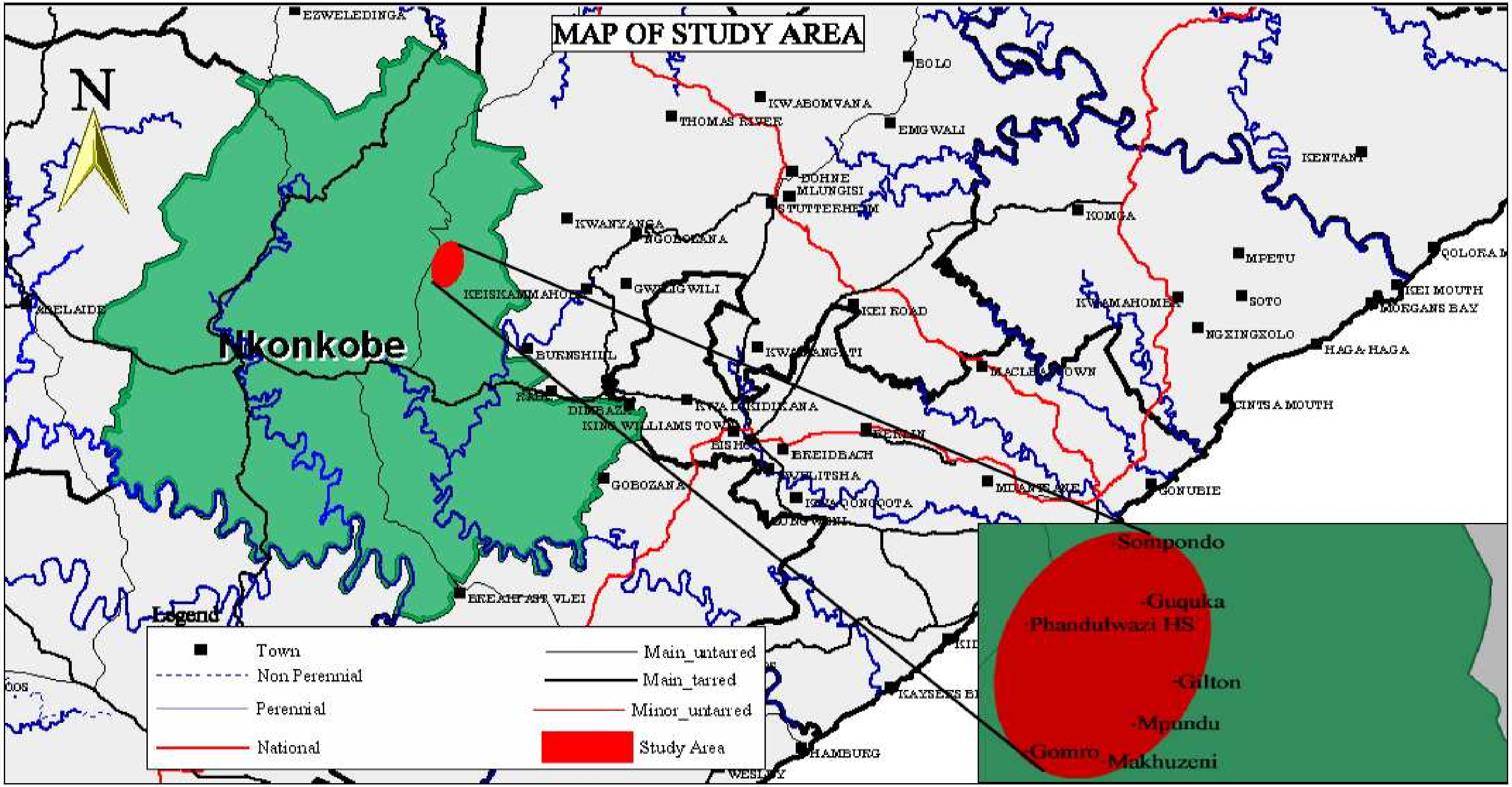

Figure 3.1: Map locating Amakhuze Tribal Authority and Phandulwazi Agricultural High School at Nkonkobe Local Municipality in the Eastern Cape province of South Africa.

3.1.2. Climate of the study areas

The study area was covered by climate zones as defined by Dent *et al*. (1988) (Homogeneous climate zone - HCZ 165). According to Köppen climate classification, the study area was classified as humid subtropical with annual rainfall ranging from 700 mm to 1200 mm (Bennett *et al*. 2007; Marais 1975) and the warmest month less than 22^{o}C (Thackrah *et al*. 2002). The main ecotope characteristics that affect agricultural productivity were characterised in detail to ensure extrapolation of the results on these ecotopes to all other similar ecotopes (i.e. pedotransfer functions) (Hensley *et al*. 2000). The term ecotope can be defined as a three-dimensional representation of the atmosphere-plant-soil (APS) system in which the natural resources that influence production (climate, topography, and soil) are reasonably homogeneous (MacVicar *et al*. 1974). The characteristics, productivity, and stability of the APS system depend on these natural resources factors. Points in the landscape at which the characteristics of one or more of the factors (climate, topography, and soil) change significantly (Hensley 1995) determine the boundaries of such a system.

There were two ecotopes identified for the study area viz Guquka/Cartref and Phandulwazi/Westleigh ecotopes. To describe these ecotopes, the long-term climate data from nearby weather stations were used to characterize the climate. For both ecotopes, PLEASANT VIEW (11106) weather station for climate with geographical coordinates 32.67^{o}S and 26.9^{o}E at an altitude of 701 m.a.s.l and was 3 km southwest from the study area was used for rainfall. The KEISKAMMAHOEK (30380) weather station for climate with geographical coordinates 32.68^{o}S and 27.13^{o}E at an altitude 668 m.a.s.l and located at 19 km to the east of the study area (Figure 3.2).

The AgroMet DataBank was used to find the long-term climate data representative of the HCZ of the study area. This databank contains data collected by organisations including the Agricultural Research Council – Institute for Soil, Climate, and Water (ARC-ISCW) and the South African Weather Services (SAWS). One rainfall and one climate station were chosen to represent the area. The rainfall station PLEASANT VIEW (11106) best represents the study area with rainfall data of 39 years, from 1928 until 1968. The mean annual rainfall was during data collection period was 630 – 640 mm, however, rainfall at the actual sites (further up valley) is likely to be slightly higher but still at the very low end of climate classification (c700 mm/annum).

The ARC-ISCW developed climate surfaces for South Africa with a grid resolution of 1 x 1 km. These surfaces were found to be accurate to within 1 ^{o}C for temperature and 10 mm for rainfall. These surfaces include maximum, minimum, and average temperature, rainfall, and sunshine hour's surfaces on a 10 – daily, monthly, and annual basis.

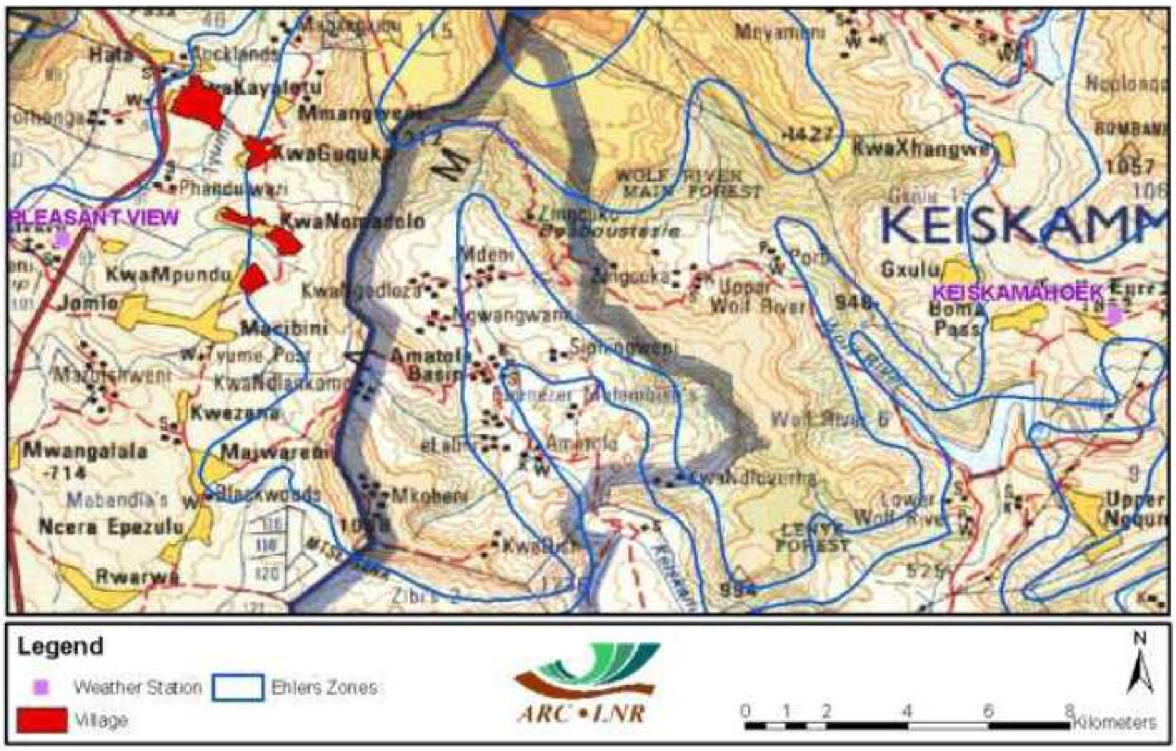

Figure 3.2: The map indicating an orientation of Weather Stations relative to the study area

3.1.3. Rangeland and livestock management

Livestock grazing at the Amakhuze Tribal Authority was described as open-access with little institutional control on the rangeland area (Bennett and Barrett 2007). During summer months of the year animals free-range to the upper reaches of the rangeland and are rarely kraaled. However, smallstock (sheep and goats) are kraaled at night to prevent predation and theft. Grazing management at Phandulwazi Agricultural School rangelands could be characterised as relatively controlled (rotational grazing), this has been practiced with the use of beef cattle (Nguni and Bonsmara), sheep, and goats, with dairy cattle grazing on cultivated pastures. However, rotational grazing was not dependent of time intervals of utilisation (period of occupation, deferment etc) but rather based on subjective observation of the vegetation condition. The rangelands on both locations within the study area were characterised by high rainfall and become nutritionally poor during the dry season (Bennett *et al*. 2007).

The communal grazing areas at Amakhuze Tribal Authority were shared among community participants and to a lesser extent with other nearby communities. The boundaries of the communal grazing land are well defined in relation to residential and arable blocks, but the high elevation grazing land shared by several communities is not well defined. Cattle may be found at or around the summits of the mountain terrain at 1600 – 1650 m. a. s. l.

Apart from nearby indigenous forest, two major vegetation units occur, namely, mixed grassland and Karoo shrubs on the bottomlands and lower slopes, and grassland on the mid to upper slopes. The grazing area is divided into unfenced camps and managed as one grazing unit. The local veld type is a combination of Dohne and Highland Sourveld (Acocks 1988). However, according to Mucina and Rutherford (2006) the vegetation type of the study area could be classified as the mixture of Bhisho Thornveld, Amathole Montane grassland, Eastern Cape Escapement Thicket, and Southern Mistbelt Forest.

Vegetation in the study area was further classified according to the season of use as sourveld. The sourveld occurs in areas with high rainfall and where parent material gives rise to soils with a high base status (Tainton 1999). These sour veld types are nutritionally deficient during winter months and do not generally tolerate high grazing pressures. Both cattle and sheep are forced to compete for available forage on the arable lands in winter. Preferred grazing resources such as crop residues are quickly exhausted and thereafter shortage of adequate winter forage becomes a real problem at the village. The lack of central control over grazing exacerbates the problem and has, in many cases forced livestock production efforts to devolve to the individual level.

3.1.4. Soil classification and description

The soils at Amakhuze Tribal Authority are dominantly brown in colour overlying iron concretions, which overlie weathered rock. The soils are very shallow with maximum depth of about 600 mm. The dominant soil forms are Cartref and Westleigh (Potgieter 2005). Bulk density ranges from 1.9 g/cm in the topsoil to 2.2 g/cm in the subsoil. The clay content increases from 12.7% in the topsoil to 15.1% in the subsoil.

The soil at Phandulwazi High School was classified according to the Soil Classification Working Group (1991), as belonging to the Helena Family of the Westleigh Form. It is dark greyish brown, poorly structured, loam orthic A horizon overlying a yellowish red soft plintic B horizon at a depth of 400 mm. The bulk density ranges from 1.6 g/cm in the topsoil to 1.75 g/cm in the subsoil. The effective rooting depth is up to about 1 m. The clay content decreases with depth; it is 26% in the topsoil and 17% in the subsoil.

4. PERCEPTIONS OF COMMUNAL FARMERS ON CAUSES, TYPES OF DEGRADATION AND TECHNIQUES TO RESTORE DEGRADED RANGELANDS

4.1. Introduction

Communal rangelands are used primarily for grazing mostly domestic animals such as cattle, sheep, goats, horses, and donkeys. There are also some wild animals found grazing in some of the communally owned areas especially with dense forest. There are other secondary resources such as water, firewood, and wild foods. These areas are owned and used as common property resource by low resourced poor farmers for grazing livestock. Rangelands provide ecosystem services upon which the well-being of current and future human societies are predicated (Teague *et al*. 2009). These services include maintenance of stable and productive soils, delivery of clean water, and sustaining plants, animals, and other organisms that support the livelihoods and aesthetic and cultural values of people (Grice and Hodgkinson 2002).

There is a common perception amongst the rangeland scientists that communal rangelands are degraded and this is caused by improper grazing management. Gemedo-Dalle (2004), Vetter *et al*. (2006) and Azadi *et al*. (2007) indicated that policy makers, development planners, and researchers do not understand rangeland degradation; it is rather confused with desertification (Mortimore 2005), however, desertification the form of land degradation. Degradation in biological and physical rangeland resources has become a serious challenge in communal rangelands, bearing negative influences to the pastoral ecosystems, livestock production, and livelihoods thereof (Vetter 2005). Biologically, degradation reduces vegetation cover and palatable plant species, while increasing undesirable and unpalatable plants. Physically land degradation causes various forms of soil erosion and depletion of soil quality (Haileslassie *et al*. 2005). Land degradation further reduces carrying capacity and that results in the reduced economic productivity of rangeland ecosystems.

Rangeland users' perceptions have been overlooked in the determination of whether the rangelands are degraded or not (Allsopp *et al*. 2007; Gemedo-Dalle *et al*. 2006), and the communal production system has been considered to be ecologically unfriendly and unsustainable (Lamprey 1983). Herskovitz (1926) developed the hypothesis that communal rangeland users accumulate vast numbers of livestock mostly for reasons of social power and prestige. Hardin (1968) noted the concept of the tragedy of commons; this notion further illustrated the irrational and destructive nature of communal management. While there is a broad perception amongst the scientists that rangelands are degraded and the major cause being ecologically unfriendly rangeland management practices, the objectives of communal rangeland users for production from the rangeland are not considered.

Moyo *et al*. (2008) indicated that there is a failure by policy-makers to recognise that implementation of scientific knowledge is shaped by social, cultural, and political frames. Incorporating end-users in formulating and implementing policies affords the policy-makers an opportunity to capture perceptions of resource users, and hence shape the policy in ways that will improve uptake.

There are large numbers of factors that influence land degradation and its impact on communal areas of Eastern Cape. In communal areas, members of the community keep livestock and therefore, influence utilisation of rangelands. Hence, there is a need to engage communal residents in the identification of degradation as a problem, vegetation restoration, and proper rangeland management as solutions. Identification of land user's interests such as an improved livestock production and rangeland condition, followed by land production capacity assessment governed by rangeland management, climatic, edaphic, and topographic features could precede improved communal rangeland management.

Kavana *et al*. (2005) suggested that there should be complementarities of modern scientific knowledge and traditional natural resource management for sustainable livestock productivity, biodiversity, and soil conservation in traditional agricultural systems. A scientific view might promote restoration goals derived from geomorphological and ecological imperatives (Kondolf 1998). However, restoration is more of a process of modifying the biophysical environment and captures the interaction between scientific definitions and the goals of society as a whole (McDonald *et al*. 2004).

This chapter aims to investigate land users' perceptions of the causes of rangeland degradation, the characteristics they use to describe degradation, and the alternative restoration techniques they propose. The null hypothesis was that according to farmers perceptions, there are no policies for rangeland access and utilisation, farmers have rangeland management skills, and control livestock movement within the rangelands, thus leading to good rangeland management practices, hence, no rangeland degradation in communal areas. The assumption on which this hypothesis has been described in section 1.2.2.

4.2. Materials and methods

4.2.1. Data collection

The soft system analysis (Checkland 1981) was used through informal and unstructured discussions to determine communal rangeland residents' perceptions on rangeland management, degradation, and restoration. Furthermore, focus group discussions were conducted to determine the perceptions of men, women, and youth on rangeland management, degradation, and restoration at Makhuzeni, Gomro, Mpundu, Gilton, Guquka, and Sompondo. Through the use of the Sustainable Livelihoods Analysis (Scoones 1998), approach community members identified and described the financial, natural, human, physical, institutional and social capital assets that community have access to. The context of the perceptions of communal land users was established through local community consultation that identified strengths, weaknesses, opportunities, and threats for specific communal animal production practices (Reed *et al*. 2006). Participatory tools such as participatory mapping, activity calendar, oral histories, transect walks were used to describe communal area livelihood systems (Chambers 2002) (the program for village visits and activities during village visits are presented in Appendix 1 and 2 respectively).

A quantitative structured questionnaire survey (Reed *et al*. 2006) was conducted at four villages viz Gomro, Guquka, Makhuzeni, and Sompondo to represent Amakhuze Tribal Authority. These four villages were selected randomly from the total of six, and thirty-five households were selected randomly in each community. The total number of the respondents was 140. Prior to the administration of questionnaires, a reconnaissance survey was conducted in each of the sample locations to obtain the number of households and their layout. The questionnaire survey (Appendix 4) was used to establish an understanding of perceptions of communal area residents on the scale, scope, and nature of rangeland management, degradation, and restoration. The questionnaire included questions concerning different aspects of demographic information, livestock production, communal rangeland management, and degradation status and restoration ability.

4.2.2. Data analysis

Participatory Rural Appraisal (PRA) and focus group discussion data were analysed qualitatively (Beyene 2009). The analysis began from revising detailed field-notes and consolidating similar information with the use of a summary table. Three steps are crucial to the qualitative analysis. First, information from the field-notes (from focus group discussions) was sorted out in order to group responses. This was carried out independently for each village in a way the information source was traceable. In the second step, data from focus group discussions were assembled. The third and final step was cross-case comparative analysis to examine differences and overlaps across the six villages with the underlying themes of the investigation. The comparison had focused on identification of trends and patterns in order to delineate deep structure and to get to the roots of the issues studied. While analysing, there has been a move from describing a specified situation and processes to identifying comparable patterns (Miles and Huberman 1994) (Summary of PRA analysis is presented in Appendix 3).

The questionnaire data were analysed with SPSS-PC version 15.0 (SPSS 1999). The Pearson's Chi square tests of independence was used to test whether what the people said (observed frequencies) tallied with what was expected (expected frequencies) amongst the villages for different aspects of perceptions investigated. The association between the observed and expected frequencies was considered significant at $p < 0.05$. The observed and expected frequencies were reported as percentages (%) of the total sample size (n). The Chi square results were reported as ($\chi^2_{df,\ n}$ = chi square value). One way ANOVA was used to compare livestock (cattle, sheep, and goats) ownership between marital status, education, and occupation of the respondents. The villages were used as the replicates. The villages were used as replicates because there are no fundamental differences existing among these villages are under the same Tribal authority and within similar climatic regimes, soil, and vegetation types. Before the analysis, the data were tested for normal distribution. The difference was considered significant at $p < 0.05$.

4.3. Results

4.3.1. Household demographics and ownership of livestock

During the focus group discussion, the majority of participants were men, followed by women while the number of the youth was low in all the six communities. They identified cattle and sheep production, availability of water and rangelands, indigenous chicken and vegetable production as the strengths of their tribal authority. The opportunities of the villages were identified by the land users as including cattle and sheep genetic improvement through the University of Fort Hare Nguni Project and Ram Program of the Government with South African Wool Growers Association (SAWGA). The community threats were stock theft, rangeland burning, land degradation and livestock diseases.

The weaknesses on the communal production included lack of fencing on rangelands and arable lands, lack of knowledge on rangeland management and low level of commitment of the youth to agricultural practices. The land users in all the focus groups (men, women, and youth) mapped their resources such as grasslands, arable lands, mountains, roads, graveyards, dams, rivers, and settlement areas. They also identified socio-economic issues such as major sources of income, which were dominated by government grants; sources of food mostly coming from agriculture and government food packages.

The policy issues included access to rangeland resource utilization, availability, and implementation of rules governing use of rangeland resources. The participants from men and women focus groups highlighted that there are rules; however, these are not implemented. The youth group indicated that they do not know of any rules governing rangeland utilization and rangeland resources are accessed by anyone without limitation to quantity of duration of use. Participants identified cattle, sheep, and goats as the major components of livestock production practice within the villages. Communal farmers also discussed the issues pertaining to rangeland management, degradation, and restoration. The summary of the Participatory rural appraisal (PRA) and focus group discussion is presented in the appendix 3.

The majority (55.5%) of the respondents were older people (> 60 years old), this was significantly higher ($\chi^2_{2, 137} = 31.547$, $p < 0.05$) than the expected frequencies (33.4%). Most (67.9%) of the respondents ($\chi^2_{1, 137} = 17.526$, $p < 0.05$) were males. Majority (42.3%) of these were married ($\chi^2_{3, 137} = 54.328$). The greater (39.4%) number of the respondents at least acquired secondary level of education ($\chi^2_{4, 137} = 68.511$). Most (51.1%) of them were unemployed ($\chi^2_{4, 137} = 126.686$, $p < 0.05$). Majority (47.5%) of the households were smaller (1 – 4 members) in size followed by the medium (5 – 8 members) sized households (44.5%), the results were significantly higher ($\chi^2_{2, 137} = 39.650$, $p < 0.05$) than the expected frequencies (32.8%). The number (71.5%) of adults per household was significantly higher ($\chi^2_{8, 137} = 100.876$, $p < 0.05$) at the households that were composed of 2 to 4 members.

People with tertiary education level owned significant ($F = 2.54$, $p < 0.05$) higher number of sheep (21) (Table 4.1). The number of cattle was also significantly higher ($F = 2.94$, $p < 0.05$) for people who were employed (15).

4.3.2. Rangeland -Livestock management and handling infrastructure

Significantly higher number (65%) of farmers indicated that there is too much forage available during the wet season ($\chi^2_{2, 137} = 63.255$, $p < 0.05$) (Figure 4.1). Whilst on the other hand, farmers significantly (86.9%) indicated that there is a shortage of forage during the dry season ($\chi^2_{1, 137} = 57.818$, $p < 0.05$) (Figure 4.2). The shortage of forage during dry/winter season was significantly (67.2%) attributed to low rainfall by most of the respondents ($\chi^2_{2, 137} = 88.920$, $p < 0.05$).

Table 4.1: Livestock ownership across gender, marital status, education and occupation at all four villages (Mean ± SE, n = 138, p < 0.05)

Household demography		Number of animals		
		Cattle	Sheep	Goats
Marital status	Divorced	1.00±1.00[a]	0.00±0.00[a]	0.00±0.00[a]
	Married	6.58±1.15[a]	7.73±2.36[a]	4.03±1.28[a]
	Single	7.82±1.66[a]	8.82±2.72[a]	2.63±0.96[a]
	Widowed	2.68±0.74[a]	2.64±1.22[a]	0.96±0.54[a]
Education	Metric	10.3±4.15[a]	5.14±2.25[c]	2.79±1.70[a]
	None	5.36±2.28[c]	10.73±5.74[b]	0.55±0.39[a]
	Primary	4.60±1.20[c]	4.08±2.14[c]	1.92±0.67[a]
	Secondary	7.00±1.20[b]	6.43±1.60[c]	4.35±1.40[a]
	Tertiary	4.18±1.89[c]	20.82±11.1[a]	2.00±1.20[a]
Occupation	Employed	15.13±6.79[a]	5.25±3.83[a]	4.38±2.54[a]
	Learner	7.17±2.53[b]	1.25±0.90[a]	2.17±1.32[a]
	Pensioner	5.26±1.25[b]	7.07±2.54[a]	3.98±1.58[a]
	Unemployed	5.32±0.93[b]	8.17±2.18[a]	1.90±0.56[a]

Different superscripts within the same column indicate that the means of animal numbers were significantly different within the marital status, education, and occupation.

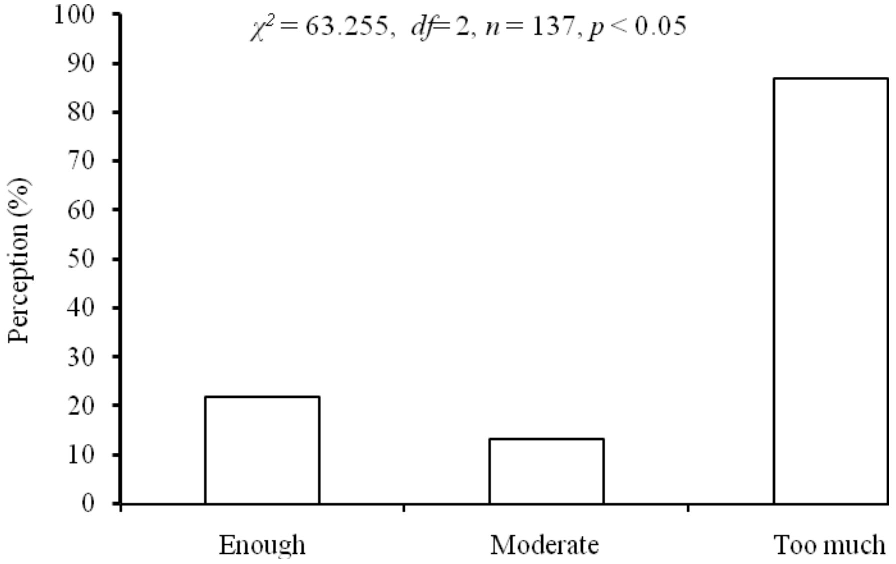

Figure 4.1: Perceptions of Farmers on forage availability during the wet season.

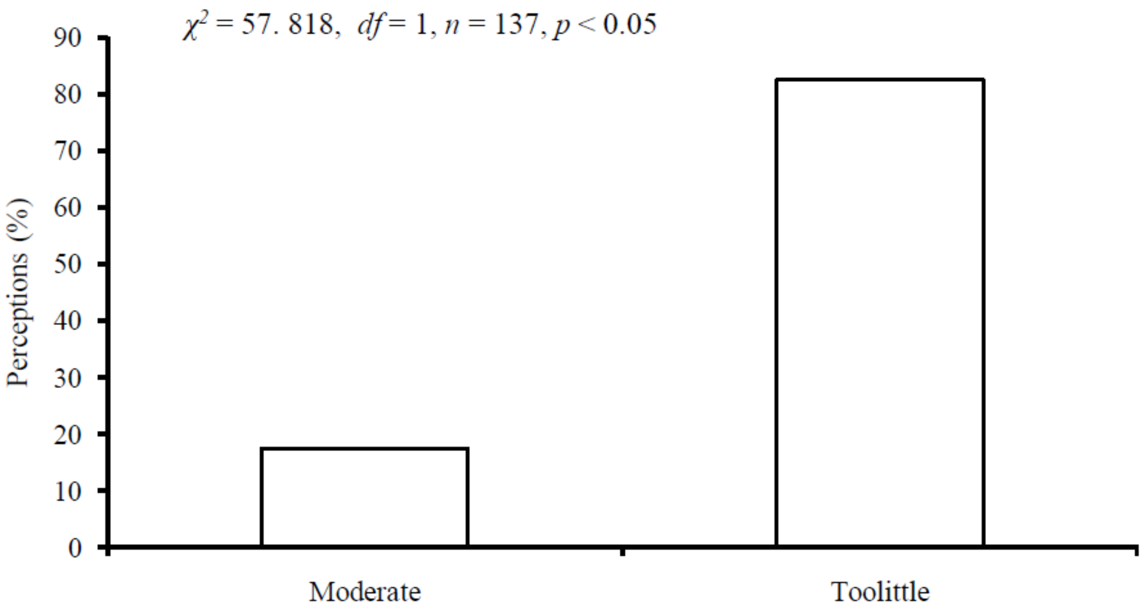

Figure 4.2: Perceptions of farmers on forage availability during dry season.

There was a significantly higher (86.9%) number of farmers who indicated that they do not provide any feed supplements for their animals ($\chi^2_{1,\ 137} = 74.460$, $p < 0.05$). Those who indicated (13.1%) that they give feed supplements to their animals further highlighted that they give these supplements in winter (10.2%). The majority of the farmers (55.5%) indicated that they use the arable land for grazing and the decision about when to use arable land for grazing is taken by the household head ($\chi^2_{4,\ 137} = 111.212$, $p < 0.05$). On the question about the impact of grazing on the arable land, the majority of farmers (54%) significantly pointed out that grazing on the arable land causes soil compaction ($\chi^2_{4,\ 137} = 145.810$, $p < 0.05$).

A significantly higher number (43.8%) of farmers indicated that they do not kraal their cattle at all ($\chi^2_{3,\ 137} = 60.869$, $p < 0.05$). Most of the respondents (65.5%) did not own sheep ($\chi^2_{1,\ 137} = 9.993$, $p < 0.05$), all of those respondents (34.5%) who owned sheep indicated that they kraal them daily. Furthermore, few farmers (25.5%) own goats, thus, the majority (74.5%) of the respondents did not farm with goats ($\chi^2_{1,\ 137} = 32.766$, $p < 0.05$). There was a significantly high (43.1%) number of farmers who believe that there were no conflicts on the use of rangeland resources between neighbouring villages ($\chi^2_{5,\ 137} = 49.175$, $p < 0.05$), the respondents further believed that this was because of cooperation between the villages.

The majority (65%) of rangeland users significantly admitted that the rangelands are demarcated into camps ($\chi^2_{1,\ 137} = 12.270$, $p < 0.05$). The purpose of demarcating rangelands into camps was significantly identified by majority (66.4%) of farmers as to facilitated the practice of controlled grazing between the camps ($\chi^2_{1,\ 137} = 14.781$, $p < 0.05$). There was no significant association ($\chi^2_{1,\ 137} = 0.182$, $p > 0.05$) between (51.8%) the farmers who indicated that they manage livestock movement and farmers (48%) who do not manage animal's movement within the rangelands.

There was significantly larger ($\chi^2_{1,\ 137}$ = 47.881, $p < 0.05$) number of the farmers (79.6%) who showed that the distances between grazing areas and drinking points was less than 1 km. The significant ($\chi^2_{1,\ 137}$ = 80.474, $p < 0.05$) number of farmers (88.3%) further mentioned that they do not experience water problem at any time of the year.

4.3.3. Perceptions of farmers on rangeland condition, management, degradation and restoration

There was a significantly larger (79.6%) number of farmers who indicated that they have full access to communal rangelands and they further mentioned that access to rangelands is a residential right ($\chi^2_{2,\ 137}$ = 139.153, $p < 0.05$). The larger number (68.6%) of farmers indicated that no one controls access to rangelands ($\chi^2_{2,\ 137}$ = 95.139, $p < 0.05$). It was further significantly indicated by farmers (75.2%) that communal rangelands are accessed for grazing and/or browsing ($\chi^2_{1,\ 137}$ = 34.752, $p < 0.05$). The larger number (74.5%) of farmers significantly ($\chi^2_{1,\ 137}$ = 32.766, $p < 0.5$) alluded to the fact that there are no grazing rules at Amakhuze Tribal Authority.

Majority (92%) of rangeland users indicated significantly ($\chi^2_{1,\ 137}$ = 34.752, $p < 0.05$) that rangelands are accessed for the whole year, with no restrictions (94%) to times of access and quantities or duration of use ($\chi^2_{1,\ 137}$ = 106.869, $p < 0.05$). It was significantly highlighted by farmers (92.7%) that the rangelands are not fenced ($\chi^2_{1,\ 137}$ = 217.87, $p < 0.05$). They (92.7%) furthermore, significantly pointed out that rangelands are burned regularly ($\chi^2_{1,\ 137}$ = 99.92, $p < 0.05$). Farmers did not know (96.2%) as to who decides to burn the rangelands ($\chi^2_{1,\ 137}$ = 117.73, $p < 0.05$). It was perceived by farmers that the reasons for burning rangelands was a mistake (8.8%), promotion of an early green grass regrowth (34.3%) and while the majority (48.9%) thought, it was due to mischief ($\chi^2_{1,\ 137}$ = 66.29, $p < 0.05$).

Most of the farmers (63.5%) perceived the rangeland condition ($\chi^2_{4, 137} = 178.88$, p < 0.05) to be poor (Figure 4.3). The poor condition of rangelands was significantly attributed to burning (10.2%), bush encroachment (12.4%), land formation (14.6%), poor soil quality (16.8%) drought (20.4%), and poor grazing practices (25.6%) ($\chi^2_{5, 137} = 12.91$, $p < 0.05$).

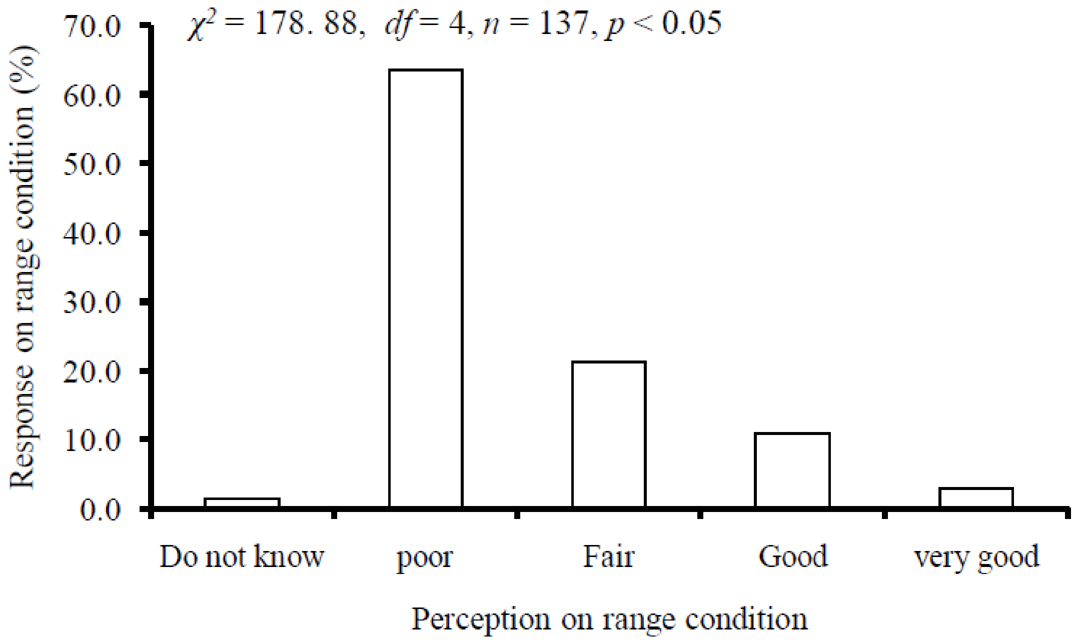

Figure 4.3: Perception of farmers of the condition of rangelands

Farmers (87.6%) perceived that the rangelands are degraded ($\chi^2_{1, 137} = 77.44$, $p < 0.05$) and they indicated that the reasons for this perception ($\chi^2_{3, 137} = 29.22$, $p < 0.05$) were presence of rills (8.8%), general soil erosion (31.4%) and presence of gullies (39.4%), however, some still believe that the rangelands are not degraded (20%). The level of degradation was perceived to range from average (34.3%) to high (51.8%) ($\chi^2_{3, 137} = 80.66$, $p < 0.05$). Farmers (89.1%) indicated that they have not tried to apply any rehabilitation control measures on degraded parts of rangeland ($\chi^2_{1, 137} = 83.66$, $p < 0.05$).

Farmers (43.8%) pointed out that animals grazed all over the grazing area in summer and winter, thus, arable lands, foothills, mountaintops are without much of area grazing preference ($\chi^2_{4,\ 137}$ = 92.09, p < 0.05). Nevertheless, they (45.3%) indicated that goats exhibited some degree of movement in terms of grazing preference throughout the year ($\chi^2_{2,\ 137}$ = 15.61, p < 0.05). The movement of animals within the grazing areas was significantly (65.7%) perceived to be due to the variation of feed quality at different areas and times of the year ($\chi^2_{2,\ 137}$ = 72.5, p < 0.05). It was indicated by farmers (33.6%) that the area that was preferred by cattle ($\chi^2_{3,\ 137}$ = 14.39, p < 0.05) was the midslope.

Farmers (57.7%) perceived that livestock grazing preference is influenced by the quality of forage ($\chi^2_{2,\ 137}$ = 49.15, p < 0.05). The majority of farmers (75.2%) perceived that fencing of camps ($\chi^2_{4,\ 137}$ = 271.58, p < 0.05) could serve as the best way to ensure sustainable utilization of grazing resources. They (49.6%) have suggested that the major constraint in ensuring rangeland management is lack of fencing ($\chi^2_{4,\ 137}$ = 115.96, p < 0.05).

Rangeland degradation indicators identified by the farmers include vegetation change, soil deposition, pedestals, and gullies (Figure 4.4). However, the highest (54.8%) indicator identified was the presence of rills ($\chi^2_{5,\ 137}$ = 161.73, p < 0.05). On answering the question about the types of soil erosion occurring in rangelands, farmers named sheet erosion (6.7%), gully erosion (38%) and the highest ($\chi^2_{3,\ 137}$ = 96.14, p < 0.05) was rill erosion (52.6%). Rangeland areas with sloping terrain were identified by the farmers (86.9%) to be the most ($\chi^2_{4,\ 137}$ = 384.42, p < 0.05) degraded. Such grazing areas with higher ($\chi^2_{2,\ 137}$ = 95.14, p < 0.05) degradation level as perceived by farmers (70.1%) were located at the midslope along the mountain gradient. On the level of degradation with the distance from the homesteads, farmers (85.4%) indicated that grazing areas closer to homesteads were the most ($\chi^2_{4,\ 137}$ = 226.91, p < 0.05) degraded.

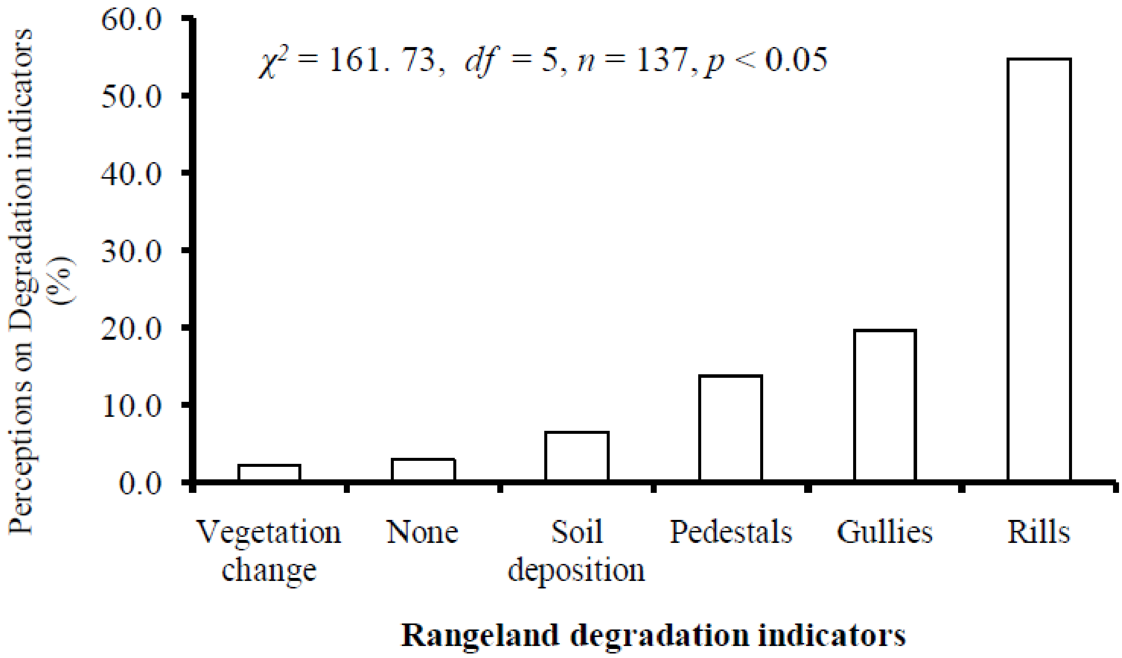

Figure 4.4: Perceptions of farmers on rangeland degradation indicators at Amakhuze Tribal Authority

Grassland vegetation type was perceived by farmers (65.7%) as the most ($\chi^2_{4, 137} = 195.66$, $p < 0.05$) degraded part of rangeland (Figure 4.5). Most of the farmers (65.69%) are of the perception ($\chi^2_{1, 137} = 13.5$, $p < 0.05$) that degraded rangeland still has a potential to recover. The proposed possible methods to facilitate rangeland recovery from degradation are presented in Figure 4.6. However, the method that was ($\chi^2_{6, 137} = 63.45$, $p < 0.05$) proposed by the majority (34.3%) of farmers was the building of stonewalls.

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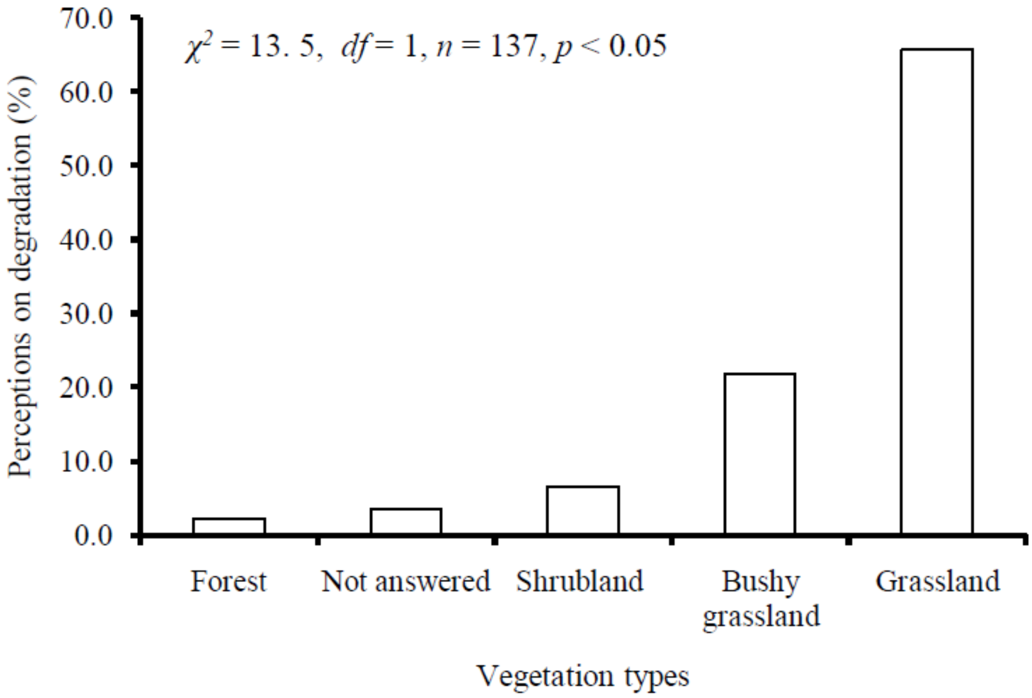

Figure 4.5: Perceptions of farmers on rangeland degradation at different vegetation types

A higher proportion of farmers significantly recommended that fencing and dividing rangelands into camps (32.9%), appointment of rangers (22.6%) and rotational grazing practices (14.6%) would improve rangeland management and therefore, prevent land degradation ($\chi^2_{9, 137} = 136.50$, $p < 0.05$). The respondents during the focus group discussion indicated that they have less knowledge on rangeland management. Whilst on the questionnaire, they significantly ($\chi^2_{3, 137} = 21.86$, $p < 0.05$) indicated that their knowledge for rangeland management could range from none (29.2%), low (35.8%) and average (26.3%). They (91.2%) furthermore, indicated that there was never a training program on rangeland management previously at Amakhuze Tribal Authority ($\chi^2_{1, 137} = 93.20$, $p < 0.05$). The larger number of (54%) rangeland users indicated with significance ($\chi^2_{5, 137} = 169.88$, $p < 0.05$) that they would like to be trained on rangeland management.

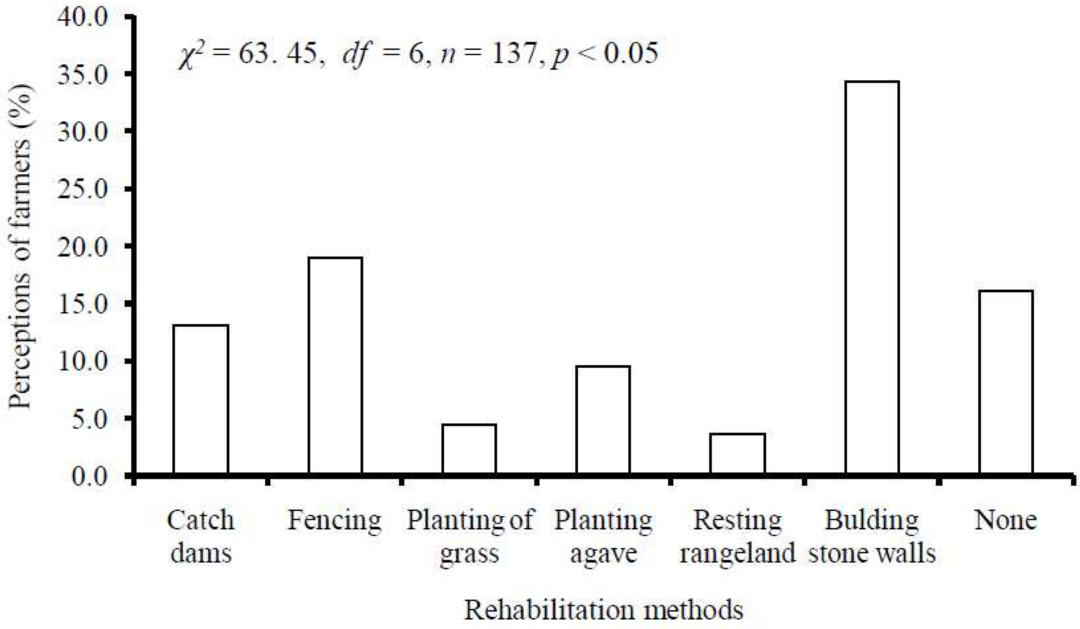

Figure 4.6: Rangeland rehabilitation methods proposed by farmers at Amakhuze Tribal Authority.

4.4. Discussion

4.4.1. Participatory Rural Appraisal (PRA) and Focus Group Discussion

During the focus group discussion, the majority of participants were men, followed by women whilst the number of youth was low in all the six communities. This could indicate the dependency and reliance of men and women in rural areas on communal grazing resources. Beck and Nesmith (2001) indicated that communal property resources are central poor women and men’s coping and adaptive strategies, contributing to sustainable livelihoods, and play a major role in poverty reduction. It was further mentioned that even those youth who were still within the villages demonstrate low interest and commitment in agriculture. The low level and/ or lack of participation of the youth in agriculture and specifically in livestock-rangeland management could partly contribute into poor rangeland management. This is because of the fact that majority of participants are old and struggle with the strenuous work of cultivation and herding animals (Moyo 2009) and that further appends to the challenge of adherence to community rules.

The implication of poor youth participation is that the indigenous skills transfer from the elders to youth is affected and that could lead into further rangeland mismanagement. This is in contrast with the work of Freudenberger *et al*. (1997) at Gambia, Guinea, and Sierra Leone who indicated that the monitoring and enforcement was the responsibility of the village youth, which ensures the transfer of community knowledge to youth. The fact that participants perceived livestock production, availability of water and rangelands as the community's strengths, could be related to the climate, the study area has relatively higher rainfall, which makes the water available for animal drinking. This could also have effect on soil moisture and lead to more forage production from rangelands, which together with high forage quality, could result in higher animal production performance.

The participants also held the view that keeping indigenous chicken and producing vegetables from home gardens is the community's strength. Keeping indigenous chicken and growing vegetables from home gardens are activities conducted within and around the homesteads. Since the majority of participants were old men and women, the interest of keeping indigenous chicken could be ascribed to the age distribution and gender composition of the participants. The low input costs and low management requirements associated with indigenous chicken and home garden vegetable production could also be the reason, especially given that most of the participants were not employed.

The opportunities of the villages were identified by the land users as including cattle and sheep genetic improvement through the University of Fort Hare Nguni project and the Ram program of the Government with South African Wool Growers Association. Identification of the need for livestock genetic improvement could serve as an indication that participants want to improve animal production. The proximity of these villages to the University of Fort Hare could be the reason why they believe that benefiting from the university is the opportunity at their disposal. Furthermore, the thought that keeping sheep is their strength could be the reason why the ram improvement project of the government was considered as the opportunity.

The communities identified stock theft, rangeland burning, and degradation and livestock diseases as their challenges. The identified strengths were based on animal production performance, availability of rangelands; therefore, threats were more related to the issues that are negatively affecting the agricultural production potential of these villages. This suggests that the communities require intervention on measures that will reduce stock theft, unplanned rangeland burning, mitigation on land degradation and improvement of livestock health.

Most of the participants at different villages identified the lack of fencing on both rangelands and arable lands as the weaknesses for the community. This suggests that for these villages to achieve maximum animal production, fencing of rangelands and arable lands should be considered. They furthermore, cited lack of knowledge on rangeland management and low level of commitment of the youth to agricultural practices as the community's weaknesses. This suggests that the view of participants is that those activities that can improve their skills on rangeland management and encourage youth participation could strengthen production at these villages. The perception that animal production and rangeland management, improvement of animal genetic material as an opportunity, lack of skills and youth commitment as the weaknesses were consistent with the report of Goqwana *et al*. (2008). They reported that the improvement of livestock breeds, provision of camps through fencing, improvement of veterinary services and encouragement and empowerment of the youth and women in agriculture were identified by the farmers at Blinkana and Hohobeng as the best options for agricultural production in communal areas.

The land users in all the focus groups (men, women and youth) were able to map and identify communal resources during the transect walk. This suggests that communal rangeland users are aware of the available resources and structures and their location within the villages. The socio-economic issues that were identified by land users include major sources of income and food. The major sources of income at the Amakhuze villages were dominated by social grants such as old age and child grant. However, contribution of livestock and crop production was sparingly mentioned as the other sources of income at the communities. This is consistent with the findings of Goqwana *et al*. (2008) who indicated that the most important source of income was old age grant and contribution of livestock and crop production as a secondary source income for most of the respondents at Blinkana and Hohobeng in Sterkspruit. Sources of food that were named include government food packages and food production at homestead level. The community responses on sources of income and food suggest that these communities depend largely on government support. This further indicates the low level of community self-reliance, resource independence, and self-sufficiency.

The policy issues discussed by the participants were more inclined to rangeland access regulation and control. There was consistency between the focus groups about access to rangelands. They all indicated that everyone without limitations to quantity and duration of use, accesses the rangelands. However, there was a clear disparity between the focus groups on availability and implementation of rules on rangeland management. These came with differences in age between the focus groups. Thus, the older people, both men and women indicated that there were rules regulating and controlling rangeland access and management.

However, they are not implemented. Whilst on the other hand the youth pointed out that, they were not aware of any rules on rangeland management.

Although the respondents who indicated that there are rules for managing communal resource utilisation there are number of formal and informal policy frameworks. Most of these policies have been reviewed overtime. These include an Environmental Conservation Act (Act 100 of 1982) which was the first attempt in South Africa to address environmental protection, it was reviewed in 1989 and became Environmental Act of 1989 (Brauteseth 2000). The Common Property Association Act of 1996 was established to ensure security of tenure for all, even within common property resources (Makhanya 1999). The National Heritage Resource Act of 1999 gives communities and opportunity to take part in the management of their cultural and religious resources (Zeni and Mistri 2005). The Communal Land Rights Act of (ClaRA) 2004 was aimed at supporting communities living in communal areas by promoting security of tenure for South Africans living on rural areas. In these communities, interests in communal land are held by means of formal and informal land rights generally known as “permission to occupy,” which are managed and administered by traditional authorities (Mokhahlane 2009).

There were some informal rules which were discovered by Mokhahlane (2009) working at three communities (Tsaba, Lashington and Magwiji) in the Eastern Cape. These include:

- There are clearly defined boundaries in communal areas, which exclude neighbouring villages from utilising the rangelands.
- There are rules which describe the structure of the decision making body and the cooperation between members of the communities in terms of adhering to set rules.
- Herding is practiced when a portion of rangeland is at rest.

- Controlled burning of grass in the rangelands is one the common management practices in communal areas.

- The chairpersons of the agricultural groups and their committees are responsible for monitoring and enforcing the set rules.

- Penalties for violation on the use of grazing lands are widely used in the communities and

- The chairperson and his committee, which consists of respected elders and the chief, are responsible for solving the community problems.

Although some people at Amakhuze Tribal Authority indicated that the rules are there, Twine (2005) argued that in some rural areas of southern Africa, rules imposed by the traditional authorities are no longer effective. Traditional institutions for natural resource management have been weakened and communities are no longer able to impose some rules regarding the use of rangelands. The difference on responses between youth and elders on whether rules are there or not could be attributed to the fact that the communal Land Rights Bill and the Traditional Leadership and Governance Framework Act No. 41 of 2003 stripped structures of all functions except land administration and cultural affairs. Thus most of their former functions, and even some related to land, are now under control of municipal and government departments. This conflicting authority around land administration could influence the lack of commitment to obey community rules.

Agricultural production practices that were identified by participants were livestock production utilising cattle, sheep, goats, and vegetable production in the villages. These production practices were identified by all the focus groups at all the villages. This suggests that there was a consistency in the knowledge of farming practices between youth, women, and men. The animal production practices identified at Amakhuze Tribal Authority are similar to those reported by Goqwana *et al*. (2008) in the study that was conducted at two villages in Sterkspruit. The rangelands were perceived to be degraded by the majority of the focus groups; however, the youth at Gomro and Guquka did not perceive rangelands to be degraded. This indicates that there are differences in the way youth and old people view the rangeland condition. This could be ascribed to the fact that youth were reported to demonstrate low level of commitment on agriculture; hence, their limited interaction with the rangeland ecosystems.

The perception that rangelands were degraded was justified by identifying some of the degradation indicators viz. presence of gullies, rills, and vegetation change. Most of the focus groups perceived that rangelands still have the potential to recover from degradation. The methods suggested for rangeland recovery include planting agave, building stonewalls and developing diversion furrows. The responses on focus group discussions indicate that participants are aware of rangeland degradation, indicators and have knowledge on measures used to rehabilitate degraded rangelands.

4.4.2. Demographic information and Livestock ownership

The demographic information reveals that the majority of household heads were old people, married, who acquired secondary education and are not employed. This suggests that people with lower economic activity particularly because of age and employment status headed most of the households. This is in agreement with the work of Moyo *et al*. (2008) which was conducted in eleven communal areas of the Eastern Cape. They indicated that old people who struggle with the strenuous work of cultivation and herding the animals headed most of the households. Rwelamira *et al*. (2000) obtained similar results in a study of 586 households in 24 villages of the Northern Province of South Africa.

People with at least tertiary qualification owned the larger number of wool sheep at Amakhuze Tribal Authority. This suggests that the level of exposure to information has the effect on selection of livestock production systems in the communal areas. The fact that majority of sheep were owned by people with tertiary education could be ascribed to the access of information about sheep production, ease of management, low level of production costs and shorter generation interval but large annual income primarily from wool. According to Moyo *et al*. (2008), literacy levels may be an important determinant of the farmers' view, on management, and on accepting new intervention in the management of their resources. This could further be attributed to the people also having enough disposable income from other jobs due to being educated to buy and keep sheep.

The people who owned large numbers of cattle were in formal employment. The relationship between formal employment status and ownership of cattle was not clearly understood. However, this could imply that whilst the employed people are not available to monitor their animals and grazing resources, they have money to pay somebody to look after their animals. This further suggests that people with constant incomes in the communal areas are spending their money to invest in livestock production.

4.4.3. Livestock grazing management

The majority of farmers perceive that forage availability is high during the wet season and too little during the dry season. The shortage of forage in winter/dry season was attributed to the low rainfall experienced in winter. The seasonal variation of forage availability at Amakhuze Tribal Authority could be because of the seasonal climatic variations since this is a sourveld area and such deficiencies are characteristic. The perception that forage availability is low during winter at Amakhuze Tribal Authority is in agreement with the perception that was reported at Blinkana and Hohobeng (Goqwana *et al*. 2008). They reported that, farmers perceived that there was a need for support with winter or drought feed as an option. This need was attributed to the relatively dry winter season, which was described as a difficult period with inadequate feed supplies as the productivity of the natural grazing declined.

Livestock farmers at the Amakhuze Tribal Authority indicated that they do not provide feed supplements to their animals. This could be attributed to the lower income from livestock and livestock products sale. However, the few who indicated that they do provide feed supplements to animals indicated that they give them in winter. This could be attributed to the fact that forage quality and quantity in winter becomes low. For the same reason of low forage quality and quantity in winter, farmers use arable lands for grazing in winter after harvesting maize. The fact that farmers indicated that they use arable lands for grazing in winter corresponds with the work of Hoffmann *et al*. (2001) that was conducted in northern Nigeria. They reported that after harvesting, the fields were opened for pastoral herds and village flocks for uncontrolled grazing during the rest of dry season. However, grazing in the arable land at Amakhuze Tribal Authority was perceived by farmers to cause soil compaction, this was ascribed to trampling.

At Amakhuze Tribal Authority, cattle were not kraaled. This suggests that they spend most of the time in the grazing areas. Although most of the farmers indicated that, they do not farm with sheep and goats, the few that are keeping them indicated that they kraal them daily. This could be attributed to the higher susceptibility of sheep to predation and theft compared to cattle. The fact that the cattle at Amakhuze Tribal Authority were not kraaled does not agree with the report of Moyo *et al*. (2008), working at eleven villages in the Eastern Cape, they reported that in most villages, animals were kraaled daily, which was attributed to the fear of theft. The reason for cattle not being kraaled at Amakhuze Tribal Authority is not fully understood, especially where stock theft was reported (during focus group discussion) as a threat and lack of fencing as a weakness for communal livestock production. Kraaling the animals in the communal areas could be an indication of high responsibility by the farmers especially where stock theft is a threat, fencing absent, some arable land used and rangeland degraded.

The fact that farmers at Amakhuze Tribal Authority do not control movement of their livestock within the rangelands is not consistent with the work that was reported by Allsopp *et al*. (2007) working at the Namaqualand commons. In contrast to Amakhuze Tribal Authority, it was reported that communal farmers at Namaqualand practice livestock movement control through herding by which herders daily select a "target zone" for grazing and routes through which animals get to the target-grazing zone. The differences for control that herders exercise over their herds on daily herding routes, have led into herders being divided into four categories viz. "leaders", "delegatory leaders", "managers when necessary" and "followers" (Allsopp *et al*. 2007). While using the Namaqualand case to illustrate the question of farmers' responsibility, livestock herding and kraaling practices could demonstrate daily and seasonal livestock-rangeland management.

The land users admitted that their rangelands are demarcated into grazing camps and they perceive that these camps are meant to facilitate controlled grazing, however the camps are not fenced. The fact that land users are aware that rangelands are demarcated into camps and that the camps were meant for controlled grazing implies that land users have an understanding of some rangeland management practices. Some of the livestock farmers control their livestock movement within the rangelands. However, some do not have any control on their livestock movement. This implies that there are inconsistencies in livestock movement management amongst the farmers at Amakhuze Tribal Authority. This in turn means that other land users monitor changes such as disease occurrences in their livestock as well as change in rangeland vegetation. This is because of periodic interactions with the animals and rangeland ecosystems. However, some do not care much about the periodic occurrences to livestock and rangelands. Because of these inconsistencies in the frequency at which farmers interact with their animals and rangelands, livestock and rangeland management becomes difficult.

The fact that the majority of farmers indicated that the distance between grazing and drinking areas was less than 1 km suggests that the drinking points are within the rangelands and are accessible to livestock. They have indicated that livestock drinking points are in the form of dams, rivers, streams, and natural wells. This was evidenced during the transect walk. Amakhuze Tribal Authority has a larger numbers of permanent water bodies (rivers, dams, waterfalls) some extending from the Hogsback waterfalls. Farmers held a view that their area does not experience water scarcity. The responses on water points imply that livestock farmers at Amakhuze Tribal Authority thought that livestock drinking water is available, sufficient, and accessible within the rangelands.

The availability, accessibility, and distribution of water could be the cause for low livestock mobility and higher concentrations around drinking points in communal rangelands. The findings were different with the work of Kassahun *et al*. (2008) working with the Somali pastoralists in Eastern Ethiopia, who reported that the pastoralists perceive water availability to be a problem for 7 months of the year and that it is the reason for livestock mobility within rangelands at different times of the year.

The farmers at Amakhuze Tribal Authority perceive that there is no conflict on rangeland resources between them and the neighbouring communities. The reasons for the absence of conflicts amongst the villages at Amakhuze Tribal Authority and other surrounding villages could be attributed to the fact there is sufficient water, therefore there is no scarcity in rangeland resources. However, this could mean that the Amakhuze Tribal Authority has cooperation with the surrounding villages.

4.4.4. Perception of farmers on the communal rangeland condition, management, degradation and restoration

The fact that most of the respondents indicated that they have access to rangelands and that they gained access because they are residents in the villages suggests that access to rangeland resources is a residential right. The farmers also mentioned that access to rangelands was not controlled by anyone. They also indicated that rangelands are accessed the whole year with no restriction to time and quantity. This suggests that communal rangelands at Amakhuze Tribal Authority are characterised by open access and no restrictions to duration and intensity of utilization of rangeland resources. The fact that rangelands are characterised by open access concurs with the assertion that current rangeland management in the central Eastern Cape Province of South Africa is characterised by an open-access approach (Bennett *et al*. 2010). This implies that the rules are not implemented or are not there together with the absence of monitoring policies, and controlling access to rangeland resources that could lead to overutilization of resources. More crucially, open access suggests that resources are also available to other users from outside the community.

Rangeland users indicated that these areas were accessed mostly for grazing and / or browsing. This suggests that at Amakhuze Tribal Authority grazing and/or browsing are the main traditional land use practices and serve as the most productive (livestock production) way in which communal rangelands are utilised. This is in agreement with the work that was conducted in Eastern Ethiopia by Kassahun *et al*. (2008) who reported that communal grazing/browsing is the main traditional land-use management system.

It was indicated by farmers that the rangelands were not fenced and this was verified during transect walks and livestock grazing distribution survey. Lack of communal rangeland fencing was identified as the major constraint in rangeland management and hence the perception that rangelands should be fenced to ensure sustainable utilization of rangeland resources. Fencing of rangeland boundaries, division into camps and appointment of the rangers were thought be a solution on instituting controlled grazing practices. The absence of fencing is perceived to have led into difficulty in instituting rangeland management practices and controlling access to quantities of rangeland resources harvested and the duration of their utilization.

The perception that lack of fencing is the problem and addressing it could help in improving communal rangeland management has become autochthonic in a number of reports (Ainslie 1999; Moyo *et al*. 2008, Bennett *et al*. 2010). This could support the logic that fencing may be regarded as the ultimate solution to poor rangeland management in the communal areas and results in reduced rangeland degradation. However, Moyo *et al*. (2008) reported that the need for fencing was motivated by the benefits of reduced labour and time spent herding rather than improved grazing management and rangeland condition. Furthermore, Bennett *et al*. (2010) reported an irony in communities such as Lushington and Roxeni, which destroyed their fences as political statements, expressing a desire for their reinstatement to facilitate boundary definition. This could serve to underline the endemic “fencing complex,” which prevails in the region (Bennett *et al*. 2010).

There was an indication of regular burning on rangelands and it was indicated that the people who decide to burn were not known. Furthermore, there were a number of reasons for burning identified by farmers and these include burning to promote an early green grass regrowth. However, the majority perceive rangeland burning as accidental or deliberate acts of arson. The fact that rangelands were burned without authorization for unknown reasons and by the unknown people implies that there was unplanned rangeland burning. This could be attributed to lack and/ or poor enforcement of rangeland management rules, low knowledge on rangeland management practices, and carelessness.

The rangeland users perceive that their rangelands are in poor condition and they attribute this poor condition largely to drought and poor grazing practices. This implies that the communal rangeland users are aware of the rangeland condition change and whilst they ascribe that to natural causes, they take responsibility through accepting that the grazing management was poor. There was a perception among the rangeland users that the rangelands are degraded. The reasons for this perception were stated to be the observation of vegetation change, rills, and gullies. The results suggest that farmers are aware that the rangelands are degraded, they can identify some degradation indicators, and they suggest the causes of degradation. This is in agreement with the work of Oba and Kaitira (2006) in northern Tanzania who reported that pastoralists could identify landscapes that were degraded; they also associated land degradation with loss of plant species in response to the changing patterns.

Furthermore, the pastoralists indicated that landscapes vary with vulnerability to degradation, thus some landscapes due to the nature of their soils were more at the risk of degradation. As the response to the fact that landscapes vary with vulnerability, the pastoralists had adopted a rangeland management practice. Oba and Kaitira (2006) further indicated that degradation vulnerable landscapes were grazed mostly during the wet season, and landscapes that are more resilient were grazed during the dry season. Proximity of rangelands to homesteads was also identified by the farmers at Amakhuze Tribal Authority as the factor that causes some landscapes to be vulnerable to degradation. The same was reported in the northern Tanzania (Oba and Kaitira 2006), thus under the conditions of settlements, some landscapes were continuously grazed compared to the traditional system of wet-dry season grazing cycles.

The level of degradation was reported to be high by the farmers at Amakhuze Tribal Authority. It was further reported that no rangeland rehabilitation control measures applied in the past. The perception that rangelands were degraded, and some rangeland degradation indicators identified, and that rangeland degradation level was high, indicates that the rangeland users were aware that there was degradation in communal rangelands. The fact that farmers have not done anything to restore the rangelands could be attributed to lack of knowledge on restoration, poor commitment to sustainability of rangeland resources and inconsistencies in the concern about rangeland resources.

The farmers indicated that livestock show less preference for arable lands, foothills, or mountaintop during summer and winter. This implies that the animals are left at liberty to choose where to feed on within the different landscapes throughout the year. That could lead to certain areas being more utilized than others are which could expose them to degradation. However, the farmers have noted that goats exhibit some degree of movement and grazing preference within the rangelands throughout the year. The movement of goats was attributed to the variation of feed quality at different seasons of the year. The farmers indicated that cattle preferred midslope of the mountain and this was ascribed to the variation in forage quality at different locations within the rangelands.

Rangeland degradation indicators identified by the farmers include vegetation change, soil deposition, pedestals, and gullies while the rills were dominant. They further identified the types of soil erosion occurring on the rangelands as sheet erosion, gully and rill erosion. This implies that the rangeland users have knowledge of rangeland degradation indicators and the type of degradation occurring in their rangelands. On locating areas that are mostly degraded, the areas with sloping terrain were identified by the farmers as the most degraded within the rangelands. These grazing areas were located on the midslope along the mountain gradient. This could be attributed to the rate of runoff accelerated by slope gradient. This also indicates that famers identified the areas with rough terrain as more susceptible to degradation; the same perception that sloping areas are more susceptible was also reported at Namaqualand (Allsopp *et al*. 2007) and northern Tanzania (Oba and Kaitira 2006).

Grassland vegetation was believed by the farmers to be the most degraded part of the rangeland. This implies that different vegetation types within the rangelands vary in vulnerability to degradation. This perception could be credited to higher grazing pressure on grasslands that renders areas covered by grasslands more susceptible to runoff, raindrop impact and soil mechanical disaggregation through moving objects. This is in agreement with Lesoli *et al*. (2010) working at Magwiji and Upper Mnxe villages in the Eastern Cape, they reported that soils at the areas with different vegetation types responded differently to mechanical disaggregation test. This was attributed to the low contribution of litter material, which after defoliation contributes into soil organic carbon, which together with clay content is responsible for soil aggregate stability. Low contribution of litter material could result from severe overgrazing leaving no litter to accumulate and decompose in the soil.

Nevertheless, farmers held the view that degraded communal rangelands can still recover. The possible measures proposed by the farmers for restoration include rangeland resting, planting grasses, planting agave, building stonewalls, fencing and the use of stonewalls. The fact that farmers believe that the land degradation can be reversed and they came up with set of activities that could aid in reversing land degradation implies that farmers have some knowledge on restoration practices. However, land users both during the focus group discussion and during questionnaire survey indicated that their knowledge on rangeland management is poor. They perceive that the training on rangeland management could be important to reduce rangeland degradation and will enhance livestock production. Moyo *et al*. (2008) reported the same and they suggested that education levels might hamper the dissemination of information on policies and rangeland management; hence, the high number of respondents indicating little knowledge of rangeland management practices. This could indicate that literacy levels may be an important determinant in the way farmers view, manage, and accept new interventions in the management of their rangeland resources.

4.5. Conclusion

There are no policies or rules and/ or poor enforcement of such policies for rangeland access and utilisation at Amakhuze Tribal Authority. If there were policies or if the policies were enforced, the access and utilisation of rangelands would be regulated. When rights and duties are adequately enforced through common property regimes, common property resources would not always be subject to open access and degradation (Cousins 2000; Dietz *et al*. 2002).

Farmers do not have livestock-rangeland management skills, and livestock movement within the rangelands was not controlled. If the farmers have livestock-rangeland management skills, they would understand rangeland management practices and the rationale behind such practices. That would lead to farmers comprehending the reasons for responsibility in livestock movement control, which could be accomplished by among other means kraaling at night and herding during grazing.

Lack policies or rules and/ or poor enforcement, lack of skills for livestock-rangeland management and poor responsibility of farmers expressed by uncontrolled grazing movement have lead to poor rangeland management practices, and subsequently to rangeland degradation in communal areas. Development and/ or review of community livestock-rangeland management policies, livestock-rangeland management capacity building to farmers, and assumption of responsibilities and duties on livestock movement control by farmers would result in a proper livestock-rangeland management and subsequently to less or no land degradation with higher animal production performance.

5. RANGELAND DEGRADATION CHARACTERISTICS IN THE COMMUNAL LIVESTOCK PRODUCTION AREAS OF EASTERN CAPE

5.1. Introduction

Rangeland degradation is a worldwide phenomenon (Call and Roundy 1991, Ludwig and Tongway 1996). Rangeland degradation is normally evident as a decline in productivity, loss of biodiversity and an increasing rate of soil erosion bearing on the inability of the rangeland to support animals and provide an income for land-users (Beukes and Cowling 2003, van den Berg and Kellner 2005). Land degradation further involves loss of vegetation cover, plant density, species composition, and disruption of the hydrological cycle, including increased surface run-off, causing changes in the microclimate (Curtin 2002; Snyman 2003; van den Berg and Kellner 2005). South Africa has a long history of concern about land degradation, particularly soil erosion (Vetter 2007). Chrisholm and Dumsday (1987) defined rangeland degradation as the loss of utility; or potential utility reduction, and loss or change of features of rangeland ecosystem.

Land degradation results in declining functional capacity, increased poverty, and food insecurity (Cohen *et al*. 2006). Major changes in rangeland surface morphology and soil characteristics have a drastic effect on the primary productivity of the rangeland ecosystem and in turn on livestock production (Payton *et al*. 1992). This indicates a need for interventions to halt degradation and improve the functional capacity of communal rangelands.

Rangelands in the arid and semi-arid areas are perceived as non-equilibrium systems, thus they are variable but resilient ecosystems, and the influence of drastic events, cyclic variation over time, and spatial heterogeneity are emphasised (Walker 1993). However, Dahlberg (2000) indicated that arid and semi-arid rangelands are stable but fragile, and thus if left undisturbed, would remain in a state of equilibrium, but which, are sensitive to human disturbance. The variation in climate especially rainfall and episodic events such as drought explain most of the observed environmental changes and have overriding effects on different management strategies (Dahlberg 2000).

The null hypothesis for this research was that rangeland degradation does not vary between rangeland management practices, and it does not vary in terms of occurrence and intensity between landscapes within communal rangelands. Furthermore, rangeland degradation is not characterised by poor vegetation and soil compaction/infiltration characteristics, and physical land degradation indicators. This hypothesis is based on the premises that, grazing intensity and frequency are not controlled in the communal areas and this leads to rangelands degradation. Rangeland degradation could be indicated by the dominance of grass species such increaser II category, and poor basal cover.

Furthermore, occurrence of physical rangeland degradation indicators such as pedestals, terracettes, rills, and gullies would be high on communal rangelands due to high runoff rates preceded by poor soil cover. In the communal areas, because of poor grazing management control, rangeland degradation would vary between the landscapes, thus, areas receiving high utilisation would be more degraded than areas with low utilisation intensity. The rate of soil loss varies within the rangelands, thus, it has affected and related to innate characteristics of physical indicators such depth, length, breadth, and catchment area covered.

5.2. Materials and Methods

5.2.1. Data collection

5.2.1.1. Visual assessment of rangeland degradation indicators

To conduct visual rangeland degradation assessment four experimental units were selected and these were Valley bottom (672 to 779 m.a.s.l), Foothills (780 to 893 m.a.s.l), Midslopes (894 to 1131m.a.s.l) and Mountaintops (1132 to 1825 m.a.s.l). In each experimental unit eight plots (10 000 m^2) were selected randomly adding up to 32 plots in the study area. Each plot was subdivided into 25 observation sub-plots (20 m x 20 m), 12 sub-plots were selected randomly out of 25 and each of the selected sub- plots was further sub-divided into four quadrats (10 m x 10 m each). In each quadrat identifying groups of herbaceous vegetation species according to their dominance, three dominant groups were identified viz; dominant, sub-dominant I and sub-dominant II visually assessed herbaceous vegetation characteristics. Dominance refers to the degree of influence that a plant species exerts over a community as measured by its mass or basal area per unit area of the ground surface or by the proportion, it forms of the total cover, mass or basal area of the community (Trollope *et al*. 1990).

Herbaceous species were further categorised into their ecological status. The ecological status of grass refers to the grouping based on their reaction to different levels of grazing. A grass species react to grazing in one of two ways: it can increase or decrease (van Oudtshoorn 2009). The following were the grass categories; decreaser, increaser I, increaser II, increaser III and others (forbs, sedges, Karoo vegetation etc). Increaser I are grass species that are abundant in underutilised rangeland, they are usually unacceptable, robust climax species than can grow without any defoliation, and examples include *Hyperthelia dissoluta* and *Trachypogon spicatus*. Increaser II are grass species that are abundant in overgrazed rangeland. These grasses increase due to the disturbing effect of overgrazing and include mostly pioneer and sub climax species such as *Aristida adscensionis* and *Eragrostis rigidor*. They produce much of viable seed and can thus quickly establish on new exposed ground. Increaser III are grass species that are commonly found in overgrazed rangeland. These are usually unacceptable, dense climax grasses such as *Elionurus muticas* and *Aristida junciformis*. These grasses are strong competitors and increase because the palatable grasses have become weakened through overgrazing (van Oudtshoorn 2009). In each quadrat, soil cover was estimated visually as the proportion of land covered by vegetation compared to the total size of each quadrat.

The presence and extent of pedestals, terracelets, solution notches, sedimentation, rills, and gullies were also visually assessed within the same experimental units, plots and sub-plots (Figure 5.2). However, eight sub-plots (20 m x 20 m) were selected randomly out of 25 sub-plots in each of 32 plots. In each sub-plot, the presence of pedestals, terracelets, solution notches, armour layer, sedimentation, rills, and gullies was recorded as present/absent per unit area (20 m x 20 m).

The extent of degradation as indicated by pedestals, terracelets, and rills was estimated by depth/height in centimetres and categorised according to the intensity at which they indicate rangeland degradation. Thus, Pedestal/terracelet height/depth - Negligible = 0 - 5 cm, Light = 5 – 10 cm, Moderate = 10 – 20 cm, High 20 – 30 cm, Severe = > 30 cm; Rill depth- Negligible = 0 – 5 cm, Light = 5 – 20 cm, High = 20 – 30 cm and Severe = > 30 cm. The extent of rangeland degradation indicated by gullies, solution notches, amour layer, and sedimentation was estimated by the percentage frequency at which they were observed at each sub-plot.

5.2.1.2. Physical soil loss characteristics as indicators of rangeland degradation

To quantify rangeland degradation, seven degraded sites (100 m x 100 m each) were selected based on visual impression of degradation on foothills and midslopes. The rangeland degradation indicators were measured in each plot depending on their presence. The presence of rangeland degradation indicators was already measured on visual degradation assessment and therefore, this section put more emphasis on the extent of degradation. The indicators measured were gullies, rills, pedestals, and terracettes.

Rills and gullies are channels cut by flowing water (Figure 5.2 F). The presence of rills and gullies indicate that water flows rapidly off the landscape, carrying both litter and soil particles. Pedestalling is the result of soil removal by erosion of an area leaving the buses of surviving plants on a column of soil above the new general level of landscape (Figure 5.2. B). Exposed plant roots are typically further indicators for pedestalling (Figure 5.2. D). Pedestalling indicates that the soil type is erodible and that loss of vegetation in the landscape was preceded by erosion and not the other way around. Terracettes are abrupt walls about 10 cm high, aligned with the local contour. Terracettes are progressively cut back up-slope by water flow, eroded material being deposited in an alluvial fan down-slope of the feature (Coetzee 2005).

Gullies were present in five sites (D1, D4, D5, D6, and D7); the extent of gully formation was estimated by measuring top and basal gully breadth and gully height at 2 m intervals along the gully length. Furthermore, gully length was measured and cross-sectional area and soil loss per metre equivalent were calculated. Rills were present in all the seven sites (D1, D2, D3, D4, D5, D6, and D7); the extent of rangeland degradation was estimated through measuring rill breadth, length, and height/depth. Rill cross sectional area was calculated for each site and volume of soil loss on rills per catchment area was estimated.

Pedestals were present at six sites (D1, D2, D3, D5, D6, and D7), the extent of rangeland degradation characterised by pedestals was estimated through measuring pedestal heights and volume of soil loss per catchment area was calculated. Terracettes were observed on three sites (D5, D6, and D7) and the volume of the soil lost per catchment area was calculated. The following sections explain further details on how each of the physical rangeland degradation indicators was measured.

5.2.1.2.1. Measurement of soil loss in gullies

The gully length was measured with a tape measure in each plot of 100 m x 100 m area. The gully top and bottom breadth (base and central base) were measured with the tape measure and depth was measured with the 2 m aluminium rod at regular intervals (2 m) along the gully length. The mean gulley top and bottom breadth, and depth were calculated for each plot. The following mathematical formula was used to estimate the soil loss through gully erosion (Stocking and Murnagham 2000):

$$Y = (\frac{1}{2} bh * 2 + Cb * h) GL$$

Where: Y= Soil loss,

b = Gully base,

h = Gully height,

Cb = Central base,

GL = Gully length

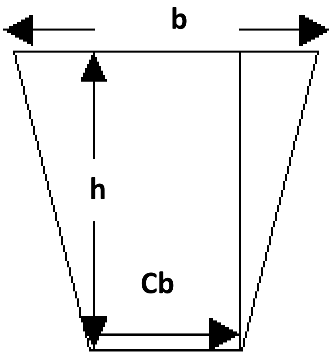

Figure 5.1: The hypothetical schematic depiction of the gully.

Rangeland degradation intensity and potential of the gullies to develop further were estimated through observation of vegetation presence and soil physical appearance along and around the gully. The gully head (physical and vegetation), gully wall (physical, soil and vegetation) and gully base features (physical, soil and vegetation) were visually assessed on 11 gullies found on site D1, D4, D5, D6, and D7. The gully walls and bases were assessed for vegetation cover on the wall and base, physical appearance and soil features at the interval of 2 m along the length of the each gully.

5.2.1.2.2. Measurement of soil loss indicated by rills

The rills were counted in each plot; their lengths were measured with a tape measure. The width and depth were measured with a measuring stick (1m) at regular intervals (1 m) for each rill. The average cross-sectional area (m^2) of rills was determined using the formulae for triangle (i.e. ½ horizontal width x depth). The volume (m^3) of soil lost from the rill was calculated by multiplying its cross-sectional area (m^2) by length. Soil loss was calculated from each rill with the mathematical formula (Stocking and Murnagham 2000):

$Y_n = (½ bh * 2) RL.$

Where:

Y_n = soil loss for each rill

b = base

h = height

RL = Rill length

The total volume of soil lost was converted to a volume per square metre of a catchment area (20 m^2). Thus: volume lost (m^3)/ catchment area (20m^2) = soil loss (m^3/m^2)

5.2.1.2.3. Measurement of soil loss indicated by pedestals and terracettes

The heights of the pedestals and terracettes were measured with the measuring stick (1 m), a minimum of 20 pedestals and 20 points per terracelet within an observation area and 20 root exposures were measured at each plot. The mean pedestal and terracette height per measurement area were used to estimate the soil loss through sheet erosion. The net soil loss (represented by the average pedestal height) from pedestals and terracettes was calculated using an average bulk density of 1.3g/cm^3. A 1 mm loss of soil is equivalent to 13 t/ha^{-1} (Stocking and Murnagham 2000).

5.2.1.3. Vegetation characteristics of degraded rangelands

Herbaceous vegetation and soil samples were collected at two sites, which were visually assessed for rangeland degradation indicators such as presence of gullies, rills, pedestal, solution notches, sediment accumulation, root exposures, bare patches, amour layer, terracettes, and soil build up against barriers. Ten sites were selected based on whether the visual degradation indicators were present or not. For this study, the sites with no visible rangeland degradation indicators were referred to as non-degraded sites and sites with visible indicators as degraded sites. Five non-degraded sites (100 x 100 m each) were selected at

Phandulwazi Agricultural High School and five degraded sites at Amakhuze Tribal Authority. In each site 3 x 100 m line transects were laid randomly and along each transect four quadrats (1m x 1m) were systematically placed at the regular interval of 25 m.

In each quadrat species were identified (Van Oudtshoorn 2009) to determine species composition, the tuft diameter of every plant that was located and tuft-to-tuft distance was measured with the 100 cm ruler to estimate the basal cover. Vegetation species were classified according to life form, functional groups, grazing values, and grazing status according to Van Oudtshoorn (2009). The presence of forbs, sedges, and invaders was acknowledged by indication and their contribution was regarded as the whole, therefore, they were not classified as the grass species but were regarded as the classes or categories on their own.

5.2.1.4. Soil resistance and hydraulic conductivity

Along each transect a pocket penetrometer (Model 16-T0171, 1999) was used to measure unconfined compressive strength (UCS) of the soil. Fifty penetrometer points were collected at an interval of two meters.

Furthermore, in each transect a mini disk infiltrometer was systematically placed at four observation times at the interval of 25 m along the line transect (100 m) to estimate infiltration rate as described by (Decagon Devices, Inc. 2007). The infiltration was measured 15 times at the time interval of 30 seconds, which resulted in total infiltration time per observation point into the total of 420 seconds.

5.2.2. Data analysis

The association of visual rangeland degradation as indicated by vegetation species composition, soil cover, pedestals, terracettes, rills, solution notches, armour layer, sedimentation and gullies was tested with Chi-square between valley bottom, foothills, midslopes and mountaintop. The data for visual gully characteristics, thus, gully head (physical and vegetation presence), gully wall (physical, soil and vegetation) and gully base features were analysed with Chi-square to estimate the frequency at which such characteristics were occurring. Furthermore, data were analysed by cross tabulation with χ^2 (SPSS 1999) the results were considered significant at $p < 0.05$.

The data for physical land degradation measurements were analysed with descriptive statistics and displayed by the use of box and whisker plots. The relationship between all possible paired combinations of degradation variables for gullies and rills was determined using Pearson correlation coefficients and was considered significant at $p < 0.05$. Before Pearson correlation was ran, the data were tested for normality.

The Chi-square test was used to determine association between the species composition related variables and degraded and non-degraded rangelands, the association was considered significant at $p < 0.05$. The difference between degraded and non-degraded rangelands for tuft diameter, tuft-to-tuft distance, plant density unconfined compressive strength (UCS) and hydraulic conductivity was determined using one-way ANOVA in SPSS (1999).

Hydraulic conductivity was determined using mini disk infiltrometer user's manual, version 4 (Decagon Devices, inc. 2007). The soil was classified as silty clay loam and the values of *A* (value relating the van Genuchten parameters for a given soil type to suction rate and radius of the infiltrometer disk) computed for the mini disk infiltrometer at the suction of 4 cm for degraded and non-degraded rangelands soils was 9.6. Soil hydraulic conductivity was determined according to Zhang (1997).

$$I = C_1\,(m\ s^{-1})\ t + C_2\,(m\ s^{-1/2})\ \sqrt{t}$$

Where:

I = is infiltration

C_1 (m s^{-1}) = is related to hydraulic conductivity

C_2 (m $s^{-1/2}$) = is related to soil sorptivity

t = time

$\mathcal{K} = C_1/A$

Where:

$\mathcal{K}$ = is the hydraulic conductivity of soil

C_1 = is the slope of the curve of cumulative infiltration vs. the square root of time

A = is a value relating the van Genuchten parameters for a given soil types to suction rate and radius of the infiltrometer disk, A was computed from:

$$A = \frac{11.65\,(n^{0.1}-1)\,\exp\,[2.95\,(n - 1.9)\,\alpha h_0]\;n \geq 1.9}{(\alpha r_0)^{0.91}}$$

$$A = \frac{11.65\,(n^{0.1}-1)\,\exp\,[7.5\,(n - 1.9)\,\alpha h_0]\;n \geq 1.9}{(\alpha r_0)^{0.91}}$$

Where:

n and α are the van Genuchten parameters for the soil

r_o = is the disk radius

h_o = is the suction at the disk surface

The van Genuchten parameters for the 12 texture classes were obtained from Carsel and Parrish (1988). One way ANOVA was used to compute the infiltration rate difference between degraded and non-degraded sites.

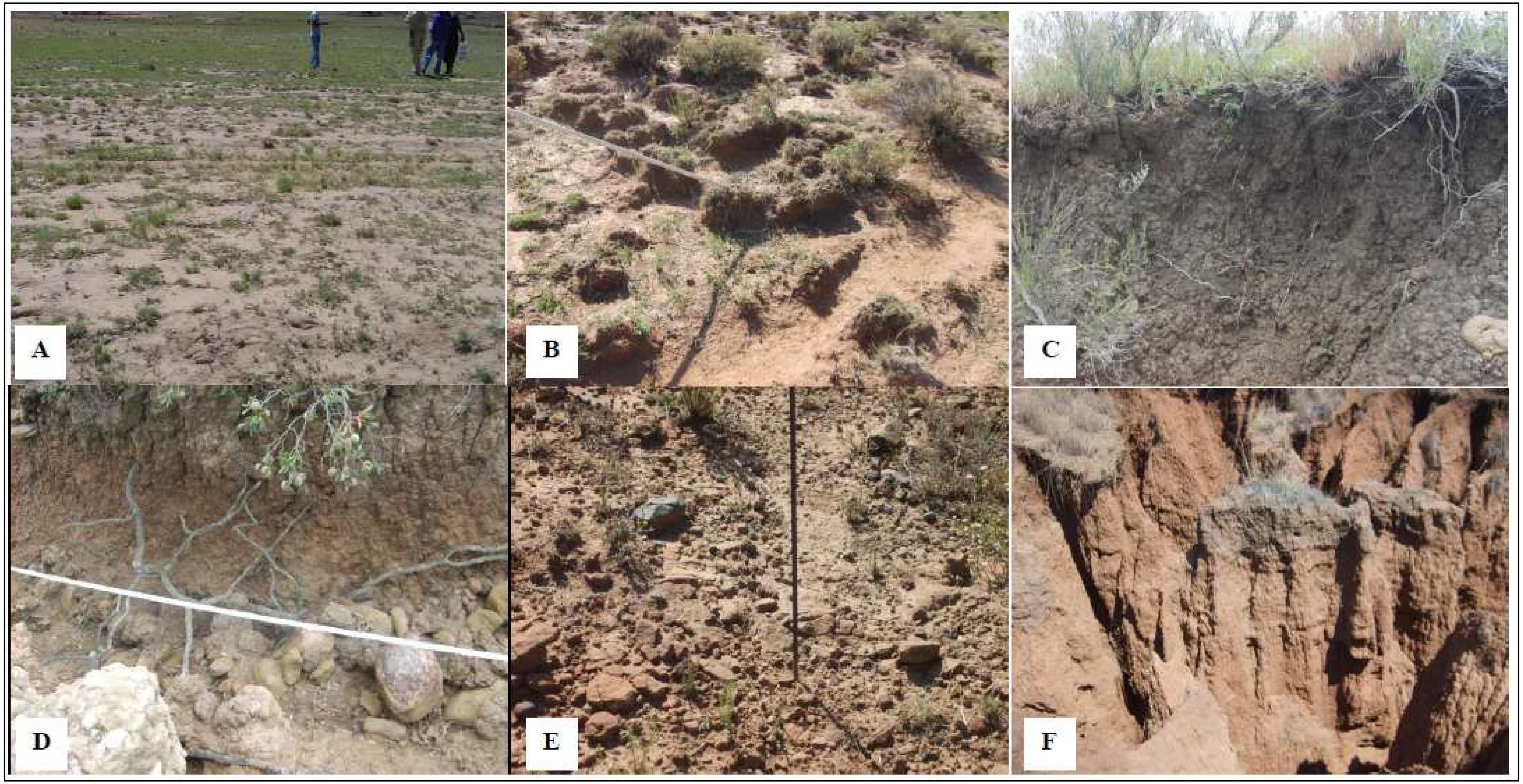

Figure 5.2: Rangeland degradation indicators; (A) bare vegetation patches, (B) pedestals, (C) Terracettes, (D) root exposures, (E) Armour layer and (F) gullies.

5.3. Results

5.3.1. Degradation characteristics of the communal rangelands

5.3.1.1. Visual observation of degradation

Rangeland degradation along the landscape gradient as characterised by herbaceous species ecological status, was such that the valley bottom (54%) and foothills (49%) were dominated by increaser II species (χ^2 = 1059.28, *df* = 12, *n* = 1536, $p < 0.01$). The midslopes were dominated by increaser III species categories (Table 5.1). While decreaser species were dominant at the mountaintops, (54%) followed by increaser I species (37%). Rangeland degradation as indicated by poor vegetation cover was high at valley bottom (65%), foothills (62%), and midslopes (59%) (χ^2 = 825.58, *df* = 9, *n* = 1536, $p < 0.01$). On the mountaintops, rangeland degradation as indicated by vegetation soil cover was light (79%).

The pedestals were dominant at valley bottom (98%), foothills (100%), and midslopes (100%), they were low at mountaintop (61%) (χ^2 = 78.26, *df* = 3, *n* = 256, $p < 0.01$). The extent of rangeland degradation as indicated by pedestal height was significantly severe (>30 cm) at the valley bottom (63%) and foothills (53%) (χ^2 = 196.28, *df* = 12, *n* = 256, $p < 0.01$). There was an indication of moderate (10 – 20 cm) degradation extent at the midslope (44%). Rangeland degradation extent as indicated by pedestals ranged from negligible (36%) to light (34%) at the mountaintop (Table 5.2).

The presence of terracettes was also high (χ^2 = 40. 47, *df* = 3, *n* = 256, $p < 0.01$) at the valley bottom (83%) followed by foothills (69%) and midslopes (58%) and low at the mountaintop (30%). The extent of rangeland degradation as characterised by terracette depth ranged between high (20 – 30 cm) (33%) and severe (>30 cm) (33%) at the valley bottom (χ^2 = 121.36, *df* = 12, *n* = 256, $p < 0.01$). The most severe terracettes were observed at the foothills (44%). The terracettes on the midslopes (53%) and mountaintops (94%) were at the negligible extent (0 – 5 cm) (Table 5.3).

The presence of rills was higher at the valley bottom (72%) and foothills (83%) compared to midslopes and mountaintop (χ^2 = 74.95, *df* = 3, *n* = 256, *p* < 0.01) (Table 5.4). The magnitude of rangeland degradation as characterised by rill depth was severe at the valley bottom (48%) and foothills (44%) (>30 cm) (χ^2 = 101.12, *df* = 9, *n* = 256, *p* < 0.01). The extent of land degradation indicated by rill depth was negligible (0 – 5 cm) at the midslopes (63%) and mountaintops (84%).

Rangeland degradation was further characterised by the presence of gullies, solution notches, armour layer, and sediment accumulation at the valley bottom, foothills, midslopes, and mountaintop. Rangeland degradation as characterised by the frequency of gullies was high (75%) at the valley bottom (χ^2 = 71.23, *df* = 3, *n* = 256, *p* < 0.01). The valley bottom was further observed to have more (41%) of solution notches (χ^2 = 10.35, *df* = 3, *n* = 256, *p* < 0.05). The presence of an armour layer was also high (51%) at the valley bottom ($\chi^{2=}$ 22. 0, *df* = 3, *n* = 256, *p* < 0.01). The frequency at which sedimentation was observed was high (86%) at the valley bottom (χ^2 = 64.52, *df* = 3, *n* = 256, *p* < 0.01) (Table 5.5).

Table 5.1: Indication of rangeland degradation by dominant herbaceous vegetation species categories (χ^2 = 1059.28, df = 12, n = 1536, p < 0.01) and by vegetation cover (χ^2 = 825.58, df = 9, n = 1536, p < 0.01) along the landscape.

Experimental unit	**Herbaceous vegetation species categories (%)**					**Degradation indicated by vegetation cover (%)**			
	Decreaser	Increaser I	Increaser II	Increaser III	Other	Severe	High	Light	None
Valley bottom	7.8	7.0	54.2	11.5	19.5	13.5	65.1	21.1	0.3
Foothills	13.3	2.6	49.0	18.8	16.4	21.6	62.5	15.9	0.0
Midslope	27.3	2.1	16.9	52.9	0.8	1.8	59.1	39.1	0.0
Mountaintop	54.4	37.2	0.8	7.6	0.0	0.0	1.0	79.7	19.3
Average	**25.7**	**12.2**	**30.2**	**22.7**	**9.2**	**9.2**	**46.9**	**38.9**	**4.9**

Severe = vegetation cover < 25 %, High = soil cover between 26 – 49%, Light = soil cover between 50 – 74%, and None = no indication of soil cover loss with cover > 75 %.

Table 5.2: Frequency (χ^2 = 78.26, df = 3, n = 256, p < 0.01) and intensity (χ^2 = 196.28, df = 12, n = 256, p < 0.01) of pedestals as indicators of rangeland degradation at Amakhuze Tribal Authority.

Experimental unit	**Pedestals (%)**	**Pedestal height (%)**				
	Present	Negligible	Light	Moderate	High	Severe
Valley bottom	98.4	1.6	4.7	4.7	26.6	62.5
Foothills	100.0	0	0	9.4	37.5	53.1
Midslope	100.0	0	23.4	43.8	17.2	15.6
Mountaintop	60.9	35.9	34.4	26.6	3.1	0
Average	**89.8**	**9.4**	**15.6**	**21.1**	**21.1**	**32.8**

Pedestal height: Negligible = 0 - 5 cm, Light = 5 – 10 cm, Moderate = 10 – 20 cm, High 20 – 30 cm, Severe = > 30 cm

Table 5.3: Visual observation of the frequency (χ^2 = 40. 47, df = 3, n = 256, $p < 0.01$) and intensity (χ^2 = 121.36, df = 12, n = 256, $p < 0.01$) of terracettes as indicators of rangeland degradation at Amakhuze Tribal Authority.

Experimental Unit	**Terracettes (%)**	**Terracettes depth (%)**				
	Present	Negligible	Light	Moderate	High	Severe
Valley bottom	82.8	17.2	9.4	7.8	32.8	32.8
Foothills	68.8	26.6	.0	10.9	18.8	43.8
Midslope	57.8	53.1	4.7	3.1	31.3	7.8
Mountaintop	29.7	93.8	6.3	.0	.0	.0
Average	**59.8**	**47.7**	**5.1**	**5.5**	**20.7**	**21.1**

Terracettes depth: Negligible = 0 – 5 cm, Light = 5 – 10 cm, Moderate = 10 – 20 cm, High = 20 – 30 cm, Severe = >30 cm

Table 5.4: The distribution of rills (presence) ($\chi^2 = 74.95$, $df = 3$, $n = 256$, $p < 0.01$) and extent (depth) ($\chi^2 = 101.12$, $df = 9$, $n = 256$, $p < 0.01$) as an indication of rangeland degradation.

Experimental unit	**Rills**	**Rill depth**			
	Present	Negligible	Light	High	Severe
Valley bottom	71.9	28.1	6.3	17.2	48.4
Foothills	82.8	28.1	12.5	15.6	43.8
Midslope	35.9	62.5	26.6	9.4	1.6
Mountaintop	15.6	84.4	12.5	1.6	1.6
Average	**51.6**	**50.8**	**14.5**	**10.9**	**23.8**

Rill depth: Negligible = 0 – 5 cm, Light = 5 – 20 cm, High = 20 – 30 cm and Severe = > 30 cm

Table 5.5: The distribution of gullies ($\chi^2 = 71.23$, $df = 3$, $n = 256$, $p < 0.01$), solution notches ($\chi^2 = 10.35$, $df = 3$, $n = 256$, $p < 0.05$), amour layer ($\chi^2 = 22.0$, $df = 3$, $n = 256$, $p < 0.01$), and sedimentation ($\chi^2 = 64.52$, $df = 3$, $n = 256$, $p < 0.01$) along the topographic position at Amakhuze Tribal Authority.

Experimental unit	**Gullies**		**Solution notch**		**Armour layer**		**Sedimentation**	
	Present	Absent	Present	Absent	Present	Absent	Present	Absent
Valley bottom	75.0	25.0	40.6	59.4	51.6	48.4	85.9	14.1
Foothills	46.9	53.1	29.7	70.3	34.4	65.6	60.9	39.1
Midslope	21.9	78.1	25.0	75.0	15.6	84.4	92.2	7.8
Mountaintop	7.8	92.2	15.6	84.4	48.4	51.6	32.8	67.2
Average	**37.9**	**62.1**	**27.7**	**72.3**	**37.5**	**62.5**	**68.0**	**32.0**

5.3.1.2. Physical characteristics of rills in the communal rangeland

The rills varied with the breadth, length, and depth within the degraded sites in communal rangelands. The broadest rill was more than 100 cm and the narrowest was about 20 cm (Figure 5.6). The length of the rills varied between 5 m to 32 m between the degraded sites. The rill height ranged between 17 cm to 58 cm. The cross-sectional areas of the rill in degraded rangelands ranged from about 0.05 m^2 to 0.4 m^2 between the degraded sites. The volume of the soil lost from the rills was estimated between 0.03 m^3 to 0.72 m^3. The length of the rill had the greater effect on the volume of soil lost. Degraded site D2 had the longest rills and in turn had the highest volume of soil lost (0.72 m^3) (Figure 6.3). The volume of the soil lost per unit area varied between the sites, it ranged between 0.5 m^3/m^2 and 760 m^3/m^2. The volume of soil lost per unit area was higher in the degraded sites that had longer rills than those that had shorter but wider rills. The site D2 with 32 m length had lost 760 m^3/m^2 volume of soil.

There was a significant positive and strong relationship between rill length and depth ($r = 0.462$, $p < 0.05$), rill length and breadth ($r = 0.433$, $p < 0.0.5$) (Table 5.6), rill length and volume of the soil lost per catchment area ($r = 0.710$, $p < 0.01$), and rill length and soil loss per unit area ($r = 0.710$, $p < 0.01$). The depth of the rill was significantly positively related to rill breadth ($r = 0.499$, $p < 0.01$), cross sectional area ($r = 0.620$, $p < 0.01$), volume of soil lost per catchment area ($r = 0.711$, $p < 0.01$) and volume of soil lost per unit area ($r = 0.711$, $p < 0.01$). The rill breadth was significantly positively and strongly related to the cross-sectional area ($r = 0.638$, $p < 0.01$), volume of the soil lost per catchment area ($r = 0.718$, $p < 0.01$) and per unit area ($r = 0.718$, $p < 0.01$). There was a significant positive and strong relationship between rill cross-sectional area and volume of soil lost per catchment area ($r = 0.719$, $p < 0.01$) and per unit area ($r = 0.719$, $p < 0.01$).

Table 5.6: Correlations between rill characteristics at Amakhuze Tribal area (*n* = 28)

	Length	**Depth**	**Breadth**	**Cross sectional area**	**Volume of soil lost/catchment area**	**Volume of soil lost /meter equivalent**
Length	1.000	0.462*	0.433*	NS	0.710**	0.710**
Height		1.000	0.499**	0.620**	0.711**	0.711**
Breadth			1.000	0.638**	0.718**	0.718**
Cross sectional area				1.000	0.719**	0.719**
Volume of soil lost/catchment area					1.000	1.000**
Volume of soil lost /meter equivalent						1.000

* Correlation is significant at the 0.05 level, ** Correlation is significant at the 0.01 level

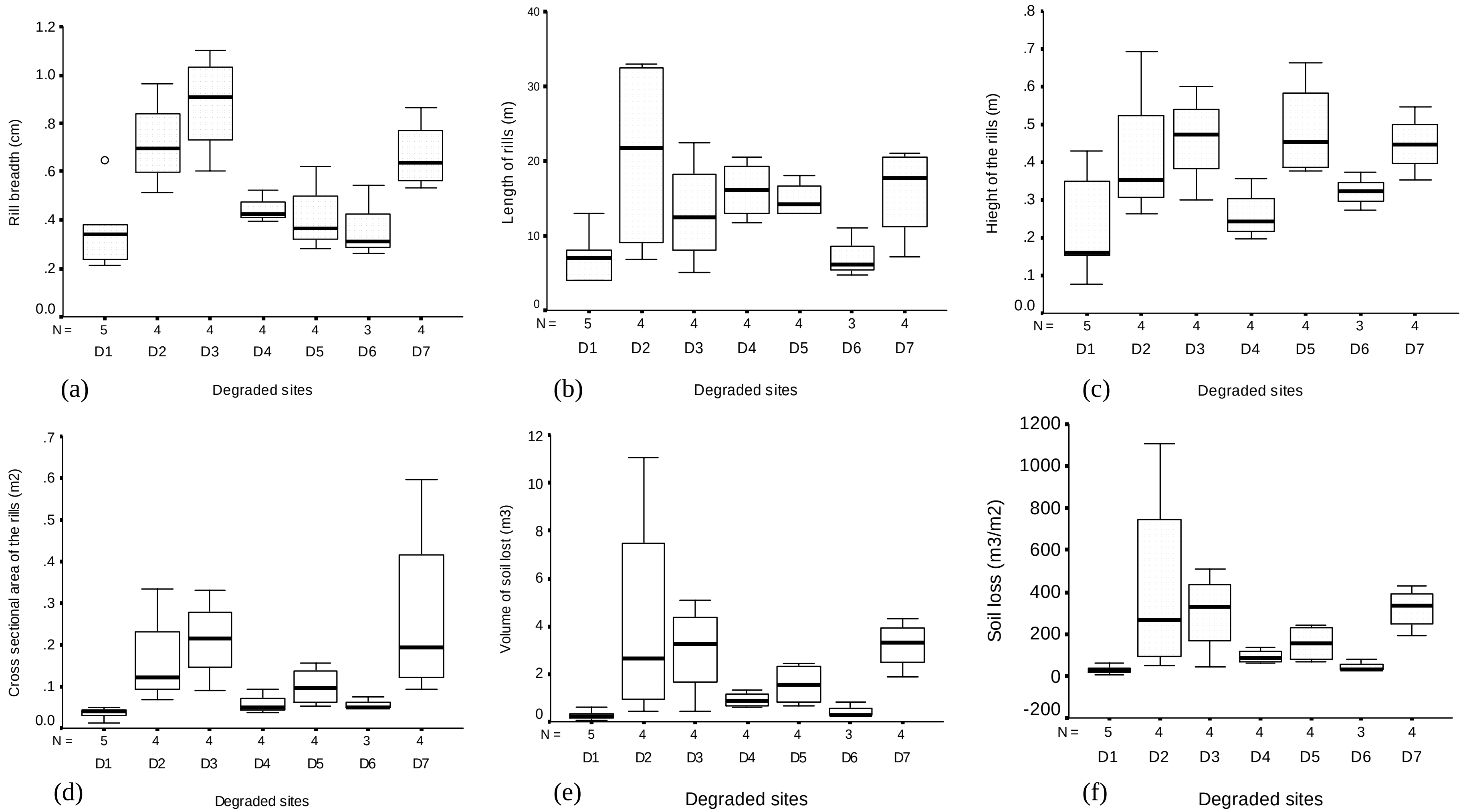

Figure 5.3: Characteristics of the rills on degraded sites at Amakhuze Tribal Authority: (a) rill breadth, (b) Rill length, (c) rill height, (d) rill cross sectional area, (e) Volume of soil lost and (f) volume of soil loss per catchment area.

5.3.1.3. Characteristics of gullies in the communal rangeland

The gully depth character varied between shallow (0.6 m) and deeper (1.6 m) within the degraded rangelands. The top breadth ranged from narrow (1.3 m) to wider (6.8 m) gullies (Figure 5.4). The bottom breadth varied between narrow bottom (1.5 m) and wider bottom gullies (3.7m). The gully length varied from shorter (20 m) to longer (180 m) gullies. The gully cross sectional area ranged from 1.2 m^2 and 4 m^2. The volume of the soil lost from the gullies varied across the degraded rangelands, thus it ranged between 20 m^3 and 700 m^3 (Figure 5.5). The volume of soil lost per metre equivalent also varied with the rangelands sites, thus, 0.005 m^3/m^2 to 0.06 m^3/m^2.

There was a strong positive correlation between the gully length and height (r = 0.845, p < 0.01), between the gully height and volume of soil lost (r = 0.855, p < 0.01) and length and volume of soil lost per metre equivalent (r = 0.855, p < 0.01) (Table 6.7). The gully top breadth was significantly positively and strongly related (r = 0.769, p < 0.01) to gully bottom breadth, the top breadth was also significantly related to cross sectional area (r = 0.848, p < 0.01). Furthermore, the bottom breadth was significantly positively and strongly related (r = 0.796, p < 0.01) to gully cross sectional area.

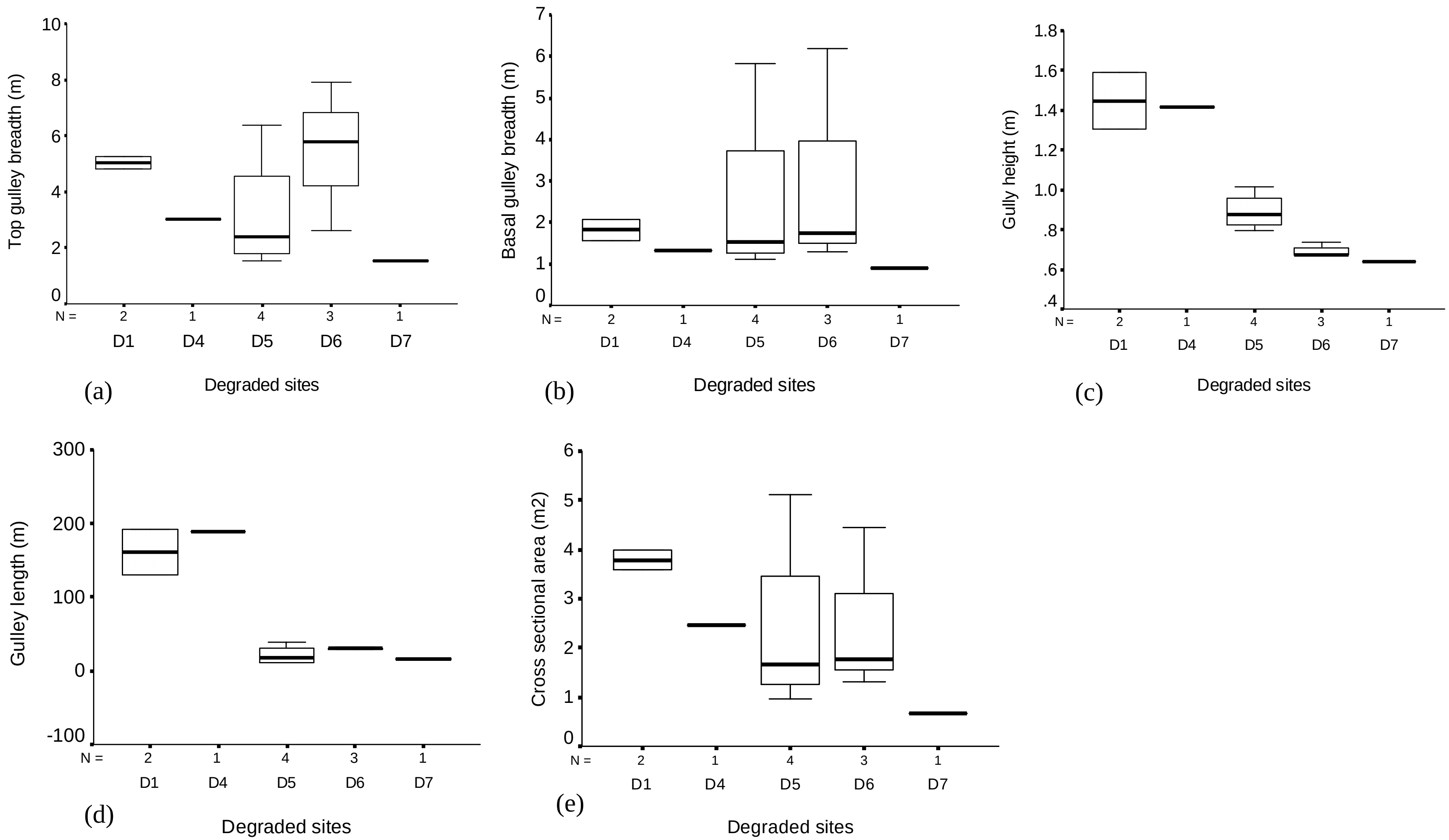

Figure 5.4: The gully characteristics in communal areas of Amakhuze Tribal Authority in the Eastern Cape: (a) Top gully breadth, (b) Basal gully breadth, (c) Gully height, (d) Gully length, and (e) Gully cross sectional area.

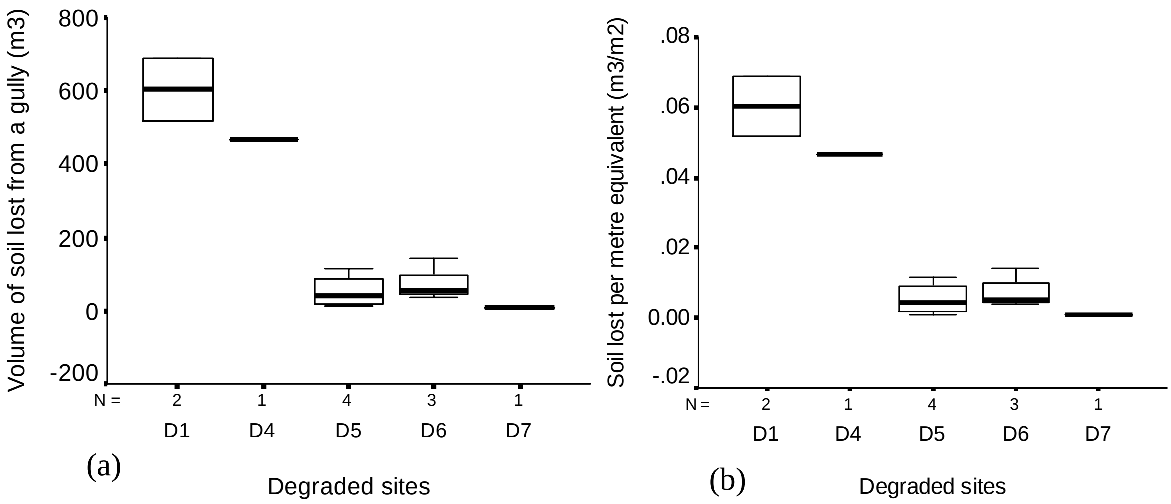

Figure 5.5: The volume of soil lost because of gully formation: (a) soil loss from gullies, and (b) soil loss per metre equivalent.

Table 5.7: Correlations between gully features and soil loss at Amakhuze Tribal Authority (*n* = 11)

	Height	Top breadth	Bottom breadth	Length	Cross sectional area	Volume of the soil lost	Volume of soil lost/ metre equivalent
Height	1.	NS	NS	0.845**	NS	0.855**	0.855**
Top breadth		1.	0.769**	NS	0.848**	NS	NS
Bottom breadth			1.	NS	0.796**	NS	NS
Length				1.	NS	0.959**	0.959**
Cross sectional area					1.	NS	NS
Volume of the soil lost						1.	1.000**
Volume of soil lost/ metre equivalent							1.

** Correlation is significant at the 0.01 level

5.3.1.4. Pedestal and terracette characteristics of degraded communal rangelands

The pedestal height on degraded rangeland sites ranged between 100 mm to 400 mm (Figure 5.6). The volume of soil lost measured through pedestals ranged between 2393 t/ha and 4329 t/ha. The terracettes were also observed on degraded rangelands, their heights ranged between 380 mm to 1400 mm. The volume of soil lost through terracettes ranged between 5083 t/ha and 13559 t/ha.

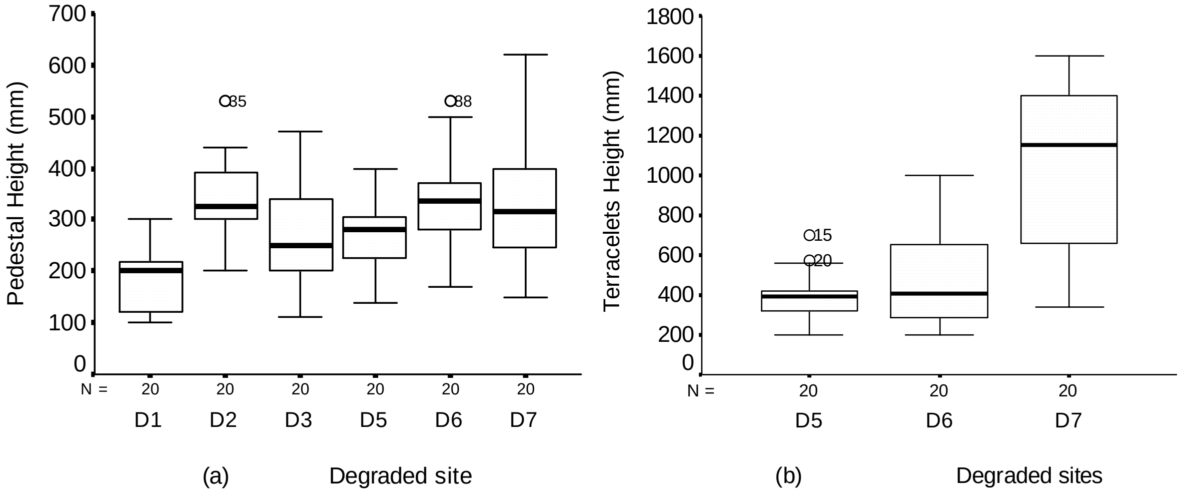

Figure 5.6: Distribution of pedestal and terracettes across the degraded sites: (a) Pedestal and (b) terracettes height

Gullies were assessed for characteristics of the head cut, gully walls, and gully base. Gully head cuts were characterised by loose soil (χ^2 = 13.36, n = 11, df = 3, p < 0.05) and with bare internal surfaces (χ^2 = 4.45, n = 11, df = 1, p = 0.05). The gully walls (χ^2 = 643.87, n = 428, df = 5, p < 0.05) were solid with poor vegetation cover (χ^2 = 199.38, n = 428, df = 2, p < 0.05). The gully bases were characterised by loose soil base (χ^2 = 234.82, n = 428, df = 2, p < 0.05), sediment accumulation (χ^2 = 311.46, n = 428, df = 2, p < 0.05) and barely covered with vegetation (χ^2 = 169.38, n = 428, df = 2, p < 0.05).

5.3.2. Vegetation characteristics of degraded rangelands

5.3.2.1. Species composition between degraded and non-degraded rangelands

Non-degraded sites had a significantly higher (93.6%) proportion of perennial tufted grasses compared to degraded sites (54.1%) (χ^2 = 2612.07, $p < 0.01$). Other categories such as annual tufted, creeping, forbs, invader, weak perennial, and sedge species were low at non-degraded sites compared to degraded sites (Figure 5.7). Rangeland degradation was significantly associated (χ^2 = 1675.79, $p < 0.01$) with vegetation ecological status (Figure 5.8). The non-degraded sites were dominated by climax grass species (67.1%) such as *Themeda triandra* and *Tristachya leucothrix*.

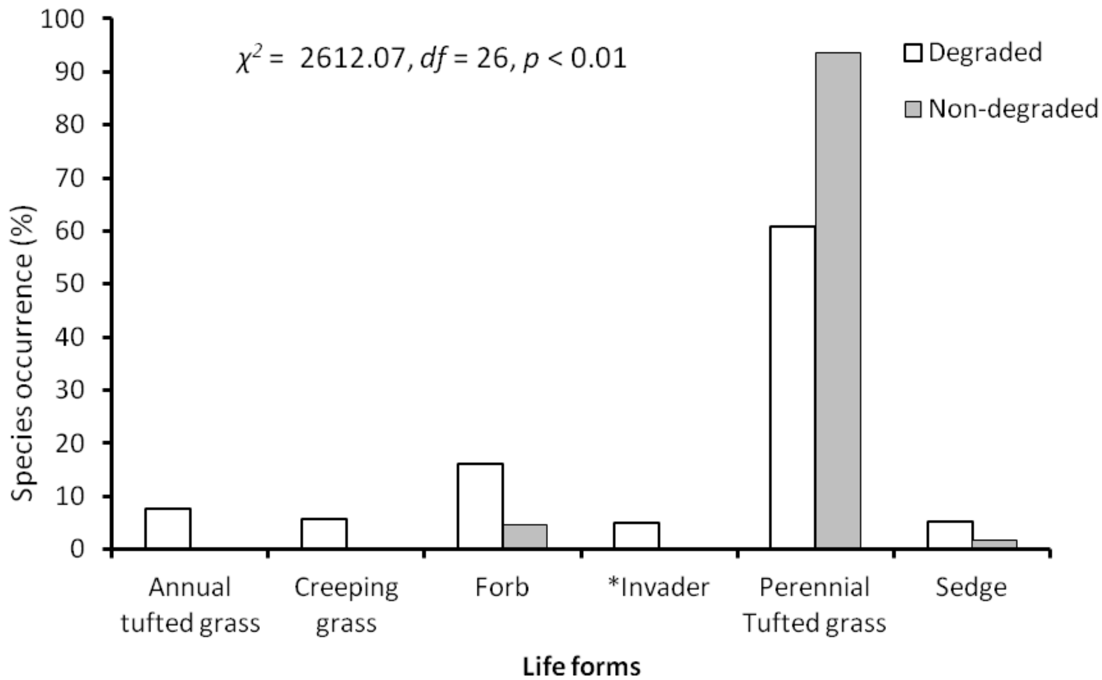

Figure 5.7: Herbaceous vegetation distribution according to their life form between degraded and non-degraded rangelands (* = invaders species were not categorised into life forms and their inclusion in the figure only indicates their occurrence).

The degraded sites were dominated by sub-climax grass species (43.7%) such as *Sporobolas africanus, Eragrostis capensis,* and *Eragrostis chloromelas*. Furthermore, pioneer grasses were higher in degraded rangelands (16.1%) while they were not observed at non-degraded rangelands.

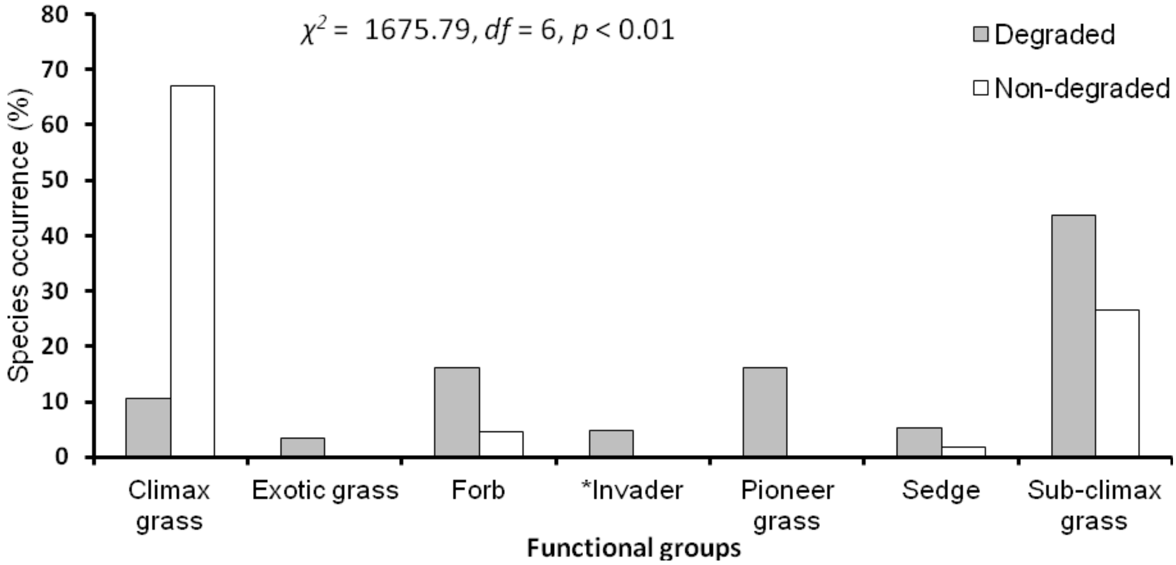

Figure 5.8: Herbaceous plant species functional groups between degraded and non-degraded rangelands (* = invaders were not categorised into functional groups and their inclusion only indicates their occurrence).

There was a significant association (χ^2 = 1044.82, $p < 0.01$) between the degradation and grazing values of grass species (Figure 5.9). The non-degraded rangelands (63.3%) were dominated by grass species with average to high grazing values.

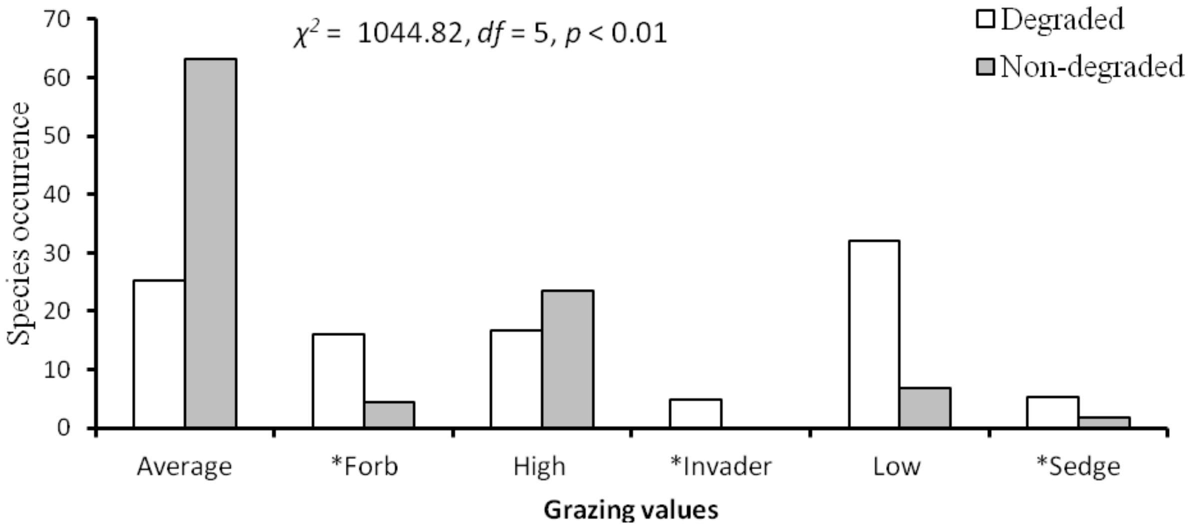

Figure 5.9: Species composition according to grazing value between degraded and non-degraded rangelands (* = Forbs, invaders, and sedges were not categorised into grazing values and their inclusion in the figure only indicates their occurrence).

Rangeland degradation was significantly associated (χ^2 = 2323.69, $p < 0.01$) with vegetation grazing status. Degraded rangelands were dominated by increaser II and increaser III grass species, while the non-degraded were dominated by decreaser and increaser I species (Figure 5.10).

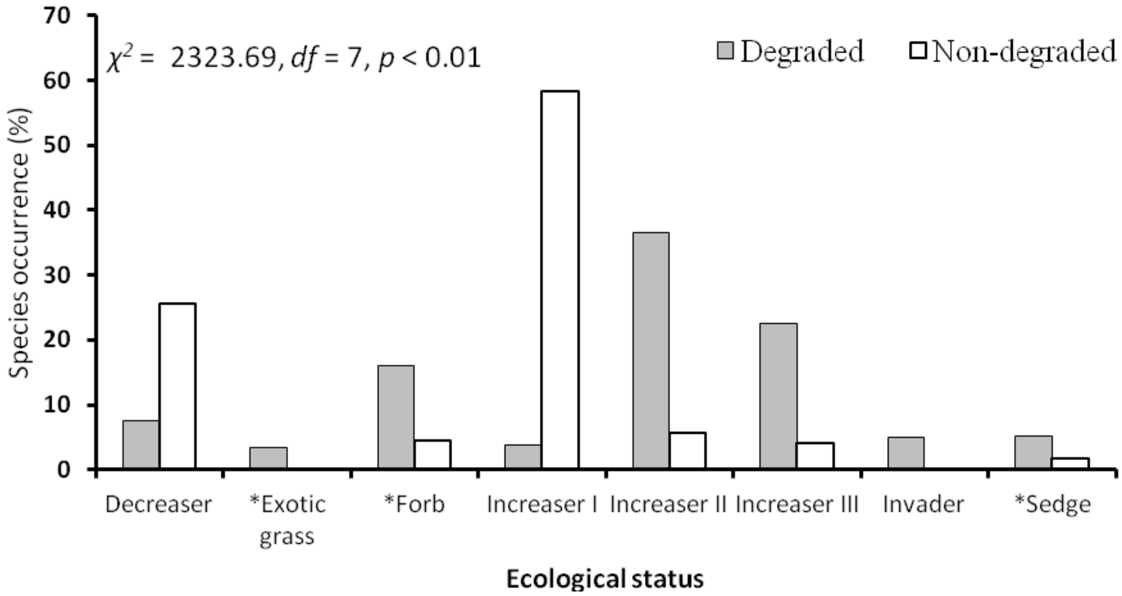

Figure 5.10: Species composition according their grazing status between degraded and non-degraded rangelands (* = exotic grasses, forbs, and sedges were not categorised into their ecological status and their inclusion only indicates occurrence).

5.3.2.2. Characteristics of vegetation for soil protection against erosion

The tuft diameter was significantly different (F = 8.07, p < 0.01) between degraded (5.31 cm) and non-degraded (5.62 cm) sites. Furthermore, the tuft-to-tuft distance was significantly different (F = 18.05, p < 0.01) between the degraded (4.01 cm) and non-degraded (3.46 cm) sites (Figure 5.11).

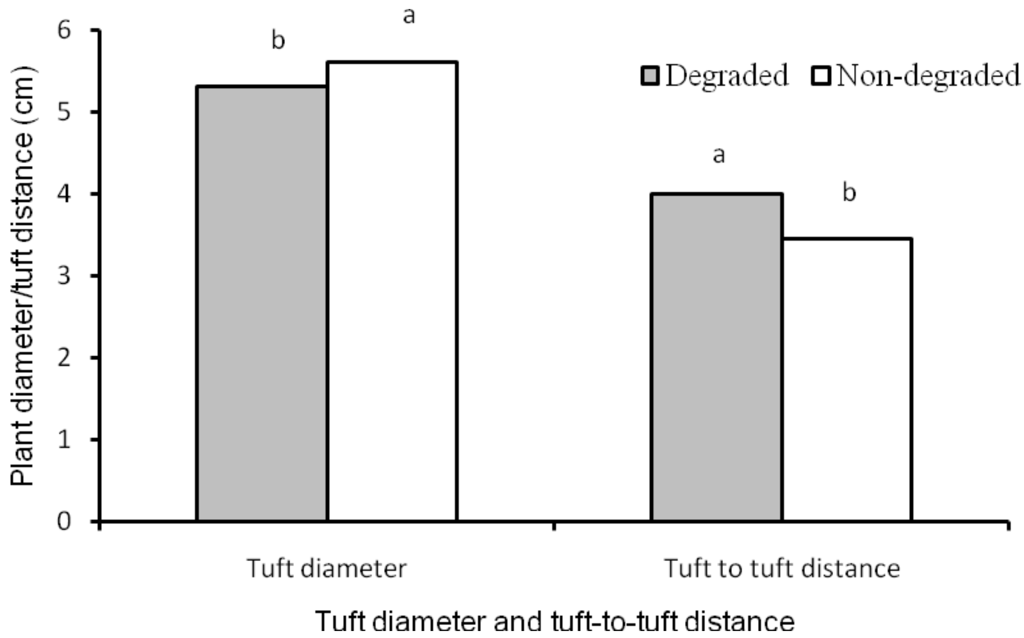

Figure 5.11: Grass tuft diameter and distance between tufts as an indication of basal cover between degraded and non-degraded sites (different letters within the pair indicates that the means for tuft diameter and tuft-to-tuft distance between degraded and non-degraded sites were significantly different).

Tuft diameter was significantly different ($F = 23.56$, $p < 0.01$) between the perenniality categories (van Oudtshoorn 1999) of herbaceous vegetation species. The tuft diameter was higher on forbs, weak perennial (growing for < 5 years) and perennial tufted grasses compared to creeping grasses, annual tufted grasses and sedges (Figure 6.12). Non-degraded (98.27 plants/m^2) rangelands were significantly higher ($F = 9.93$, $p < 0.01$) in plant density than degraded (72.4 plants/m^2) rangeland sites.

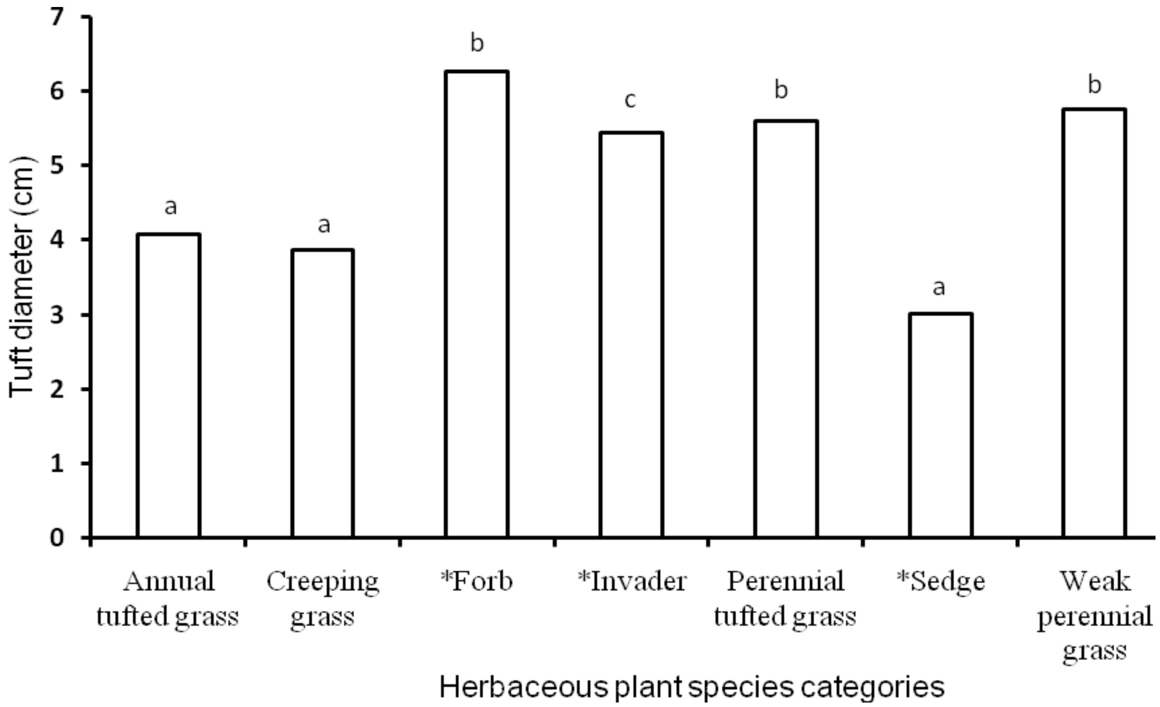

Figure 5.12: Plant diameter of the herbaceous vegetation according to their life form (Different letters denote that means for tuft diameters between herbaceous vegetation species categories were different; * = forbs, invaders, and sedges were not categorised into their life forms and their inclusion in the figure only indicates their occurrence).

Plant density was significantly negatively related (r = -0.702, p < 0.001) with tuft diameter. The tuft diameter was significantly related reciprocally (r = -0.627, p < 0.001) with tuft-to-tuft distance.

5.3.3. Penetration and infiltration characteristics of communal rangeland soil

The value of unconfined compressive strength (UCS) of the soil was significantly different (F = 165.75, p < 0.01) between degraded and non-degraded sites (Figure 5.13).

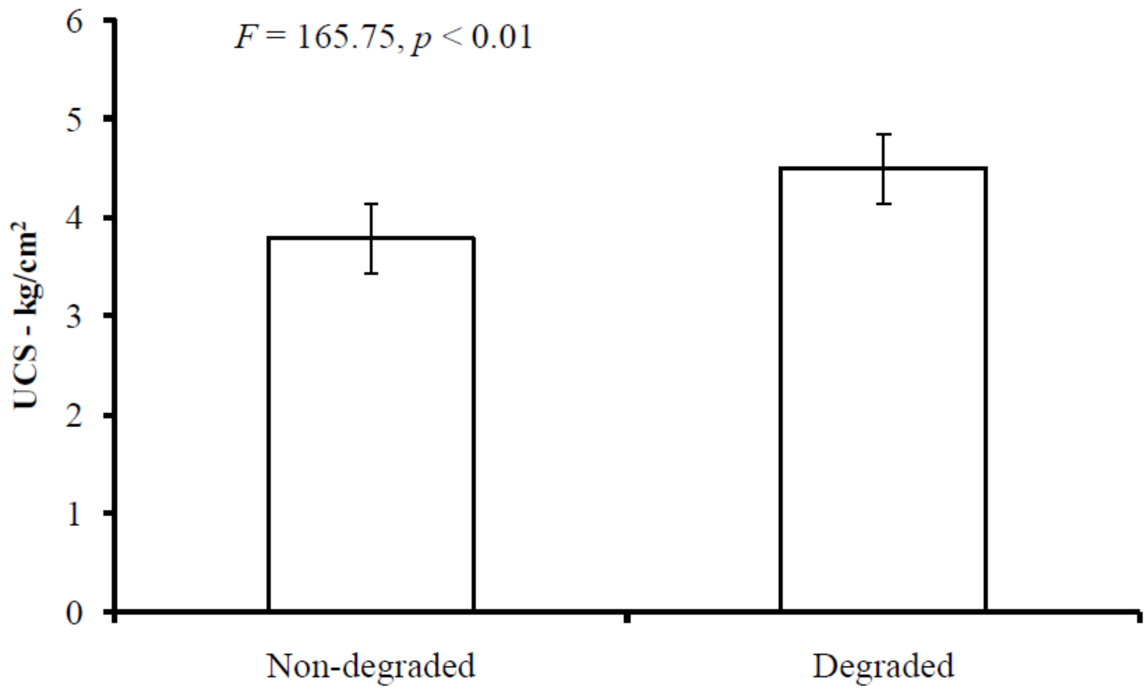

Figure 5.13: Unconfined compressive soil strength (UCS) between degraded and non-degraded rangelands.

Cumulative infiltration rate was significantly different ($p < 0.05$) between Non-degraded (Phandulwazi Agricultural High School) and degraded rangelands (Amakhuze Tribal Authority) at all measured time intervals. The hydraulic conductivity (k) was 1.59 x 10^{-2} cm/s and 5.21 x 10^{-3} cm/s for non-degraded and degraded rangelands respectively. Figure 5.14 demonstrates cumulative infiltration rate vs. square root of time between degraded and non-degraded rangelands.

Table 5.8: Cumulative infiltration rate (Mean, SD, F, and P) between Phandulwazi Agricultural High School (Non-degraded) and Amakhuze Tribal Authority (degraded) at 30-second time interval.

Time (seconds)	**Mean cumulative infiltration rate (cm^3)**		**Std. Deviation**		**F**	**Sig.**
	Phandulwazi A H S (Non-degraded)	**Amakhuze T A (Degraded)**	**Phandulwazi A H S (Non-degraded)**	**Amakhuze T A (Degraded)**		
Initial (0 seconds)	0	0	0	0	-	-
30	-1.44E-26	-2.41E-102	-1.12E-102	-2.78E-120	7.064	0.014
60	-1.25E+29	-2.98E-47	-2.34E-55	-7.14E-72	8.326	0.008
90	-6.75E+83	-3.12E-16	-3.47E-65	-5.33E-67	31.583	0.000
120	-5.27E+115	-2.15E+05	-1.75E-15	-3.47E-54	37.883	0.000
150	-8.84E+136	-1.37E+22	-2.91E+13	-3.47E-45	34.017	0.000
180	-1.94E+157	-6.72E+41	-2.55E+29	-7.92E-41	34.422	0.000
210	-3.74E+175	-2.01E+69	-5.04E+43	-2.48E-20	39.635	0.000
240	-4.14E+207	-2.43E+86	-2.96E+100	-1.28E+08	31.395	0.000
270	-4.72E+226	-2.12E+105	-1.12E+107	-9.00E+35	31.764	0.000
300	-3.64E+246	-4.29E+122	-4.30E+141	-1.24E+54	30.654	0.000
330	-1.08E+262	-3.13E+142	-4.31E+168	-3.37E+80	25.559	0.000
360	-3.20E+282	-3.30E+162	-2.36E+191	-1.78E+96	23.337	0.000
390	-1.56E+306	-8.82E+177	-1.07E+201	-2.18E+120	26.793	0.000
420	5.21E-299	-1.39E+197	-4.50E+218	-1.68E+136	25.788	0.000

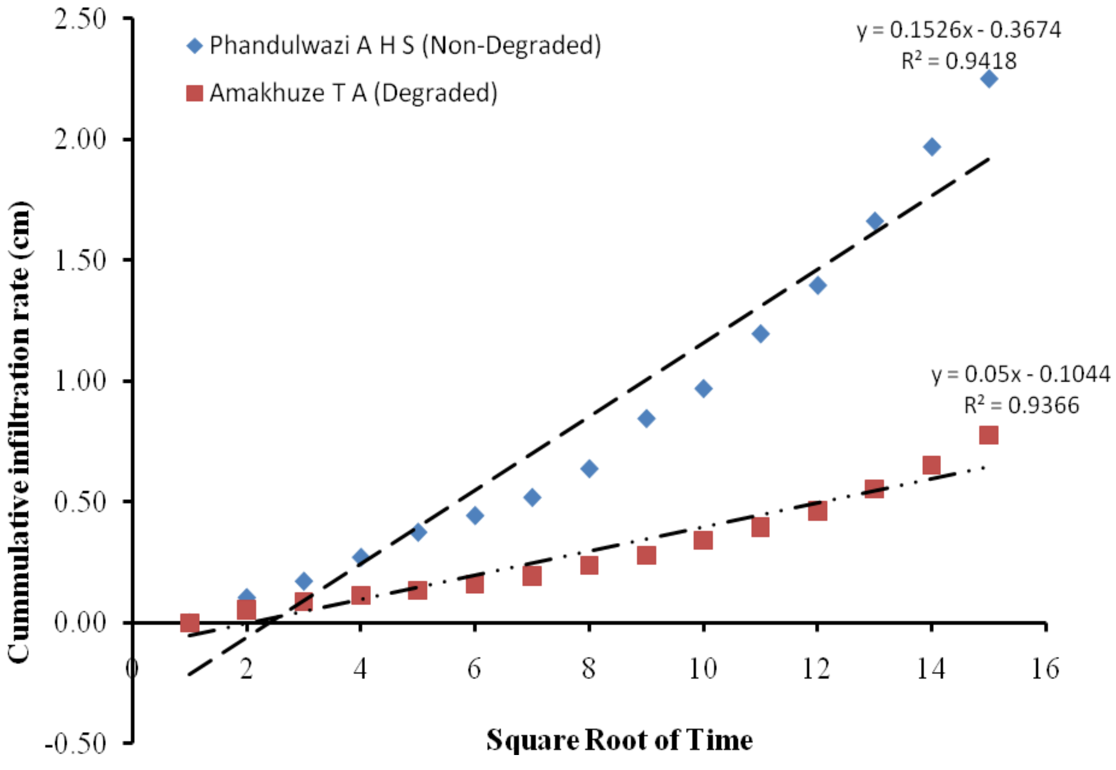

Figure 5.14: Cumulative infiltration rate (cm^3) vs. the square root of time between degraded and non-degraded rangelands.

5.4. Discussion

5.4.1. Vegetation characteristics as indicators of rangeland degradation in communal rangelands

Vegetation species presence and dominance on rangelands were used as indicators for land degradation. The results of the visual rangeland degradation assessment indicate that rangeland located on the valley bottom and along the foothills were the most degraded. This was indicated by the presence and dominance of increaser II grass species such as *Aristida congesta*, *Cynodon dactylon*, and *Eragrostis obtusa*. This was in contrast to species presence and dominance on the mountaintop, where the mountaintop was dominated by decreaser species such as *Themeda triandra* and *Heteropogon contortus*. Under heavy grazing pressure, decreaser species disappear and are replaced by increaser or invader species (Sisay and Baars 2002). Decreaser grass species are abundant in the rangeland on good condition, but they decrease in number when the rangeland is overgrazed or undergrazed.

Increaser II species are generally regarded as annual and pioneer grass species. These species are indicators of the early stages of secondary plant succession. Secondary succession indicates that there is a disturbance in plant community development (Tainton and Hardy 1999). Secondary succession starts on the secondary bare area; secondary bare area is facilitated by disturbance such as overgrazing, drought, flood, and fire. The dominance of increaser II species on the valley bottom and along the foothills could be ascribed to localised grazing pattern, which has resulted in variation in degradation intensity along the landscape. Different grazing pressure within the different parts of rangelands could result in change in species composition (Abel 1997, Hays and Holl 2003).

In the rangelands, depending on the history of management there are plant species that are more acceptable to grazing animals and those that are less acceptable. Thus, when animals are grazing in one area they tend to select species that are more acceptable and they leave other species not grazed. The species that are grazed repetitively are not given sufficient time to recover and they lose plant vigour and subsequently some tufts do not recover depending on the severity of defoliation and availability of reserved carbohydrates. Plant species that were not grazed increase in numbers and vigour, that is because they get more chance to grow and produce seeds and subsequently become dominant in the area. The higher grazing intensity results in changes on vegetation structure, composition and rangeland productivity (Moleele and Perkins 1998, Oztas *et al*. 2003, Maki *et al*. 2007).

Rangeland degradation as indicated by poor vegetation soil cover was characterised as high along the valley bottom, foothills and midslopes and light on the mountaintop. The poor soil cover indicates that most of the soil is bare; this further indicates higher rates of run-off. The poor soil cover could be due to smaller and fewer plant tufts, or fewer thicker plant tufts resulting from high grazing pressure. High intensity grazing at the certain portion of rangelands leads to excessive removal of most grazing acceptable species, which are usually perennial grasses (Todd and Hoffman 1999, Anderson and Hoffman 2006). This opens the way for less acceptable and faster establishing annual grasses and forbs, which in turn are providing poor cover to soil (Nsinamwa *et al*. 2005). The fact that soil cover varies within the landscape is an indication that land degradation varies along the landscape within grazing areas. The dominance of increaser II grass species suggests the loss of climax species and this has resulted in poor soil cover. This is in agreement with Tainton and Hardy (1999) who indicated that rangeland degradation proceeds due to the breakdown of cover, the loss of climax species and their propagules, and the invasion of pioneer grass species.

The observation of pedestal presence and their heights indicate the frequency and intensity at which land degradation has occurred because of sheet erosion. The presence of pedestals further denotes erodibility of the soil, which indicates loss of vegetation in the landscape being preceded by loss of soil while the plants are present (Coetzee 2005). That could be attributed to high runoff rate on a susceptible soil with poor soil cover. The frequency and intensity of rangeland degradation as characterised by pedestals were both higher at the grazing areas located on the valley bottom and foothills compared to mountaintop. The presence of severe pedestals at the valley bottom and foothills could be attributed to poor soil cover, which in turn facilitates runoff. Runoff on the poor soil cover washes away the soil around the plant tufts or stones and leaves the soil that is anchored by plant roots or directly covered under the stones and that result into pedestal development.

These results imply that considering the frequency and intensity of pedestal development as an indicator of rangeland degradation, communal rangeland degradation could be characterised as higher at the low-lying areas than upper areas. This could be ascribed to landscape variation and grazing distribution, thus the landscape on a sloping terrain is more susceptible to degradation due to easy movement of water from higher lying areas. As indicated in chapter 6, grazing pattern at Amakhuze Tribal communal grazing areas was more concentrated on the valley bottom and foothills than mountaintop.

The frequency and intensity of rangeland degradation as characterised by the presence and depth of terracettes was also observed to be high at valley bottom, foothills, and midslopes and low at the mountaintop. The presence of the terracettes could be due to poor soil cover and diverged water distribution because of land shape and slope. Thus, the land with a convex-slope uphill diverts water over the rangeland and can cause terracettes if vegetation cover is poor. Furthermore, if the uphill slope is convex and downhill is concave, the water flow converges into narrow channels resulting in rills and gullies on the valley bottom. Hancock *et al*. (2003) indicated that soil-mantled, fluvial erosion – dominated catchments generally have convex upper-hill slope profiles with concave profiles developing further down-slope. In water flow dynamics within the rangelands, it is important to consider that there is less force at the top of the slope because that is where the flow starts and increases momentum as it flows down slope. That would also subject the down slope areas to soil erosion especially where the vegetation cover is poor.

The occurrence and severity of rills was higher at the valley bottom and foothills as other variables were observed. The presence of gullies was also localised towards valley bottom and foothills. The results imply that the distribution of land degradation in communal rangelands at Amakhuze Tribal Authority was biased towards the valley bottom. Land degradation was decreasing with an increase in altitude resulting in areas at the mountaintop being least degraded. The land with convex shape and sloping terrain has higher waters flow because of the run-off water convergence into high concentrated water channels. The higher concentration of running water into channels results in soil within such channels being washed away and that in turn results in rills, which subsequently result in gully formation.

Other rangeland degradation indicators such as the presence of solution notches and armour layers were insignificant, thus they were generally not observed. However, that does not imply that there was no degradation, but it is just that the indicators are more dependent on presence or absence of rocks. The absence of these indictors could be attributed to the absence of rocks and stones on which to mark solution notches as well as the absence of debris, which are generally used on assessing an armour layer. However, soil deposition was observed to be especially high on the valley bottom and foothills. The presence of sediment indicates that the soil was washed away from upper slopes, which are more susceptible to soil erosion and deposited into the low-lying areas. Susceptibility of the rangeland to degradation could be due to poor soil cover and roughness of the terrain. The poor soil cover could be as a result of low plant species distribution density or the presence of plant species with poor soil cover such as annual grasses. As the soil particles carried in runoff get to areas with gentle terrain or a bit of soil cover with reduced water flow in terms of both quantity and speed, they settle down and accumulate into sediment. Land degradation caused by soil erosion does not only involve the loss of topsoil and reduction of soil productivity, but also leads to sedimentation of reservoirs and increases suspended sediment concentrations in streams, with consequent effects on ecosystem health (Le Roux *et al*. 2007).

5.4.2. Physical rangeland degradation measurements in communal grazing areas

As indicated in the sections above, rangeland degradation could be characterised by the rills as indicators of soil loss. In this study, the visual observation of the presence and estimation of the rill height was further supported by physical measurements of rills. The important variables in characterising the rills included length, breadth, and depth. These variables indicate the degree to which soil was lost through rill development. The volume of soil loss through rill formation was affected by rill cross sectional area and rill lengths. The length and number of the rills per catchment area determines the total volume of soil lost and the volume of soil loss per unit area.

The rills present in degraded portions of Amakhuze tribal grazing communal areas varied in depth, length, and breadth. The rill breadth, depth, and length influence the rill cross sectional area. The rill cross sectional areas together with rill length indicates the volume of soil lost. The rill length had a greater impact on the volume of soil lost than the rill breadth. This shows that the longer rills even if they are narrow have more soil loss compared to shorter ones. Thus, degraded rangelands that are characterised by lengthy rills have lost the more volume of soil than the areas with multiple shorter and wider rills. The major question to answer would be “what causes variation in rill length within the ecosystem?” Although the cause of variation between rill characteristics was not measured in this study, the speculation is that differences could be due to variation in vegetation characteristics, soil infiltration rate and landscape formation within catchment areas. These factors determine runoff rates and concentration, and in turn, the volume of soil lost. Martín-Fernández and Martínez-Núñez (2011) indicated that interill and/or rill superficial erosion is one of the important types of soil erosion. This is because it influences further degradation of natural systems, the loss of soil and alteration of hydrological processes. Furthermore, Kosmas *et al*. (1997) indicated that factors determining the response of soil water dynamics by influencing infiltration and runoff rates for a given rainfall include spatial distribution of land use, vegetation cover, topography and soil type, as well as erosion processes.

The fact that there was a positive strong relationship between the length, height and breadth of the rill indicates that rill formation occurs simultaneously in increasing breadth, depth, and length. This implies that the shorter, shallower, and narrower rills could be at an early stage of degradation and would increase in three dimensions with time. As the length of the rill increases the volume of soil lost per catchment area and per unit area (m^2) also increases. That makes it necessary for rangeland scientists to develop and/or evaluate techniques specifically to address early and late stages of rangeland degradation in communal areas.

There was a positive relationship between rill depth and breadth. The rill cross sectional area was determined by the depth and in turn affects volume of soil lost per catchment area and per unit area. This implies that as the rills become deeper the soil loss per catchment area and per unit area increases. This suggests that rill breadth had a positive effect on cross sectional area, volume of the soil lost per catchment area and per unit area. The information on rill characteristics such as rill cross sectional area are ecological significant if the characterisation of such degradation indicators is intended to inform the restoration procedures. The relationship between rill cross sectional area and both soil loss per catchment area and per unit area indicates that the larger the cross sectional area the higher the soil loss volume both per catchment area and per unit area. It is therefore, important in rangeland restoration intervention to consider the restoration mechanisms that can reduce the breadth and depth of the rills and that in turn would reduce the volume soil loss per catchment area and per unit area.

It is important to note that communal rangelands are regarded to be degraded by most of rangeland scientists and policy makers. In agreement with this popular conception, the findings in chapter 4 of this study indicated that land users also perceive rangelands to be degraded. It is however, more fundamental to assess rangeland degradation characteristics in detail, that serves to provide a detailed diagnosis to the problem. As discovered with the rills, it was further found that gullies were present. However, these vary with length, breadth, and depth within the grazing areas. Gully formation is preceded by rill formation, thus as the rills deepen, widen and lengthen they result in gullies. Machado *et al*. (2010) stated that gully formation begins with interill erosion followed by concentrated runoff, thus initiating rill formation, which further evolves into gullies because of the increase in dimensions of the channel.

The volume of soil lost through gullies was higher on longer than wider shorter gullies. This implies that the greater length of gullies leads to higher soil loss than the wider shorter gullies. The presence of the rills and gullies are preceded by poor vegetation cover (Gyssels and Poesen 2003), number of factors, such as climate and drought, could affect vegetation cover in rangelands however, the most cited factor reducing soil cover is overgrazing (Bull 1997; Fanning 1999; Moir *et al*. 2000). Stavi *et al*. (2010) indicated that the decrease in vegetative cover also reduces the ability of ecosystem to retain resources. Hence, the reduction in plant biomass and vegetation cover not only indicates degradation of the ecosystem, but also enhances this process leading to further degradation of formerly more productive rangelands.

The results further indicate that length and depth of the gully are directly proportional, thus, as the length increases the depth increases. This implies that the longer gullies are the deepest; hence, the shorter gullies are the shallowest. The explanation for the relationship between the length, depth, and breadth of the gullies could be that shorter gullies develop into longer gullies with time. The results also point out that the longer gullies have higher soil loss per gully and per mitre equivalent. The fact that gully length was related positively to the volume of soil lost indicates that gully length could be used as a characteristic feature for communal rangeland degradation. According to Nachtergaele *et al*. (2001), the length of the gully is the key parameter to determine the volume of gully erosion. Furthermore, Hughes *et al*. (2001) and Cheng *et al*. (2007) indicated that there was a strong correlation between the length and volume of the gully and they have suggested that gully length is a significant and useful index to estimate the volume of gully erosion.

It was further reported in the results that the relationship between top and bottom breadth were directly proportional. Thus, as the top gully breadth widens so the bottom and they both affect the cross-sectional area of the gully. As the cross-sectional area of the gully increases, the volume of the soil lost also increases. Communal rangeland degradation could be characterised by the presence of gullies, however, within degraded sites gullies vary in length, breadth, and depth. This variation in gullies' physical characteristics denotes that degradation extent varies within the catchment area and landscape.

The fact that gullies on the head cut had loose soil with bare internal surfaces indicates that gullies are progressively developing, thus the soil on the head cut is loose and there waiting for water flow for transportation. The poor vegetation further signifies little resistance for gully head cut to fall and soil being washed away easily. The gully walls were characterised by solid walls however, with poor vegetation cover. This announces that the gully walls are not protected from further development and that threatens for further gully formation and broadening of existing gullies. The bases were characterised by loose soil, lack of vegetation and sediment accumulation. This further indicates that soil erosion has higher potential of increasing in terms deepening of the gullies due to lack of vegetation even within the gullies. Vegetation within the gullies signifies a positive trend in terms of land recovery and the absence therefore, signifies the opposite. The premise at which gully head-cut, sidewall, and internal base characteristics were assessed in this study is that they could indicate stability or the vulnerability of gully and its catchment areas. Thus, a gully that shows vegetation development at the head-cut, sidewall, and internal base indicates recovery and stability. Initiation and further development of the gully could be related to the stability of the gully head-cut, sidewall, and internal base. Betts *et al*. (2003) indicated that gullies may initiate normally through fluvial transport, but they rapidly develop into mass-movement complexes, Herzig *et al*. (2011) further indicated such complexes can result in engulfing whole first order catchments.

The question would be "can alterations in rangeland management reverse the degradation problem in communal areas and/or could restoration of vegetation with consideration of degradation characteristics serve as a mitigation procedure for communal rangeland degradation?” The assumption is that alteration of communal rangeland management may reverse the scourge of degradation but that will take longer and/or be costly especially on severely degraded rangelands. Considering that, this work was done on communal rangelands, there would not straightforward management plan recommendation. However, at the centre of any management plan there should be consideration ways to control livestock movement within the grazing area. This could be achieved through fencing, herding, and kraaling. Livestock movement control will provide rationality on the place to graze and period of grazing based on the number of animals. Adaptive management that was proposed by Walters and Hillborn (1978) and further explained by Grossman *et al*. (1999) could help in introducing the change in communal rangeland management. In this proposed management change, there should be development livestock-rangeland management objectives, determination relevant management actions, monitoring of the outcome such actions and evaluation of the results obtained against expectations could help change introduce change in communal rangeland management.

The presence of pedestals was observed in communal rangelands and could serve as a characteristic feature of communal rangeland degradation. The pedestals occurred on majority of the sites and their heights were used to determine the extent of rangeland degradation and to estimate the volume of soil lost per catchment. Terracettes were also present and indicate rangeland degradation in communal areas. The terracette presence and depth indicates that there is a large volume of soil lost. This implies that there was sheet erosion occurring on the sloping terrain in communal rangelands. Pedestals and terracettes are important indicators of the movement of soil by water and/or by wind (Satterlund and Adams 1992, Hudson 1993). Abundance of pedestalling and numerous terracettes together with their depth indicate the degree of degradation.

5.4.3. Vegetation characteristics of degraded rangelands

Vegetation characteristics between degraded (Amakhuze Tribal authority-communal) and Non-degraded (Phandulwazi Agricultural High School) rangelands were different. Rangeland degradation as characterised by vegetation species composition indicates that perennial tufted grasses were low in communal (degraded) rangelands, while the forbs and annual grasses were increasing. This implies that as the rangelands become degraded the perennial grass species decrease in frequency of occurrence and density. This could be due to species selectivity of grazing animals and high seed production of annual grasses, which could result in high germination rates in the next growing season.

The results from this study furthermore, denote that loss of perenniality of the grass species within the communal rangelands can be regarded as the characteristic feature for rangeland degradation. This is in agreement with Tainton (1999) who indicated that, vegetation changes from being dominated by perennial grasses to being dominated by annual grasses with overutilization. One of the functions of the communal rangeland ecosystems is to provide forage for livestock production. Forage production can be assessed through its quality and quantity; both these parameters are generally inherent in species composition. The poor species composition could advocate for less or reduced ability of a these ecosystems to support forage production and hence expected poor animal production potential. The nutrient value of range forage is dependent, among other factors, on species composition and as such, annual grasses and forbs are seldom considered as favourable to livestock as their perennial counterparts due to their poor nutritional characteristics (Arzani *et al*. 2006). The dominance of these annual grass species in the communal rangeland ecosystems indicates that there has been retrogression in vegetation community development. This implies that retrogressive succession patterns in communal rangelands can serve as the characteristic feature of rangeland degradation. Retrogressive characteristics of the rangelands are indicated by species composition, thus the dominance of rangeland by annual grass species indicates degradation as the farmers indicated in chapter 4, that some of the indicators of degradation included the change in species composition. This is in agreement with Malan and Van Niekerk (2005) who indicated that certain species characterize different succession stages during grassland retrogression and they could serve as characteristic attributes of rangeland degradation. Vegetation indicators for rangeland degradation serve as the early warning system for rangeland degradation and subsequently can justify the early intervention. Rangeland degradation occurs in different stages and is designated by different indicators; thus, vegetation indicators demonstrate early stage and light degradation intensity, soil loss indicators demonstrate mid-term to late stage and severe degradation.

Amakhuze Tribal communal rangelands compared to relatively non-degraded Phandulwazi Agricultural High School were dominated by grass species with low grazing value. This suggests that grasses with low grazing value dominate communal rangelands, and therefore, this could serve as a lineament of degraded communal rangeland. The fact that communal rangelands are degraded could directly relate to poor forage productivity and subsequently to low livestock production. Rangeland degradation reduces the value and utility of rangeland through replacement of grasses with high grazing value and with grasses with low grazing value and hence ensues loss of utility. Rangeland degradation result in a loss of utility and change of features of rangeland ecosystem into features that do not support production (Chrisholm and Dumsday 1987). Livestock production in communal rangelands plays an important role in the rural economy, grazing on rangelands serves as one of the means of production, thus, it reduces production costs.

Rangeland ecological status as deduced from Clementsian theory of plant succession states that plant communities progress or regress along predictable courses of defined environmental regimes, including grazing and precipitation (Clements 1920, Dyksterhuis 1949). In relation to the above assertion, the fact that communal rangelands were dominated by increaser II species, which was in contrast to non-degraded rangelands, suggests that there has been more grazing pressure on communal rangelands. The ecological status of grasses refers to their grouping based on their reaction to different levels of grazing.

The difference in ecological status between communal rangelands and non-degraded sites projects that poor ecological status could be a characteristic feature of communal rangeland degradation. Ecological status of grasses refers to the grouping of grasses based on their reaction to different levels of grazing. Van Oudtshoorn (2009) who indicated that a grass species reacts to grazing in one of two ways, thus, it can either increase or decrease supports the concept of vegetation ecological status. The mechanism through which rangeland vegetation species change as a result of grazing pressure could relate to the repetitive removal of leaves from acceptable species, which weakens the plant nutrient reserves useful for recovery after defoliation. In agreement with the foregoing assertion, Malan and Van Niekerk (2005) indicated that acceptable grasses lose their vigour because of repeated removal of leaves and constant draining on their nutrient reserves. When a plant is unable to replenish the stored resources, it fails to produce new leaves and eventually reduce photosynthetic power (Morris and Kotze 2006). As the desirable plants become weaker, die off, the number of roots in the upper layer of the soil decrease, and result into a reduced competitive ability of grasses (Sisay and Baars 2002).

The fact that vegetation species in communal rangelands had smaller tuft diameters with larger spaces between the tufts compared with non-degraded sites indicates that communal rangelands had poor soil cover. Thus, smaller tufts and larger space between them exposes more soil surface to direct sun-heat, subjecting land to desiccation, exposing land to raindrop impact, which detaches soil particles, and increasing the rate of runoff, which is responsible for soil particle transportation. Water inputs may be intercepted either by plants, infiltrate the soil, or run off the surface depending on, among other factors, soil characteristics; topography and vegetation cover (Morris and Kotze 2006). In rangeland ecosystems, little can be done to improve soil characteristics and topography cannot be changed but through proper management practices vegetation cover may be improved, which in turn may improve soil conditions. The most important single factor affecting water run-off is the amount and type of vegetative cover (Malan and Van Niekerk 2005). The poor soil cover could be attributed to uncontrolled grazing practices in the communal grazing areas. This could indicate that the tuft diameter and tuft-to-tuft interspaces could serve as the degradation characteristic attribute on communal rangelands.

The fact that vegetation cover varied between the sites could be associated with perenniality of the species present and therefore, vegetation cover is related to species composition. The poor basal cover, plant density, and species composition could be due to, among other factors high grazing intensity, subsequently resulting in accelerated runoff. In support of the foregoing assertion, Maki *et al*. (2007) indicated that perennial grasses have extensive root systems and protect the soil from erosion more effectively than annual species, however, replaced by annual species as the grazing intensity increases.

The dominance of certain species and their density in communal rangeland bears implications to basal cover, which in turn indicates rangeland degradation. Therefore, *ipso facto,* basal caver, plant density, and species composition could be considered the characteristic features of rangeland degradation in communal grazing areas. The dominance of perennial grass species locally indicates good protection against soil erosion (Morris and Kotze 2006). The excessive removal of perennial grass species reduces ground cover (Eccard *et al*. 2000; Nsinamwa *et al*. 2005). While on the other hand, the dominance of annual grasses indicates instability of the ecosystem, thus, rangeland ecosystems become susceptible to soil erosion. This is in agreement with Malan and Van Niekerk (2005) who reported that when annual grasses die, the ground remains bare for a long time becoming susceptible to soil erosion.

The fact that plant density and tuft-to-tuft interspacing were negatively related to plant diameter indicates that, as the tuft diameter increases the distance between the tufts decreases, thus the higher the tuft diameter the lower are the spaces between the tufts. This implies that the tuft diameter have positive effects on the basal cover and therefore, in soil protection against erosion. The base of a rooted plant provides the basal cover and it depends on the thickness of the tufts and plant density (Svejcar *et al*. 1999, Malan and Van Niekerk 2005, Morris and Kotze 2006).

The conception that there was higher unconfined compressive strength (UCS) on degraded than non-degraded rangeland proposes soil compaction on degraded rangelands. Soil compaction could be ascribed to animal trampling and have negative effects on rangeland production and water dynamics. Negative effects of trampling and its subsequent high UCS could include poor root growth performance and reduced infiltration rate of water during rainfall and that leads to the loss of water from the system. The higher rate of water loss from the rangeland ecosystem leaves the vegetation with little water to survive on and subject the rangeland higher run-off, which in turn result is soil erosion. The higher soil compressive strength is an important characteristic feature negatively affecting aspects of agricultural soils, such as the performance of root growth, least-limiting water range, and the trafficability (Vanags *et al*. 2004). This could imply higher resistance of soil for plant root growth and limited water storage resulting into high runoff and consequently soil erosion. Herrick and Jones (2002) pointed that soil compaction can easily reduce production and can lead to water and soil quality degradation due to increased runoff. Rangeland degradation in communal areas could be further characterised by soil compaction, which could be related among other factors to animal trampling.

The fact that communal rangelands had low hydraulic conductivity and low cumulative infiltration rate indicates that during rainfall most of the water runs off the system. This implies that other than vegetation characteristics, the soil-water relation characteristics could be a factor that increases runoff. The poor infiltration rate and hydraulic conductivity could be related to soil compaction. Soil compaction and low infiltration rates on communal rangelands could lead into accelerated runoff, which washes away soil and water out the ecosystem. Therefore, high soil compaction and low water infiltration rate could be considered characteristics of communal rangelands. Compaction of surface soil and the removal of plant cover have been identified as the major impacts of grazing on the hydrologic cycle (Thurow *et al*. 1986). Infiltration rates on rangeland integrate the complex interactions of soil and vegetation factors and could be used as indicators of hydrological conditions.

5.5. Conclusion

Rangeland degradation occurrence and extent were higher at the communally managed rangelands compared to the controlled grazing areas. In the communal areas, because of poor grazing management control, rangeland degradation varies between the landscapes, thus, areas receiving high utilisation such as low-lying grazing areas were more degraded than areas with low utilisation intensity. Communal rangeland were characterised by poor forage production and vegetation cover, high soil unconfined compressive strength with low soil hydraulic conductivity due to overgrazing and trampling. Poor forage production and vegetation cover are because of the dominance of increaser II grass species, which indicates over utilisation. The higher UCS and lower hydraulic conductivity of the soil result into higher run-off rate and the higher run-off coupled with poor vegetation cover resulted into soil erosion. Soil erosion features such as the presence and depth of the pedestals, terracettes, rills, and gullies in communal rangelands serves as the physical characteristics of rangeland degradation. In conclusion, Communal rangeland degradation could therefore, be characterised by vegetation characteristics such as poor forage productivity and vegetation cover, soil properties such as high unconfined compressive strength and lower hydraulic conductivity, and physical soil erosion indicators such as pedestals, terracettes, rills and gullies.

6. LIVESTOCK GRAZING DISTRIBUTION PATTERN IN THE COMMUNAL RANGELANDS

6.1. Introduction

Communal rangelands are used primarily as source of feed for livestock and secondary source of other resources such as firewood, foods, medicinal plants, and water. Sustainable use of communal rangelands for grazing depends on the understanding of how grazing interacts with the underlying environmental variables and ecological processes of these ecosystems (Solomon *et al.* 2006). The condition of the grazing area is influenced principally by herbivore species, herbivore densities and landscape structure (Person *et al.* 2003).

The impacts of grazing on ecosystems and the response of the ecosystems to grazing are observed initially as the change in vegetation species composition and basal cover, and soil compaction, which result in an increase of an overland volume of water flow (Belsky and Blumenthal 1997). The reduction of soil cover exposes the land to runoff and soil particles' to detachment by raindrop impact and movement of animals. This leads to soil erosion that reduces primary productivity of rangeland ecosystems through poor forage productivity, and poor soil protection (Palmer *et al*. 1997), and reduces secondary productivity through reduced livestock production performance.

Communal rangelands have been reported to be degraded, and overgrazing has been blamed for this. These grazing areas are generally found on the heterogeneous landscapes and therefore, livestock grazing distribution pattern might be affected by variations in landscape. That could result in certain areas being utilised more than others are, which in turn could expose such areas to land degradation. Furthermore, when grazing areas on a rough terrain are subjected to a similar grazing intensity to adjacent areas on gentle terrain, the areas with rough terrain are more susceptible to soil erosion.

The quality and quantity of forage in rangelands changes seasonal climate changes. That could cause changes in livestock grazing distribution within the rangelands at different times of the year. Water availability, distribution, and accessibility vary between different areas within the rangeland ecosystem and between different seasons. This could also influence the distribution of drinking points, which in turn could influence livestock grazing distribution within the rangeland landscapes.

Grazing distribution in the communal rangelands needs to be explored in order to come up with specific factors that can relate grazing to rangeland degradation. This chapter explains livestock grazing distribution in the communal rangelands along the landscape, vegetation type, land use, seasonal climatic change, and the grazing distance from drinking point gradients. The null hypothesis was that grazing distribution pattern in communal areas is not affected by landscape, vegetation type, land use practices, seasonal climatic changes and grazing distance from drinking points; thus, grazing pressure is distributed evenly, and therefore, rangeland degradation cannot be associated with grazing distribution.

6.2. Materials and Methods

6.2.1. Data collection

To conduct visual rangeland degradation assessment four experimental units were selected and these were Valley bottom (672 to 779 m.a.s.l), Foothills (780 to 893 m.a.s.l), Midslope (894 to 1131m.a.s.l) and Mountaintop (1132 to 1825 m.a.s.l). The cut-off for altitudinal ranges for each slope category was estimated through visual observation of the different landscape demarcations. Thus, the extreme points (lowest and highest) at which valley bottom, Foothills, Midslopes, and Mountaintops were observed were confirmed with the Global Positioning System (GPS) (Table 6.1). The details for visual rangeland degradation assessment are presented in chapter 5.

Table 6.1: The general experimental design based on landscape positions and altitude at Amakhuze Tribal Area

Landscape position		**Altitude (m.a.s.l)**
Valley bottom	VB	< 750
Foothills	FH	785 - 851
Midslope	MS	851- 1146
Summit	SM	1146 – 1500

Direct field observations for animal grazing distribution were conducted during two seasons based on rainfall viz. dry (May to August) and wet (September to April) seasons in

2008-2009. The observations were taken for two weeks (7 days/week) per month for 12 months from 06h00 to 13h00. The direct field observation technique was tested by observing the animal activities (such as times for active grazing, drinking times, period during the day when they are laying) for two weeks in the villages before it was used. Animals were actively grazing between 06h00 to 13h00 and at 13h00 they were mostly assembling at the drinking points after which they would be laying down ruminating. In every observed grazing location, GPS coordinates were marked, animals were counted according to their types (cattle, sheep, goats, horses, and donkeys).

Animals form herds/flocks when grazing in rangelands and the distance between individuals is influenced by various factors. The animals that were found grazing together within the area of 1 ha (10 000 m^2) were considered as a herd/flock. The herds/flocks were considered separate if the distance between them was more than 100 m. The distances between the left-most and right-most individuals were estimated with step counts (two steps ≈ 2 m) on one dimension and referred to as herd/troop length (Shyomi and Tswiki 1999). The area occupied by animals was estimated as the diameter of the herd length. The distance between grazing location and nearest drinking point was measured with step counts, and the distance between two steps was considered equivalent to 1 m. The vegetation types, land use practices, and season were also recorded.

The independent variables were land positions (Mountaintop, Midslope, Foothills and Valley bottom), Land use practices (Forest, rangeland, homesteads, abandoned arable land and cultivated arable land), and season (wet and dry). Dependent variables were distance between animal grazing locations and drinking points (grazing-drinking distance), altitude range at which animals were located, herd-length and number of observed animals per herd/flock (cattle, sheep, goats and other).

6.2.2. Data Analysis

The association of visual rangeland degradation as indicated by vegetation species composition, soil cover, pedestals, terracelets, rills, solution notches, amour layer, sedimentation and gullies was compared between Valley bottom, Foothills, Midslopes and Mountaintop. Data were analysed by cross tabulation with χ^2 (SPSS 1999) the results were considered significant at $p < 0.05$ (Chapter 5).

The data for livestock grazing distribution were analysed with loglinear model - or Poisson regression (SPSS 1999). The Poisson regression was used because the response (the number of animals) was a count variable, and therefore, was not normally distributed, but rather Poisson distributed, which was much better suited for count data. This type of analysis is often used to analyze data from contingency tables, but it goes further than a contingency table by including, not only categorical variables such as land use, but also quantitative variables such as elevation and distance to water.

For the variable Experimental unit, the base category for this categorical variable was "Valley bottom." Therefore, the parameter estimates for "Foothills," "Mountaintop" and "Midslope" were the expected differences in the animal frequency compared to the Valley bottom category. Similarly, for variable Land use, "Arable" was the base category, and the estimates for "Forest (plantation)," "Homestead" and "Rangeland" were the expected difference in frequencies compared to the "Arable" category. For the variable season, the parameter estimate for "Wet" was the difference in frequency compared to the base category of "Dry."

The other variables were all quantitative, and therefore, if the parameter estimate was negative, then it means that the frequency of animals in that particular category was expected to be less compared to the base categories. Moreover, to compare a category to another category that was not the base category, the two estimates were compared. If one estimate was smaller, then it means that this particular category had a lower expected frequency.

For the quantitative variables, if the estimate was negative, it means that as that quantitative variable increases, then the frequencies of animals were expected to decrease. In addition, if it was positive, it means that the expected frequency of animals was expected to increase as the quantitative variable increases. The Horses/Donkeys were only included on the total livestock units.

In order to carry out the analysis in such a way that the results for the different animal types were comparable, the livestock counts were converted into animal units (AU). One cattle was equivalent to one unit, five sheep were equivalent to one unit, five goats were equivalent to one unit, and one horse, or donkey was equivalent to 1.3 units (Torell and Zollinger 2008).

Model:

$$Y_{ijklm} = \mu + L_i + LU_j + S_k + LLU_{ij} + LS_{ik} + LUS_{jk} + LLUS_{ijkl} + E_{ijklm}$$

Where: Y_{ijklm} = Livestock grazing distribution

μ = Overall mean;

L_i = effect of i^{th} land positions (i = valley bottom, midslope, foothills mountaintop);

LU_j = effect of j^{th} land use practices (j = arable land, Forest, Homestead, rangeland);

S_k = effect of k^{th} season (k = dry season, wet season);

LLU_{ij} = interaction between i^{th} land position and j^{th} land use practices;

LS_{ik} = interaction between i^{th} land position and k^{th} season;

LUS_{jk} = interaction between j^{th} land use practices and k^{th} season;

$LLUS_{ijkl}$ = interaction between i^{th} land position, j^{th} land use practices and k^{th} season;

E_{ijklm} = random error term.

6.3. Results

6.3.1. Summary for the visual rangeland degradation assessment

Increaser II species dominant at the valley bottom (54%) and foothills (49%) (χ^2 = 1059.28, df = 12, n = 1536, $p < 0.01$). Poor vegetation cover was more at valley bottom (65%), foothills (62%), and midslopes (59%) (χ^2 = 825.58, df = 9, n = 1536, $p < 0.01$). Pedestals were more frequent at the valley bottom (98%), foothills (100%), and midslopes (100%) (χ^2 = 78.26, df = 3, n = 256, $p < 0.01$). Severe pedestals (>30 cm) were at the valley bottom (63%) and foothills (53%) (χ^2 = 196.28, df = 12, n = 256, $p < 0.01$). Terracettes frequency was high at the valley bottom (83%) followed by foothills (69%) (χ^2 = 40. 47, df = 3, n = 256, $p < 0.01$). The terracette depth ranged between high (20 – 30 cm) (33%) and severe (>30 cm) (33%) (χ^2 = 121.36, df = 12, n = 256, $p < 0.01$) at the valley bottom. Rills were more frequent at the valley bottom (72%) and foothills (83%) (χ^2 = 74.95, df = 3, n = 256, $p < 0.01$). Severe rills (>30 cm depth) was observed at the valley bottom (48%) and foothills (44%) (χ^2 = 101.12, df = 9, n = 256, $p < 0.01$). The high frequency of gullies (75%) was at the valley bottom (χ^2 = 71.23, df = 3, n = 256, $p < 0.01$). The frequency of occurrence for solution notches (41%) (χ^2 = 10.35, df = 3, n = 256, $p < 0.05$), armour layer (51%) (χ^2 = 22. 0, df = 3, n = 256, $p < 0.01$) and sedimentation (86%) (χ^2 = 64.52, df = 3, n = 256, $p < 0.01$) was higher at the valley bottom.

Table 6.2: Summary for visual rangeland degradation indicators and their severity in Amakhuze Tribal Authority in Eastern Cape Province (details in chapter 5).

Degradation indicators	**Dominant herbaceous vegetation species categories along the landscape** [χ^2 = 1059.28, *df* = 12, *n* = 1536, *p* < 0.01]							
	Valley bottom		**Foothills**		**Midslope**		**Mountaintop**	
	Category	**%**	**Category**	**%**	**Category**	**%**	**Category**	**%**
Vegetation species	Inc II	54	Inc II	49	Inc III	52.9	Dec	54.4
	Indication of rangeland degradation by vegetation cover [χ^2 = 825.58, *df* = 9, *n* = 1536, *p* < 0.01]							
	Indication	**%**	**Indication**	**%**	**Indication**	**%**	**Indication**	**%**
Soil cover	High	65.1	High	62.5	High	59.1	Light	79.7
	Presence and extent of pedestals terracelets and rills [Frequency - χ^2 = 78.26, *df* = 3, *n* = 256, *p* < 0.01, and intensity - χ^2 = 196.28, *df* = 12, *n* = 256, *p* < 0.01]							
	Presence	**Extent**	**Presence**	**Extent**	**Presence**	**Extent**	**Presence**	**Extent**
Pedestals	98.4	+++++	100	+++++	100	+++	61	+ - +++
Terracettes	82.8	++++ - +++++	68.8	+++++	57.8	+	29.7	+
Rills	71.9	****	82.8	****	35.9	*	15.6	*
	Presence and percentage of occurrence of Gullies, solution notches, amour layer and sedimentation **[** Frequency - χ^2 = 40.47, *df* = 3, *n* = 256, *p* < 0.01, intensity - χ^2 =121.36, *df* = 12, *n* = 256, *p* < 0.01]							
	Presence	**%**	**Presence**	**%**	**Presence**	**%**	**Presence**	**%**
Gullies	#	75	#	46.9	#	21.9	#	7.8
Solution notches	#	40.6	#	29.7	#	25	#	15.6
Amour layer	#	51.6	#	34.4	#	15.6	#	48.4
Sedimentation	#	85	#	60.9	#	92.2	#	32.8

Inc II = Increaser II, Inc III = Increaser III, Dec = Decreaser, Pedestals and Terracelets [+ = 0 – 5 cm (negligible), ++ = 5 – 10 cm (light), +++ = 10 - 20 cm (moderate), ++++ = 20 – 30 cm (High), +++++ = > 30 cm (severe)], Rills [* = 0 – 5 cm (negligible), ** = 5 – 20 cm (light), *** = 20 – 30 cm (High), **** = > 30 cm(severe)], # = present

6.3.2. Livestock grazing distribution at different land position

The number of cattle (AU) was significantly positively related ($r^2 = 0.404$, $p < 0.001$) to the foothills and significantly negatively related ($r^2 = -1.00$, $p < 0.05$) to the midslopes. The relationship between cattle numbers and both mountaintop and valley bottom was not significant ($r^2 = 0.098$, $p > 0.05$). There was a significant negative relationship ($r^2 = -0.922$, $p < 0.001$) between sheep numbers and grazing areas at the foothills. There were no significant relationships between goats and foothills, midslopes, valley bottom, and mountaintop. The minimum, median, and maximum animal units for total livestock, cattle, sheep, and goats are displayed in Figure 6.1.

There was a significant negatively weak relationship ($r^2 = -0.004$, $p < 0.001$) between the interaction of foothills and herd length, and the cattle number. In addition, the relationship between cattle numbers and the interaction of mountaintop and herd length there was a weak, positive, but significant ($r^2 = 0.005$, $p < 0.01$).

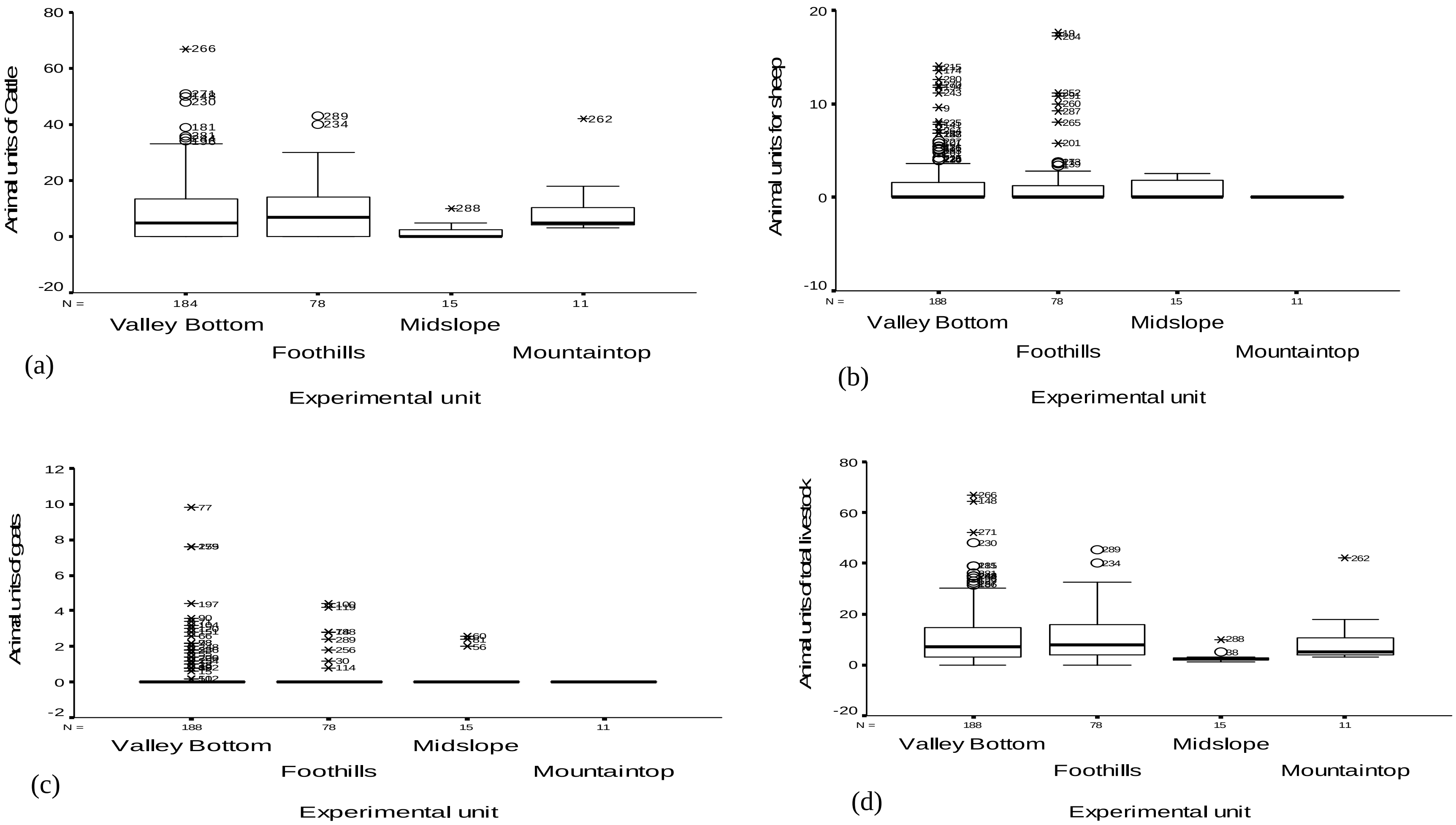

Figure 6.1: Livestock grazing distribution along different landform positions – Animal units for - (a) Cattle, (b) Sheep, (c) Goats, and (d) total livestock units.

6.3.3. Livestock grazing distribution between the different land use practices

There was a significant positive relationship ($r^2 = 0.62$, = $p < 0.001$) between grazing areas around the homesteads and the number of cattle (AU). Furthermore, there was a significant positive relationship ($r^2 = 0.20$, $p < 0.01$) between the number of cattle located at the rangelands compared to arable land. The relationship between cattle numbers and forestland was not significant ($r^2 = 0.24$, $p > 0.05$).

However, there was a significantly negative relationship ($r^2 = -0.48$, $p < 0.01$) between sheep and grazing areas around the homestead. Goats were higher in the forest than homestead, rangelands, and arable land; however, the relationship was not significant ($p < 0.05$). The homestead and rangelands had fewer goats than arable land. The minimum, median, and maximum distribution of cattle, sheep, and goats are demonstrated on Figure 6.2.

6.3.4. Relationship between livestock grazing distribution and altitude

There was a significantly negative relationship ($r^2 = -0.007$, $p < 0.001$) between the cattle and higher altitude (>850 m.a.s.l). Moreover, there was a weak but significant relationship ($r^2 = 0.000003$, $p < 0.001$) between cattle numbers and lower altitude range of 750 to 850 m.a.s.l. The relationship between sheep numbers and low elevation (750 m.a.s.l) was weak but significantly positive ($r^2 = 0.065$, $p < 0.001$). Whilst in contrast, the relationship between sheep and higher altitude (>850 m.a.s.l) was significantly negative ($r^2 = -0.037$, $p < 0.01$). There was no significant relationship ($p < 0.05$) between goats' numbers and altitude.

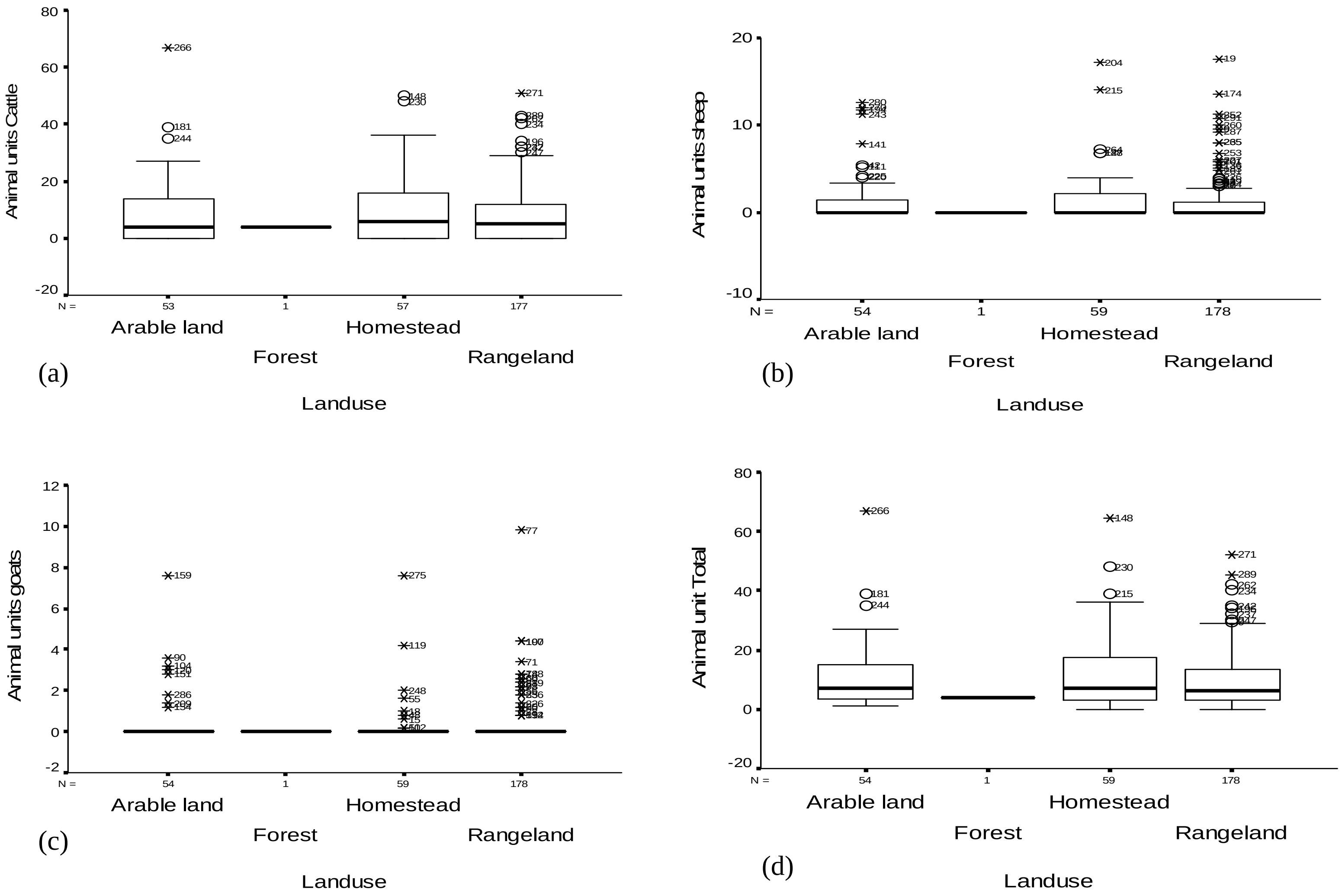

Figure 6.2: Livestock grazing distribution between different land use practices- (a) Cattle, (b) Sheep, (c) Goats and (d) total animal units.

6.3.5. Relationship between season and animal grazing distribution

The parameter estimate for the dry season was used as a base category for animal distribution between dry and wet season. There was a significantly positive relationship (r^2 = 0.322, $p < 0.001$) between cattle grazing distribution and wet season. There were no significant relationship between both sheep and goats numbers, and grazing season. Thus, during both dry and wet seasons the similar animal units were observed for sheep and goats (Figure 6.3).

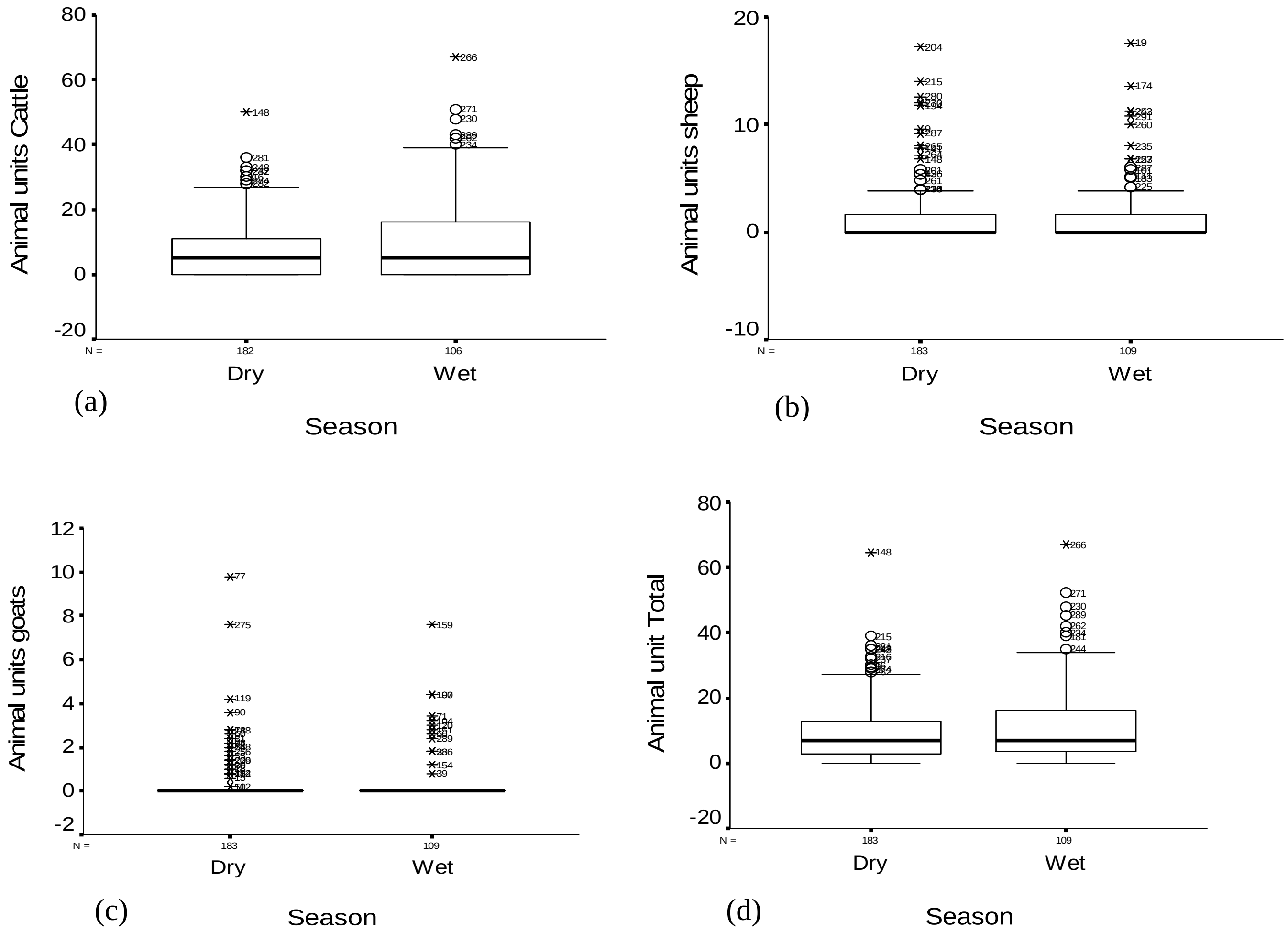

Figure 6.3: Livestock grazing distribution during dry and wet seasons – Animal units – (a) Cattle (b) Sheep (c) Goats and (d) Total animal units

6.3.6. Relationship between animal numbers, herd length and distance to water points

There was a significantly positive relationship (r^2 = 0.009, $p < 0.001$) between the number of cattle and herd length. The relationship between sheep and flock length was positive, but not significant (r^2 = 0.002, $p > 0.05$). Furthermore, the relationship between goat numbers and flock length was negative but not significant (r^2 = -0.002, $p > 0.05$).

The relationship between frequency of cattle and distance to drinking points was negative, weak and not significant (r^2 = -0.001, $p > 0.05$). There was a significant negative relationship (r^2 = -0.018, $p < 0.01$) between sheep and distance to drinking points. Furthermore, there was a significantly negative relationship (r^2 = -0.018, $p < 0.05$) between goats and drinking points (Figure 6.4).

The interaction between distance to water points and wet season was significantly negatively related (r^2 = -0.002, $p < 0.001$) with cattle numbers. However, interaction between elevation and distance from water points was positive but weak, nevertheless, significantly related (r^2 = 0.0000014, $p < 0.05$) to cattle frequency of occurrence. The interaction between elevation and distance from water points was weakly significantly related (r^2 = 0.000017, $p < 0.05$) to sheep numbers. The interaction between elevation and distance from water points was also significantly negatively related (r^2 = 0.000026, $p < 0.05$) to goats numbers.

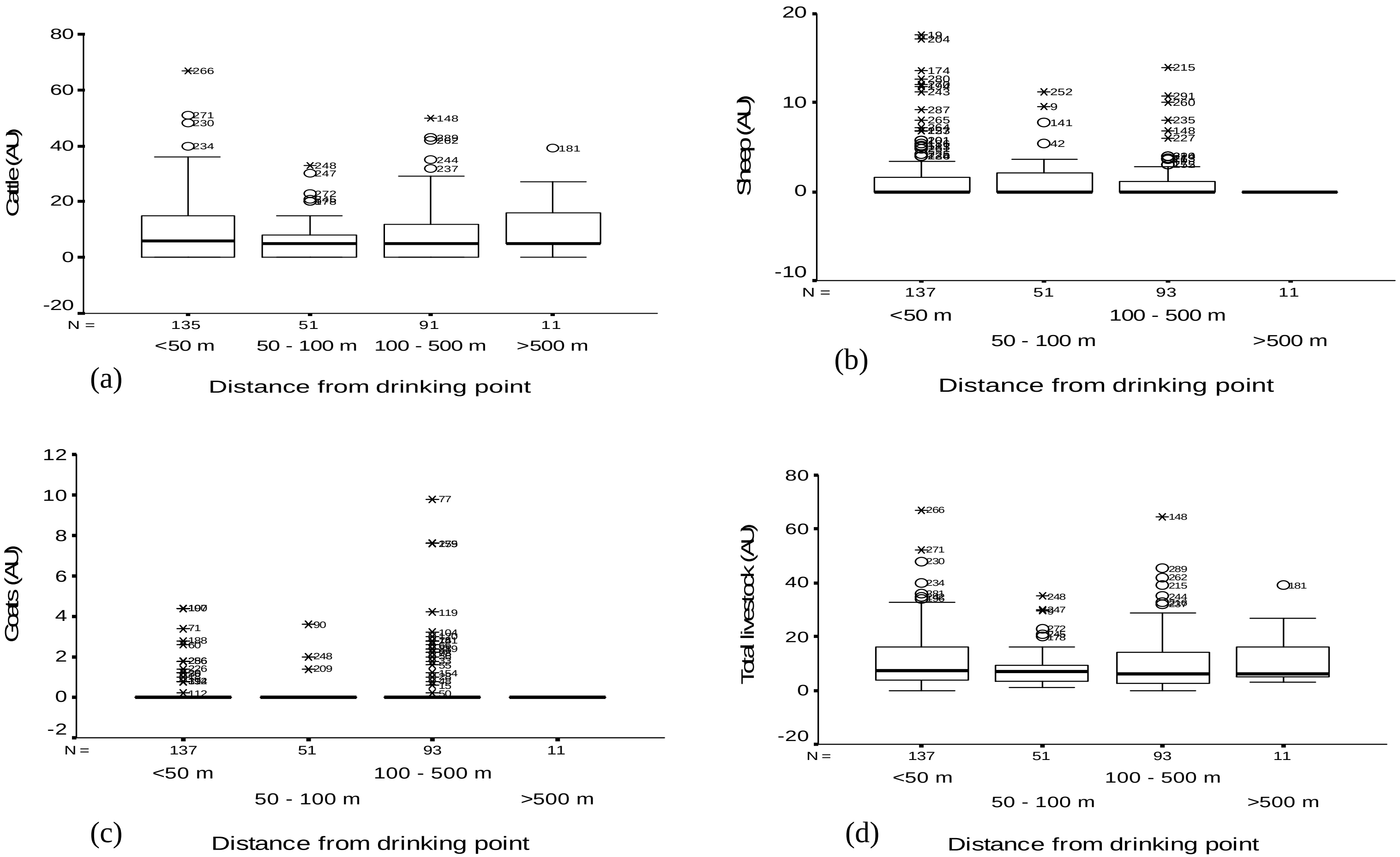

Figure 6.4: Livestock grazing distribution at different distances to drinking points- Animal units - (a) Cattle, (b) Sheep, (c) Goats and (d) Total livestock.

6.4. Discussion

6.4.1. Rangeland degradation and grazing distribution along the landscape gradient

Vegetation species dominance, vegetation cover, presence, and magnitude of pedestals, terracettes, rills, armour layers, sedimentation, and gullies on rangelands were used as early indicators for land degradation. The results of the visual rangeland degradation assessment indicate that rangelands located on the valley bottom and along the foothills were the most degraded compared to midslopes and mountaintop (crest). Rangeland degradation occurrence along the landscape gradient was used as the bases for grazing distribution pattern along the landscape gradient, thus grazing distribution was assessed along the valley bottom, foothills, midslopes and mountaintops. However, the detailed rangeland degradation assessment is discussed in chapter 5.4.1.

The number (animal units) of cattle was positively related to the foothills and negatively related to the midslopes. This indicates that cattle were grazing on the foothills more than on valley bottom, midslope, and mountaintop. This could be due to the lower forage availability at the valley bottom, which could be attributed to severe grazing related to easy access of animals and proximity to homesteads. This could also be because of the fact that the valley bottoms were already degraded as observed during visual degradation assessment. This is in agreement with Lesoli (2008) working at two communal areas of the Eastern Cape, South Africa, who suggested that the valley bottom was the most degraded because of its easy access to animals, proximity to homesteads and location of drinking points for animals. The hypothetical picture of grazing distribution patterns and degradation trend along the landscape is demonstrated in Figure 6.5.

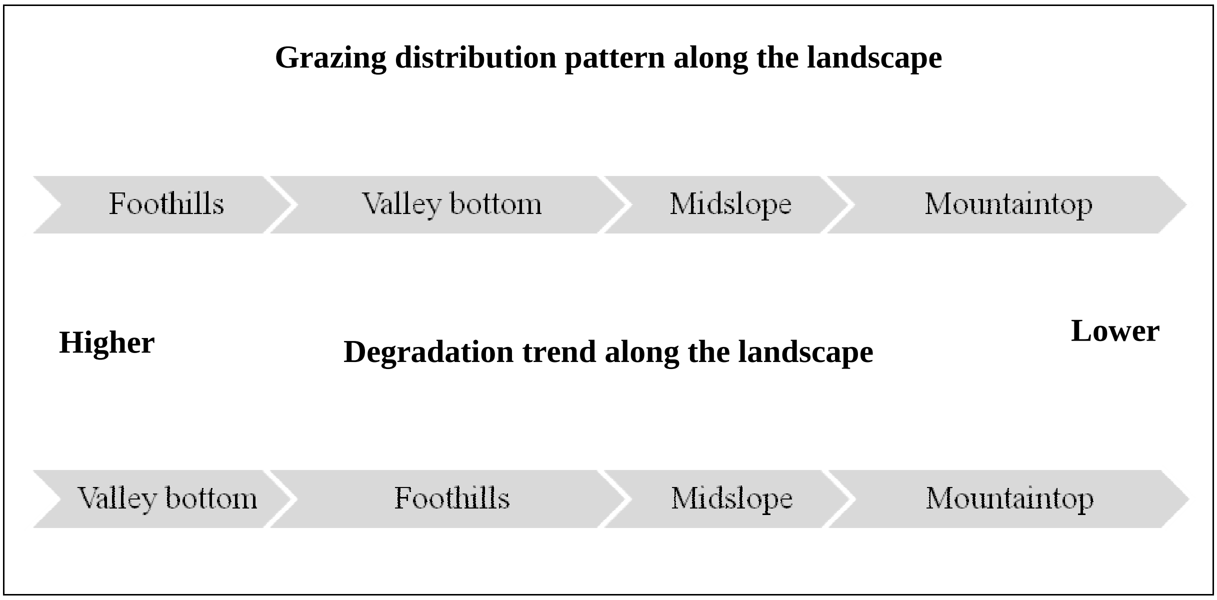

Figure 6.5: Hypothetical picture depicting cattle grazing distribution and degradation trends along the land position gradient at Amakhuze Tribal Authority.

The fact that animals were found in small numbers and frequencies on the midslopes and mountaintops than on the reference location (valley bottom) and foothills could be attributed to the terrain morphology. The midslopes were very steep and not easily accessible to animals, steepness of the slope is likely a driver for cattle grazing preference within the rangelands. The results are in agreement with Belsky and Blumenthal (1997) who indicated that cattle typically graze areas with more gentle terrain than rugged terrain.

The fact that cattle distribution was not related to the grazing areas on mountaintop could be due to difficulty in accessing these rangelands, which could be assigned to distance and altitude from valley bottom and homesteads. The grazing concentration was higher at the valley bottom and foothills, which have resulted in an uneven degradation distribution and extent within the rangelands. Bailey (2004) pointed out that many concerns about rangeland degradation related with livestock grazing in arid rangelands are because of uneven grazing distribution. Livestock grazing distribution along the land position could explain the reasons why certain parts of rangelands are more degraded than other areas. Pinchak *et al*. (1991)

supported this, thus, they indicated that physiographically diverse rangelands have areas of over utilisation adjacent to the areas with under utilisation. This was attributed to negative interaction between slope steepness and distance to water, which promotes over concentration of use on areas adjacent to water sources.

The fact that the relationship between sheep and foothills, midslope, and mountaintop compared to valley bottom was negative indicates that sheep grazed more on the valley bottom than on other parts of the rangelands. This could be attributed to the fact that sheep are selective grazers and therefore, because of heterogeneity of the landscape at Amakhuze Tribal Authority, they have selected to graze on the valley bottom because they were easily accessible compared to the foothills, midslopes and mountaintop. Senft *et al*. (1995) supported the impression that animals exhibit area selection characteristics when grazing. They have pointed out that on the rangelands that consist of a mixture of uplands and lowlands, lowlands are generally 5 to 30 m lower and are grazed approximately three times more intensely, than associated uplands due to easy access by animals. The grazing distribution of sheep that was characterised by higher grazing intensity at the valley bottom could explain the reason why low-lying areas of rangelands were more degraded than higher laying areas. The conception that sheep grazed more on the valley bottom than foothills, midslopes, and mountaintop, could be assigned to the fact that sheep were kraaled during the night and released in the morning. That could have had an impact on time for movement and selection of grazing areas within the rangelands.

The fact that there was a negative relationship between herd size and the interaction of foothills and herd length could indicate that, on foothills as the herd size increases the herd length decreases. This implies that on the foothills, there were few cattle per herd and they were more scattered in the bigger grazing areas. This further indicates that animal units per unit area for cattle were smaller in the foothills. This could be attributed to the sparseness of vegetation caused by overgrazing, which result in poor forage availability on the foothills.

The herd length of cattle grazing at the mountaintop increases as the animal grazing density increases. This proposes that as the animals were grazing on the mountaintop, they aggregate at one grazing patch, which increases the herd sizes and lengths. This could be attributed to the heterogeneity of grazing areas, where certain parts of the grazing areas could be more nutritious than other parts. Animals aggregate together on the areas with more nutritious forage and scatter on the grazing areas with low nutrition. This implies that at Amakhuze Tribal Authority, the herd structure (herd size and length) varied with the landscape at which animals were grazing and that have resulted in varying impacts of animals on vegetation at different landscapes. The negative effects of grazing on vegetation could be due to higher intensity of defoliation and trampling. These could be manifested as the change of species composition and could be dependent on grazing intensity and distribution within the landscape. The fact that effects of grazing are dependent on grazing intensity and distribution, and that they are manifested by the change in vegetation species composition, poor vegetation cover and low biomass production was supported by (Belsky and Blumenthal 1997).

The fact that there was a positive relationship between herd size and area occupied by animals indicates that as the number of animals increases the area occupied increases. This implies that the number of animals per herd (herd size) determines their distribution per unit area, which in turn, determines grazing intensity. Shiyomi (1995), who indicated that the number of animals per herd per unit area (AU/herd/area) determines grazing intensity, affirmed this.

6.4.2. Relationship between animal grazing distribution and land use

The fact that there was a positive relationship between cattle herd size and grazing areas around the homesteads indicates that there were more animals (cattle) around the homesteads than on the reference variable (arable land). The positive relationship between cattle and grazing areas around the homesteads and grassland vegetation types could be attributed to the fact that cattle are grazers and prefer areas with grass than other types of vegetation. The implication on the relationship between cattle herd size and grazing areas close to homesteads and grassland vegetation type is that grazing intensities were higher at grazing areas around homestead and grassland vegetation as the herd size determines grazing intensity (Shiyomi 1995; Belsky and Blumenthal 1997). As the grazing intensity increases due to lager herd sizes, the area becomes susceptible to rangeland degradation. The negative effects of grazing drive changes in successional pathways or lead to degradation of rangelands (Pastor and Cohen 1997; Person *et al*. 2003), these negative effects determine rangeland dynamics and are due to population densities of grazing animals and intensity of their foraging (Kieland *et al*. 1997; Pastor and Cohen 1997; Olff and Ritchie 1998; Stewart *et al*. 2006).

This relationship could further be associated to the farmers' perceptions as discussed in chapter 4, thus, areas that were more degraded were grazing areas at the closer proximity to homesteads and grassland vegetation. The results indicate that cattle preferred grazing areas around homesteads, rangelands, and forestland than arable land. This could be due to the difference in vegetation species composition between the land uses and the fact that the arable lands were only open (officially) for part of the year. Furthermore, most of the arable lands at Amakhuze Tribal Authority were abandoned and most were occupied by grassy vegetation and therefore, used for grazing. The abandoned arable lands were disturbed through ploughing before and therefore, were at the secondary succession of vegetation community development. Most of the grass species within this land use practice are annual grasses and increaser II species which are less preferred by animals especially cattle. Tainton and Hardy (1999) indicated that vegetation on abandoned cultivated lands passes through a succession of plant communities usually starting with broad-leaved weeds and annual grasses.

The conception that sheep were grazing on the abandoned arable land than other land use practices could be attributed to vegetation composition on the abandoned arable land, which includes the forbs and short grasses that are preferred by sheep (Bennett *et al*. 2007).

6.4.3. Animal grazing distribution along the altitude

The positive relationship between the lower lying parts of the rangelands and cattle herd sizes, and a negative relationship between cattle numbers and higher altitude indicates that cattle preferred low-lying grazing areas. This could be attributed to the fact that energy requirement and use by animals in accessing certain parts of rangelands varies with the distance and the terrain at which animals walk. Thus, vegetation located at distant and rough terrain may not be accessible, animals would incur energetic costs for travel to other rangeland sites for grazing, and that result in reduced movement and in turn leads to high concentration of animals on easily accessible sites (Bailey *et al*. 1996). The balance between energy requirement, energy gained from grazing, and energy spent to get to the rangelands is important and can influence animal movement within the rangelands. Walking on rough terrain is about 10 times as costly in energy as walking on horizontal plane, and thus the animal grazing a hill rangeland expends more energy walking to find the herbage in addition to other muscular activities (Osuji 1974).

The positive relationship between cattle and low-lying grazing areas could further be attributed to the difficulty of cattle movement to access the rangelands at the higher altitude because of the terrain steepness between lower lying areas and high-lying areas. Bailey *et al*. (1996) further support the fact that slope gradient is an important determinant of grazing distribution of large herbivores. Animals recognise changes in slope and use that information to remain on contours or to minimise changes in elevation while grazing. Several large herbivores such as cattle generally avoid grazing slopes over 10% (Bailey *et al*. 1996). This in turn exposes low-lying parts of rangeland to severe grazing and result in an uneven distribution of rangeland degradation. Senft *et al*. (1985) alluded to the fact that the low-lying areas within the rangelands are easily accessible to animals for grazing and are grazed more severely than less accessible high-lying areas and that subject low lying grazing areas to rangeland degradation.

The positive relationship between sheep and low altitude, and negative between sheep and high altitude indicate that sheep were grazing at the lower altitude. This could be attributed to kraaling, which could have provided a lesser time for movement for sheep since they were kraaled at night and released in the morning. This could also be ascribed to the grazing behaviour of sheep; sheep grazing habits have been reported to be gregarious which makes them graze together, and within the same area for a longer time that limits grazing movement. Social factors, such as the development of a home or territorial area can inhibit movement of sheep on large rangeland areas. Sheep normally spend more time-consuming food and ruminating and little time in searching for food, therefore, that would limit movement.

6.4.4. Grazing distribution of animals during dry and wet seasons

The fact that there was a positive relationship between cattle and the wet season indicates that there were more animals per herd observed grazing within the grazing during wet season than dry season. This implies that cattle at Amakhuze Tribal Authority were aggregated during wet season and become scattered during dry season, hence the numbers per herd increased during wet season compared to dry season. The aggregation and disaggregation of cattle between seasons could be due to opportunistic movement that occurs in response to seasonal fluctuations in quantity and quality of available forage. This was in agreement with Scoones (1992), and Turner and Hienaux (2002) who indicated that opportunistic cattle movements may occur over extensive areas and often in response to seasonal fluctuations in the quantity and quality of available forage, or drought episodes. It could therefore, be inferred that higher grazing intensity in communal grazing areas was observed during the wet season, thus, there were large herds within smaller distances during wet season compared to dry season where there were numerous small herds scattered. During the wet season, grasses are actively growing, and the negative effect of grazing would be higher compared with the dry period during which grasses are dormant. Therefore, if the grazing intensity is high during growing period the vegetation species composition, basal cover, and plant vigour will be affected and the area becomes vulnerable to soil erosion.

The fact that sheep and goat distribution within the rangelands did not vary with seasonal changes could be because smallstock do not have the same seasonal movement as cattle and so numbers were more constant around homestead through the year. Sheep are normally habituated to a home range, within which they forage for herbage throughout the year (Ashworth *et al*. 2000).

6.4.5. Relationship between animal grazing location and distance to drinking points

The negative relationship between both sheep and goats, and the distance to drinking points indicates that sheep and goats were mostly grazing at the areas closer to drinking points and therefore their grazing distribution was affected by distribution of water within the rangelands. This could be credited to the fact that sheep and goats have higher water dependency and have smaller home ranges than cattle. This suggests that grazing areas were not grazed evenly because of water distribution within the rangeland, which could be related to rangeland degradation at certain parts than others. This is in agreement with Pickup and Chewings (1988) who indicated that animals use landscapes unevenly, with respect to distance to water points. Thus, any efforts to characterise and/or combat rangeland degradation in the communal areas should consider rangeland water distribution.

The negative relationship between the interaction of drinking points and the wet season, and herd sizes indicates that the herd sizes became smaller with more water available on rangelands during wet season. This could be attributed to the availability and distribution of drinking points because of higher rainfall during this season. Thus, because of an ample amount and distribution of drinking water within the rangelands the herd sizes for cattle were smaller but often with shorter distance between the herds. This implies that during the wet season cattle aggregate in several small herds compared to fewer large herds during the dry season.

This relationship further indicates that cattle's water dependency is associated with season. It implies that cattle are grazing close to water points during wet season because water is distributed throughout the rangelands; however, they will be grazing further away from designated water points. During the wet season, water requirements for cattle are lower compared to their requirement during dry season. The results are consistent with the work of Western (1975) and Owen-Smith (1999) who indicated that water dependency influences the distance that animals will move from water points during dry season.

The positive relationship between herd/flock sizes and the interaction of elevation and distance from water indicates that the two factors were not independent of each other and therefore, the relative influence of each factor on animal distribution cannot be determined. Thus, it is impossible to know if the greater abundance of animals closer to water is due to them trying to minimise how far they walk or them trying to avoid steeper slopes. This implies that as the altitude at which the animals are grazing is increasing the distance to water points becomes shorter, thus animals graze closer to the water points. The animals grazing at higher altitude were more aggregated, thus there were many animals per herd/flock, and the herds/flocks were closer to water points. Bailey *et al*. (1996) also highlighted the interaction between both water points and high altitudes with steep terrains and their relationship with animal grazing. They indicated that grazing sites located far from water and on steep slopes are less preferred by herbivores even though they may have abundant forage.

In the rangelands with heterogeneous topography such as the Amakhuze Tribal Authority, as the altitude at which animals are grazing increases, grazing areas adjacent to drinking points are more utilised than areas far away from drinking points. At Amakhuze Tribal Authority, the water points at higher altitude (midslope and mountaintop) are located further apart from each other unlike at the foothills and valley bottom. The fact that areas near water points are more utilised could be ascribed to the unevenness of water distribution within the grazing areas due the heterogeneity of topography. The perception of uneven grazing distribution due to uneven water distribution is in agreement with Pinchak *et al*. (1991), they highlighted that the diverse rangelands have areas of over utilisation adjacent to areas with under utilisation. This was attributed to the negative interaction between slope and distance to water, which promotes over concentration of use on areas adjacent to water sources.

6.6. Conclusions

Grazing distribution pattern in communal areas at Amakhuze Tribal Authority was affected by landscape, vegetation type, land use practices, seasonal climatic changes and grazing distance from drinking points. Grazing intensity was not distributed evenly, thus low-lying grassland around homesteads at the close proximity to water points were grazed intensely during wet season. The low-lying areas were more degraded compared to the high-lying grazing areas. The varying degree of degradation between landscapes, vegetation types, land uses, and distance to drinking points suggests that areas subjected to higher grazing intensity were susceptible to rangeland degradation.

In conclusion, grazing distribution pattern in communal areas is affected by spatial and temporal factors. Spatial factors include landscape and altitude variation, land use practices, vegetation types, and distribution of water bodies. Temporal factors on the other hand include seasonal variations, which are responsible for change in rainfall and temperature. Rangelands that are spatially and temporally heterogeneous are subject to uneven grazing distribution pattern, thus, some areas are intensely utilised than their adjacent areas. That leads to degradation of proffered grazing patches. To minimise rangeland degradation in the communal areas there is a need develop a grazing plan, and such a plan should consider the factors such as landscape, vegetation types, land use practices, distribution to water points and seasons.

7. EVALUATION OF RANGELAND RESTORATION TECHNIQUES IN THE COMMUNAL GRAZING AREAS OF EASTERN CAPE

7.1. Introduction

Communal rangelands are used primarily as a source of feed for livestock; and for other secondary resources such firewood, wild foods, medicinal plants and water. Land degradation is the major challenge in the communal rangelands of Eastern Cape (Palmer *et al*. 1997), because it reduces rangeland primary productivity and soil protection. Rangeland degradation results in declining functional capacity, increased poverty, and food insecurity. Major changes in rangeland surface morphology and soil characteristics have a drastic effect on the primary productivity of the rangeland ecosystem and in turn, on livestock production. The fact that primary productivity and livestock production are affected by rangeland degradation translates to the negative impact of degradation on economic and ecological position of communal rangelands. The negative effect of degradation on economic and ecological status of rangeland suggests a need for interventions to halt land degradation and improve the functional capacity of communal rangelands.

There are a large number of conceptual models that have been developed by restoration ecologists to describe how ecosystem structure and functioning are related (Cortina *et al*. 2006). Bradshaw (1984) developed the model for the reclamation of derelict land, which later was termed linear structure and function model (LSF). This model assumes a linear increase in ecosystem function with an increase in complexity of its structure (Cortina *et al*. 2006). In the context of rangeland degradation and restoration, the relevance of LSF model is underlined by an assumption that rangeland degradation interferes with ecosystem structure and in turn linearly affects ecosystem functions both in terms of primary and secondary production.

The linear relationship between ecosystem structure and function suggests that ecosystem degradation and restorability are directly related. In the context of the LSF model, rangeland ecosystem structure can be any description of rangeland community composition, and the way organisms within are organised and function. According to the LSF model, restoration is defined as the simultaneous increase in structure and function promoted by human intervention, paralleling changes occurring during secondary succession. Restoration is therefore, commonly considered as an accelerated secondary succession. Management of land degradation can be divided into preventative and restorative measures. Answers to preventative measures can often be found within the causes of land degradation. In view of the massive scale of land degradation that has already occurred in parts of southern Africa's communal rangelands, restoration is of significant importance to land owners.

To evaluate water collection and storage effects of restoration techniques on performance of introduced plant propagules on degraded rangelands. The null hypothesis was that rangeland restoration is not dependent upon water availability in the soil and therefore, could not be improved by restoration techniques that promote collection and retention of water and introduction of plant propagules. This hypothesis is based on the conception that, there are barriers to vegetation natural recovery or artificial restoration success. These barriers include low soil moisture content, low soil temperature, poor sunlight-leaf interception, low soil seedbank, and high grazing pressure (disturbance). Therefore, restoration techniques should aim at addressing these natural vegetation recovery barriers.

Development of microcatchments and use of brushpacks would improve soil moisture storage. That is through collection of runoff water and reduction of soil moisture loss. These are achieved through improved infiltration rates resulting from digging and reduced evaporative loss by shading effect of brushpack. Introduction of plant propagules (seeds and seedlings) would address the low soil seedbank barrier. The higher water collection and retention levels promote germination of seeds, establishment, and growth of seedlings. Furthermore, use of water collection and retention practices such as water spreading systems, use of brushpack, and microcatchment where the plant propagules are not introduced could support germination from the seedbank and regrowth from the remaining tufts.

7.2. Materials and Methods

7.2.1. Description of study area

The study evaluating restoration techniques was conducted at Amakhuze Tribal Authority. The detailed description of Amakhuze Tribal Authority is provided in chapter three.

7.2.2. Experimental layout

7.2.2.1. Vegetation restoration techniques on degraded rangelands

Although in chapter 5 it has been reported that communal rangelands were observed to have been degraded, the level of degradation varied with different sites within rangelands and as such, there were patches, which were visually observed to have been not degraded. Therefore, to minimise an introduction of species foreign to the ecosystem (Amakhuze Tribal Authority) and promoting local grass ecotypes, thus grasses that were found present in the ecosystem, *Themeda triandra,* and *Paspalum dilatatum,* were collected from the sites that were considered not degraded within the tribal authority. It is important to remark that *Paspalum dilatatum* is a foreign grass species introduced from South America, however, it was found present in communal rangeland. The grasses were separated into single tillers and propagated in the nursery with growing medium (Hygromix and pine buck with the 1: 2 ratio) for four weeks at Fort Cox College of Agriculture and Forestry. After four weeks, the grass seedlings were taken to the field for transplanting.

The grass seeds of *Panicum maximum, Digitaria eriantha* and *Eragrostis curvula* were purchased from commercial seed producers (South African ecotypes). A degraded site (100 m x 100 m) was selected based on the visual degradation indicators present; the indicators include presence of gullies, rills, pedestals, armour layer, solution notches, plant root exposures, and sediment accumulation. Twenty-six plots of (30 m x 10.25 m) each were identified, laid and marked with 60 cm wooden pegs. The spot planting technique was applied in all the plots in which seeds and/or seedlings were used to restore vegetation. The original vegetation was not cleared; rather vegetation was introduced on bare patches. The grass seeds were planted according to the producers recommendations for specific grass species.

Restoration treatments were based on the performance of grass seeds and seedlings of different grass species. This was conducted under different microsite development, which included the use of brushpack to reduce soil moisture loss through evaporation and raindrop soil detachment impact. Development of microcatchments was used to collect and store runoff water and make it available for use by the plants. Brushpack refers to the pack or pile of tree or shrub branches to provide vegetation cover on a specific area of land in order to reduce direct raindrop impact and sun heat and in turn to reduce the rate of soil moisture loss through evaporation.

Acacia karroo was selected as a brush material because it has been reported to be a problem in encroaching grazing areas and therefore, its use as brush material could be justified, furthermore, it was the most abundant woody species within the rangelands. The seedless branches of *Acacia karroo* brush material were selected in order to avoid transportation seeds to the restoration areas. Minimum soil disturbance was done for preparation of a seedbed for planting of grass seeds with and without brushpack. There were eleven treatment plots for vegetation restoration, twelve treatment plots for estimation of water collection and retention, and a control. Each treatment was replicated twice giving 26 plots in total.

7.2.2.1.1. Vegetation restoration with grass seedlings under different microsites

Treatment 1: Microcatchment/brushpack/ *Paspalum dilatatum*

Twelve arch or semicircle shaped microcatchments were dug in each plot (Hanke *et al*. 2011). The diameter of each microcatchment was 2 m and tapered to a depth of 10-cm. Existing vegetation and rocks were not removed to minimise soil disturbance. The microcatchments were aligned with slope, and placement of microcatchments was alternated with those in adjacent rows to ensure maximum trapping of runoff water. *Paspalum dilatatum* seedlings were transplanted in each microcatchment at the depth of 2 mm. Each seedling had a single tiller with three to four leaves during transplanting. *Acacia karroo* branches were spread evenly over at least 70 – 75% of soil surface on each microcatchment. The branches were packed in a 200 mm thick layer.

Treatment 2: Microcatchment/brushpack/*Themeda triandra*

Twelve arch or semicircle shaped microcatchments were dug in each plot. The diameter of each microcatchment was 2 m and tapered to a depth of 10-cm. Existing vegetation and rocks were not removed to minimise soil disturbance and retain existing vegetation. The microcatchments were aligned with slope, and placement of microcatchments was alternating with those in adjacent rows to ensure maximum trapping of runoff water. *Themeda triandra* seedlings were transplanted in each microcatchment at the depth of 2 mm. Each seedling had a single tiller with three to four leaves during transplanting. *Acacia karroo* branches were spread evenly over at least 70 – 75% of soil surface on each microcatchment. The branches were packed in a 200 mm thick layer.

Treatment 3: Microcatchment/*Paspalum dilatatum*

Twelve arch or semicircle shaped microcatchments were dug in each plot. The diameter of each microcatchment was 2 m and tapered to a depth of 10-cm. Existing vegetation and rocks were not removed to minimise soil disturbance and retain existing vegetation. The microcatchments were aligned with slope and their placement was in an alternating order with those in adjacent rows to ensure maximum trapping of runoff water. *Paspalum dilatatum* seedlings were transplanted in each microcatchment at the depth of 2 mm.

Treatment 4: Microcatchment/*Themeda triandra*

Twelve arch or semicircle shaped microcatchments were dug in each plot. The diameter of each microcatchment was 2 m and tapered to a depth of 10-cm. Existing vegetation and rocks were not removed to minimise disturbance and to retain existing vegetation. Microcatchments were aligned with slope and their placement was alternating with those in adjacent rows to ensure maximum trapping of runoff water and accumulation of sediment. *Themeda triandra* seedlings were planted in each microcatchment at the depth of 2 mm.

7.2.2.1.2. Vegetation restoration with grass seeds under different microsites

Treatment 5: Brushpack/minimum soil disturbance/*Panicum maximum*

Twelve subplots (4 m^2) were selected on the bare patches of each plot. In each subplot, minimal soil disturbance was done by breaking soil surface to a depth of 20 mm and *Panicum maximum* seeds were spread and lightly covered with soil. *Acacia karroo* branches were spread evenly over at least 70 – 75% of soil surface on each sub-plot. The branches were packed in a 200 mm thick layer.

Treatment 6: Minimum soil disturbance/Eragrostis curvula

Soil surface was broken to the depth of 20 mm at the bare patches within the plot and the seeds of *Eragrostis curvula* were spread and covered with the soil.

Treatment 7: Minimum soil disturbance/*Panicum maximum*

Soil surface was broken to the depth of 20 mm at the bare patches within the plot and the seeds of *Panicum maximum* were spread and covered with the soil.

Treatment 8: Microcatchment/brushpack/*Digitaria eriantha*

Twelve arch or semicircle shaped microcatchments were dug in each plot. The diameter of each microcatchment was 2 m and tapered to a depth of 10-cm. Existing vegetation and rocks were not removed. The microcatchments were aligned across the slope and their placement within each plot was in an alternating order with those in adjacent rows to ensure maximum trapping of runoff water. *Digitaria eriantha* seeds were planted in each microcatchment at the depth of 2 mm. *Acacia karroo* branches were spread evenly over at least 70 – 75% of soil surface on each microcatchment. The branches were packed in a 200 mm thick layer.

Treatment 9: Microcatchment/brushpack/*Panicum maximum*

Twelve arch or semicircle shaped microcatchments were dug in each plot. The diameter of each microcatchment was 2 m and tapered to a depth of 10-cm. Existing vegetation and rocks were not removed to minimise soil disturbance and retain existing vegetation. The microcatchments were aligned across the slope, and their placement within the plot was in an alternating order with those in adjacent rows to ensure maximum trapping of runoff water. *Panicum maximum* seeds were planted in each microcatchment at the depth of 2 mm. *Acacia* *karroo* branches were spread evenly over at least 70 – 75% of soil surface on each microcatchment. The branches were packed in a 200 mm thick layer.

Treatment 10: Microcatchment/*Eragrostis curvula*

Twelve arch or semicircle shaped microcatchments were dug in each plot. The diameter of each microcatchment was 2 m and tapered to a depth of 10-cm. Existing vegetation and rocks were not removed to minimise soil disturbance and to retain existing vegetation. The microcatchments were aligned across the slope, and their placement within the plot was in an alternating order with those in adjacent rows to ensure maximum trapping of runoff water. *Eragrostis curvula* seeds were planted in each microcatchment at the depth of 2 mm.

7.2.2.2. Water collection and retention techniques on degraded rangelands

The following treatments together with all the treatments mentioned above were used for estimation of a vegetation restoration's ability to collect and store rainwater.

Treatment number 11: Brushpack (BP)

Brush packing was done by covering the soil surface with tree branches. This treatment on exposed soil simulates the protective effect of plant cover. Twelve brushpack sub-plots (4 m^2) were established in each plot. The brush was composed of branches of *Acacia karroo* tree collected at the areas that were heavily encroached, great consideration was taken to select the trees and branches that have no seedpods to minimise immigration of *Acacia karroo* into the restoration areas. The branches were spread evenly over at least 70 – 75% of soil surface on each sub-plot. The branches were packed in a 200 mm thick layer.

Treatment 12: Water spreading system

A network of diversion/conversion furrows was developed within each plot across the slope terrain. The minimum of twelve diversion/conversion furrows with 15 cm depth and varying from 5 to 10 cm length, with the distance between the furrows maintained to 150 cm. The furrows were curved, and the curved section lied in the downstream direction of water flow and helps to dam run-off water. The general outline of the furrows was such that they converge towards each other or diverge away from each other to spread rangeland water across the plot. The spillways were allowed at one or both ends of the furrow into the adjacent furrows to allow movement of water in case the furrow becomes full and that would prevent water from opening the outlet anywhere.

Using diversion/conversion furrows involves making furrows for water collection across the soil surface for rangeland restoration. This vegetation restoration technique results into number of effects on rangeland water movement, soil deposition and vegetation development. Such effects includes: (i) furrows break through impervious soil capping and collects runoff water during rainstorms resulting in infiltration rather than runoff; (ii) the cumulative and erosive runoff on degraded rangeland can be slowed down, and much of it held back, by means of an extensive network of furrows; (iii) Silt and organic material transported by runoff water collects in the furrows and retained; (iv) Windblown seeds, humus, animal droppings and dry plant material also collect in the furrows, after rains, seeds germinate in the moist soil within the furrows and they are protected as they grow, by accumulated plant debris; (v) A network of diversion/conversion furrows covering a degraded area results in numerous protected plant establishment sites helping to transform and improve the soil moisture and microclimate. Effective restoration becomes possible under the more favourable microclimatic conditions in the furrows.

Treatment 13: Control

The control plot was identified and marked; soil and vegetation were left as found throughout the study period.

7.2.2.3. Soil seedbank status on degraded communal rangelands

A soil seed-bank test was conducted to determine the availability and density of seeds between degraded (Amakhuze Tribal Authority) and non-degraded sites (Phandulwazi Agricultural School). This was done in order to estimate the possibility of germination of vegetation if disturbance is minimised. The assumption is that if the soil seed-bank is high, then the problem of poor vegetation in degraded rangelands is not the availability or density of seeds but other barriers of natural recovery. Five sites (100m x 100 m each) were selected at Amakhuze Tribal Authority (ATA) (degraded) and at Phandulwazi Agricultural High School (non-degraded). At each site three line transects (100 m) were selected randomly. Along each transect, three surface soil samples were collected randomly.

The soil samples were collected at the depth of 3 cm, on a 0.25 m^2 area. The total soil seed-bank samples were 45 cores for degraded sites and 45 cores for non-degraded sites. The samples were placed in plastic bags for immediate transportation to the green house for germination. Soil seedbank samples were collected at the end of the growing season (September-October) after seed production (Solomon *et al*. 2006). This can serve as an indication of viable seeds not germinated in the field during the season. However, this does not leave out the fact that some seeds might be viable but dormant hence they would not germinate.

In the green house, labelled plastic pots with 21 cm depth and 24 cm diameter were filled with pine buck (growing media) to the depth of 17 cm. Plant roots and fragments were removed from the soil samples, the soil within each sample was mixed thoroughly. Soil samples were spread over the pine buck in each plastic pot to a depth of 2 cm. The pots were placed at random in the greenhouse. The temperature in the greenhouse was kept between 19 and 22 ^{o}C during the day and 10 and 12 ^{o}C during the night throughout the experimental period of eight weeks.

7.2.3. Data collection

7.2.3.1. Rangeland restoration with grass seedlings under different microsites

Twelve sub-plots (1 x 1m) were established in both brushpack plots, microcatchments, and other combinations. Ten seedlings were planted at 12 cm inter and intra-line spacing in each sub-pot. Six permanent tufts were selected and survival rate was measured by counting available plants. Tillers, leaves, and inflorescences were counted to estimate growth performance of seedlings at an interval of 4 weeks for 16 weeks. Other plant species that geminated were also counted to further estimate availability of seeds in the soil.

7.2.3.2. Rangeland restoration with grass seeds under different microsites

Restoration performance of grasses that were established with seeds under different microsites was estimated through measuring germination rate, plant population density, and biomass production. The measurements were estimated within a quadrat (30 x 30 cm), the quadrat was placed on 6 randomly selected microcatchments/sub-plots in each plot. Germination rate was measured on the 8th and 16th day from planting. Plant population density and biomass accumulation data were collected at the 16th week. Biomass production data were collected by cutting the grass in each quadrat to a height of 3 cm, the fresh weight of grass samples was taken, and the samples were oven dried for 48 hours at 60^{o}C. Germination rate and plant density were expressed as number of plants germinated/present per unit area (900 cm^2). Biomass production was expressed as dry matter weight per unit area.

7.2.3.3. Soil moisture retention improvement on degraded rangelands

Soil samples were collected at six brushpack sub-plots per plot and from six diversion/conversion furrows from each diversion/conversion furrow treatment plot. Furthermore, from all the restoration plots, six soil samples were collected at six fixed points per plot at an interval of two weeks for 16 weeks. The total of 156 soil samples was collected from six subplots within each of the 26 plots after every two weeks. The soil samples were collected with a calibrated soil probe to the depth of 30 cm. The moisture content was measured gravimetrically in the same day of collection.

7.2.3.4. Soil seedbank test on degraded communal rangelands

The soil seedbank experiment ran for six weeks (48 days), the seedlings were counted in all the pots on the 8^{th}, 16^{th}, 24^{th}, 32^{nd}, 40^{th}, and 48^{th} days.

7.2.4. Data analysis

7.2.4.1. Restoration practices using grass seedlings

The data were subjected to the normality test before analysis. Grass seedling establishment and growth performance were measured in terms of tillering, leaf production, mortality rates, flowering, presence of other species and tuft diameter. These variables were compared between the observation periods at 4-week interval for 16 weeks. One way - Analysis of variance (ANOVA) with SPSS (1999) was used to compare the difference between the observation intervals in order to estimate growth performance trends.

The effects of brushpack and microcatchment treatment on grass seedling establishment and growth were also measured with tillering, leaf production rate, mortality rate, flowering rate, presence of other plant species and tuft diameter. These variables were compared between two treatments thus, microcatchment with grass seedlings (MCGS), and microcatchment with brushpack and grass seedlings (MCBPGS). The similar variables (tillering, leaf production rate, mortality rate, flowering rate, presence of other plant species and tuft diameter) were compared between grass species (*T. triandra* and *P. dilatatum*).

The differences between restoration treatments and between grass species were determined with the analysis of variance (ANOVA) with SPSS (1999). The differences between means were separated with multiple comparisons analysed with least significant difference (LSD). The difference between grass species used as seedlings for restoration and between restoration treatments were considered significant at $p < 0.05$.

7.2.4.2. Restoration practices with grass seeds under different treatments

Restoration performance of *Panicum maximum*, *Eragrostis curvula*, and *Digitaria eriantha* was compared between the treatments. The treatments were grass seeds (*Eragrostis curvular* and *Panicum maximum*) planted under minimum soil disturbance (MDGS), grass seeds (*Digitaria eriantha* and *Panicum maximum*) planted in the microcatchment (MCGS), grass seeds (*Panicum maximum*) planted under minimum soil disturbance and brushpack (MDBPGS), and grass seeds (*Digitaria eriantha* and *Panicum maximum*) planted in the microcatchment covered with brushpack (MCBPGS). Germination rate, plant density, and biomass production were measured between treatments and between grass species. The comparisons between treatments and between grass species were done with the analysis of variance (ANOVA) SPSS 1999. The difference was considered significant at $p < 0.05$ and differences between means were separated with multiple comparisons analysed with least significant difference (LSD).

7.2.4.3. Soil moisture collection and storage

Soil moisture collection and storage from the restoration treatments and from soil moisture conservation plots was compared with analysis of variance (ANOVA). The difference was considered significance at $p < 0.05$.

7.2.4.4. Soil seedbank assessment

Soil seedbank was assessed through the germination counts between degraded (Amakhuze Tribal Authority) and non-degraded sites (Phandulwazi Agricultural High School). The differences between the sites were compared with one-way analysis of variance (ANOVA). The difference was considered different at $p < 0.05$.

Model:

$Y_{ijklm} = \mu + C_i + S_j + P_k + CS_{ij} + CP_{ik} + SP_{jk} + CSP_{ijkl} + E_{ijklm}$

Where: Y_{ijklm} = Rangeland restoration;

μ = Overall mean;

C_i = effect of i^{th} soil water collection (microcatchment);

S_j = effect of j^{th} soil water storage (brushpack);

P_k = effect of k^{th} introduction of plant propagules (seeds and seedlings);

CS_{ij} = interaction between i^{th} soil water collection and j^{th} soil water storage;

CP_{ik} = interaction between i^{th} soil water collection and k^{th} plant propagules;

SP_{jk} = interaction between j^{th} soil water storage and k^{th} plant propagules;

CSP_{ijkl} = interaction between i^{th} soil water collection, j^{th} soil water storage, and k^{th} plant propagules

E_{ijklm} = random error term

7.3. Results

7.3.1. Restoration of degraded communal rangelands with grass seedlings under microcatchments and brushpacks

The tiller number was significantly ($p < 0.05$) different between the observation dates. The tiller number was increasing with observation intervals (time), thus, it was lowest in the fourth week (4.4), and increasing through the eighth week (6.6), twelfth week (14.2) and highest during the sixteenth week (16.6). The number of leaves also significantly increased ($p < 0.05$) between the fourth, eighth, twelfth and sixteenth weeks of observation (Table 7.1).

Table 7.1: The performance (Mean ± SE) of transplanted grass seedlings (*Themeda triandra* and *Paspalum dilatatum*) at four weeks observation interval after transplanting

Week interval	Number of tillers	Number of leaves	Mortality (%)	Flowering (%)	Number of Other plants	Tuft diameter
4^{th} week	$4.4±0.46^{a}$	$15.3±1.8^{a}$	$14.3±4.3^{a}$	-	$16.4±4.2^{a}$	-
8^{th} week	$6.6±0.76^{a}$	$27.3±3.9^{ab}$	$16.4±3.9^{a}$	$14.8±5.2^{a}$	$38.2±10.8^{b}$	-
12^{th} week	$14.2±2.1^{b}$	$42.5±5.8^{b}$	$20.9±4.7^{a}$	$20.9±7.4^{a}$	$38.0±7.7^{b}$	-
16^{th} week	$16.6±2.1^{b}$	$45.6±5.9^{b}$	$22.5±4.5^{a}$	$28.9±8.3^{a}$	$26.4±5.7^{a}$	4.9±0.4

Mean values with different superscript within the same column are significantly different

The number of tillers was significantly higher ($p < 0.05$) on microcatchment plots with brushpack (13.1) than on microcatchment plots without brushpack (7.2). The number of leaves was also significantly higher ($p < 0.05$) on microcatchment plots with brushpack

(41.7) than on microcatchment plots without brushpack (27.5). The grass seedling mortality percentage was significantly lower ($p < 0.05$) on microcatchment plots with brushpack (10.4%) compared with microcatchment plots without brush (28.7%). The flowering percentage was significantly higher ($p < 0.05$) on microcatchment plots with brushpack (21.7%) than microcatchment plots without brushpack (9.4%) (Table 7.2).

Table 7.2: Effects of microcatchment and brushpacks on grass (*Themeda triandra* and *Paspalum dilatatum*) seedling growth (Mean ± SE).

Treatment	Number of tillers	Number of leaves	Mortality (%)	Flowering (%)	Number of other plants	Tuft diameter
MCGS	7.2±0.91[a]	21.5±2.12[a]	28.7±3.94[a]	9.4±3.46[a]	24.5±4.95[a]	1.4±0.39[a]
MCBPGS	13.2±1.47[b]	41.7±4.09[b]	10.4±1.71[b]	21.7±5.05[a]	33.7±5.44[a]	1.1±0.29[a]

Mean values with different superscript within the same column are significantly different

NB: MCGS= microcatchment with grass seedlings, MCBPGS = Microcatchment with brush pack and grass seedlings

The number of tillers was not significantly different ($p > 0.05$) between grass species. However, *Paspalum dilatatum* had a significantly lower ($p < 0.05$) number of leaves (26.7) compared with *Themeda triandra* (39.7). The mortality rate was significantly higher ($p < 0.05$) for *Themeda triandra* (25.2%) than *Paspalum dilatatum* (12.2%) (Table 7.3). Flowering percentage was significantly higher ($p < 0.5$) with *Paspalum dilatatum* (31.0%) than *Themeda triandra* (0.7%).

Table 7.3: Growth (Mean ± SE) of different grass species (*P. Dilatatum* and *T. triandra*) under microcatchment and brushpacks

Grass species	Number of tillers	Number of leaves	Mortality (%)	Flowering (%)	Number of other plants	Tuft diameter (cm)
P. dilatatum	9. 4±0.9[a]	26.6±2.2[a]	12.2±2.0[a]	31.0±5.6[a]	29.6±4.9[a]	1.5±0.4[a]
T. triandra	11.8±1.7[b]	39.0±4.8[b]	25.3±3.7[b]	0.7±0.3[b]	29.5±5.8[a]	1.0±0.3[a]

Mean values with different superscript within the same column are significantly different

7.3.2. Restoration of degraded communal rangelands with grass seeds under microcatchments and brushpacks

7.3.2.1. Effects of microcatchment, brushpack and minimum soil disturbance on restoration performance

There was a significant difference (F = 38.84, df = 3, p < 0.05) between the treatments with brushpack combined with minimum soil disturbance (180.4), minimum soil disturbance (82.4), microcatchment with brush (75.9) and microcatchment (339.0) (Figure 7.1). Plant density was significantly (F = 37.43, df = 3, p < 0.05) higher on the microcatchment plot (348.83) than on the plots with brushpack and minimum soil disturbance (198.25), microcatchment with brushpack (70.82) and minimum soil disturbance (76.01) (Figure 7.2). There was no significant difference (F = 1.11, df = 3, p > 0.05) between treatments for biomass production (Figure 7.3). The mean differences for seed germination and plant density between restoration treatments are presented in table 7.4.

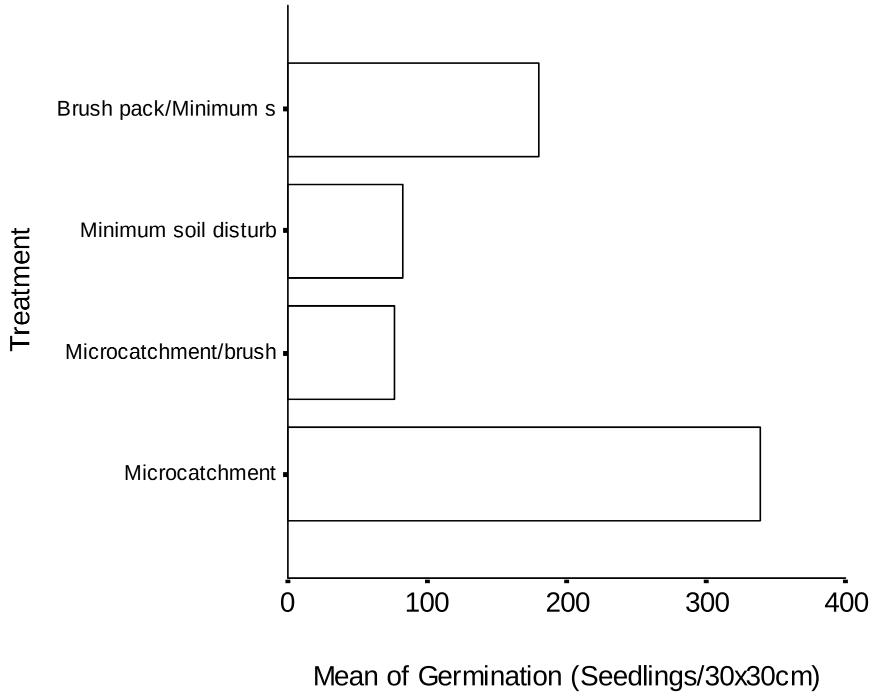

Figure 7.1: Germination (Mean) between vegetation restoration treatments ($F = 38.84$, $p < 0.05$).

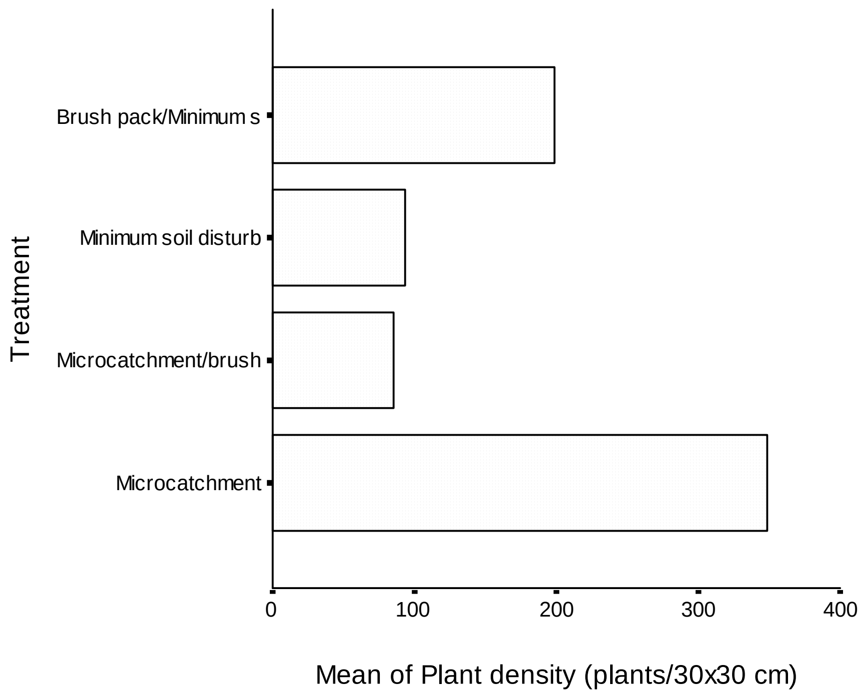

Figure 7.2: Plant density (Mean) between vegetation restoration treatments (F = 37.43, df = 3, $p < 0.05$).

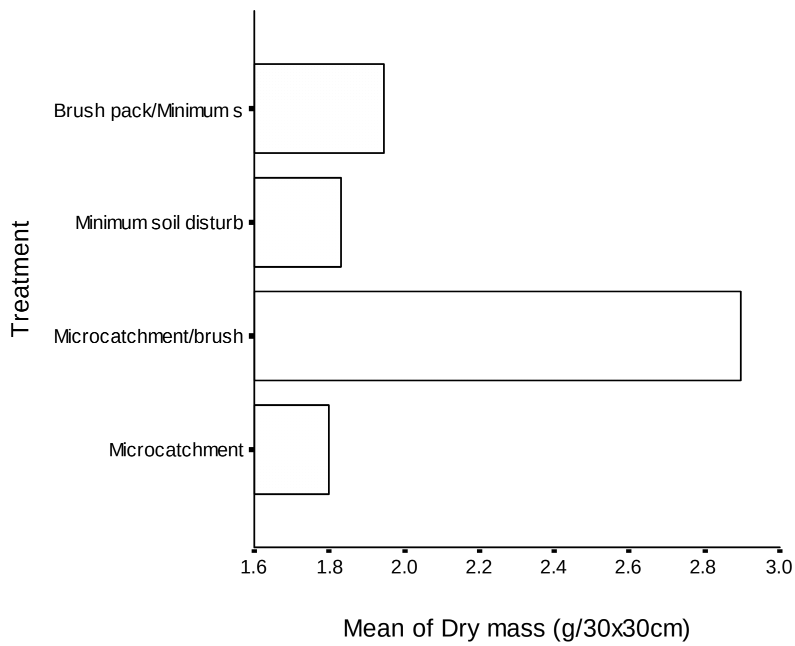

Figure 7.3: Biomass production (Mean) between restoration treatments (F = 1.11, df = 3, $p > 0.05$).

Table 7.4: Multiple comparisons (LSD, $p < 0.05$) between vegetation restoration treatments for seed germination (counts) and plant density (plants/900 cm^2) (* = $p < 0.05$, NS = $p > 0.05$).

Dependent Variable	(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error
Germination average	Brushpack/Minimum soil disturbance	Minimum soil disturbance	97.98*	26.87
		Microcatchment/brushpack	104.46*	26.87
		Microcatchment	-158.63*	31.03
	Minimum soil disturbance	Brush pack/Minimum soil disturbance	-97.98*	26.87
		Microcatchment/brushpack	NS	-
		Microcatchment	-256.60*	26.87
	Microcatchment/brushpack	Brush pack/Minimum soil disturbance	-104.46*	26.87
		Minimum soil disturbance	NS	-
		Microcatchment	-263.08*	26.87
	Microcatchment	Brush pack/Minimum soil disturbance	158.63*	31.03
		Minimum soil disturbance	256.60*	26.87
		Microcatchment/brushpack	263.08*	26.87
Plant density	Brush pack/Minimum soil disturbance	Minimum soil disturbance	104.50*	27.47
		Microcatchment/brushpack	112.67*	27.47
		Microcatchment	-150.58*	31.72
	Minimum soil disturbance	Brush pack/Minimum soil disturbance	-104.50*	27.47
		Microcatchment/brushpack	NS	22.43
		Microcatchment	-255.08*	27.47
	Microcatchment/brushpack	Brush pack/Minimum soil disturbance	-112.67*	27.47
		Minimum soil disturbance	NS	22.43
		Microcatchment	-263.25*	27.47
	Microcatchment	Brush pack/Minimum soil disturbance	150.58*	31.72
		Minimum soil disturbance	255.08*	27.47
		Microcatchment/brushpack	263.25*	27.47

7.3.2.2. Restoration performance of grass seeds of selected species

There was a significant difference ($F = 9.19$, $df = 2$, $p < 0.05$) between grass species planted under various rangeland restoration treatments for germination of seeds. *Eragrostis curvula* (218.02) had the highest germination rate compared to *Digitaria eriantha* (109.38) and *Panicum maximum* (96.86) (Figure 7.4). Plant density was significantly higher ($F = 9.08$, $df = 2$, $p < 0.05$) for *E. curvula* (230.08) than *D. eriantha* (120.5) and *P. maximum* (108.36) (Figure 7.5). There was no significant difference ($F = 1.57$, $df = 2$, $p > 0.05$) between grass species used for restoration in biomass production (Figure 7.6). The multiple comparisons between grass performance for germination, plant density, and biomass production are presented on table 7.5.

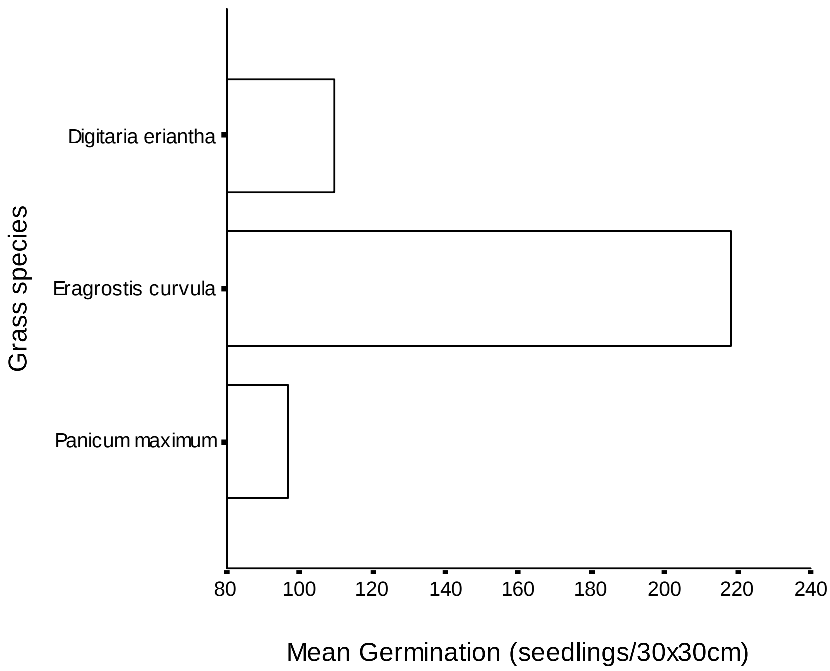

Figure 7.4: Germination performance between *D. eriantha*, *E. curvula*, and *P. maximum* under different restoration treatments ($F = 9.19$, $df = 2$, $p < 0.05$).

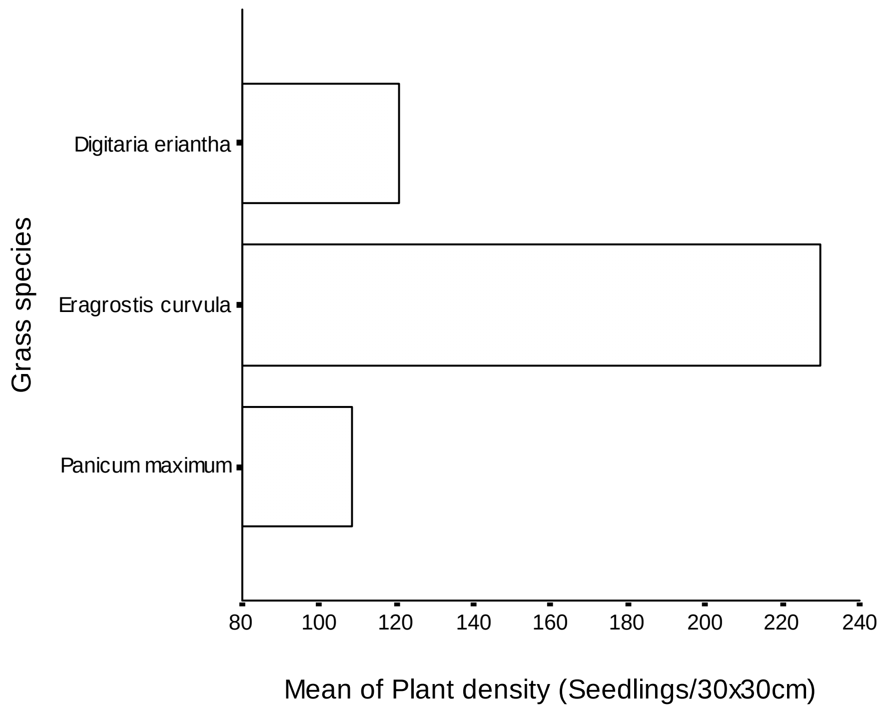

Figure 7.5: Plant density between grass seeds used under restoration treatments (F = 9.08, df = 2, $p < 0.05$).

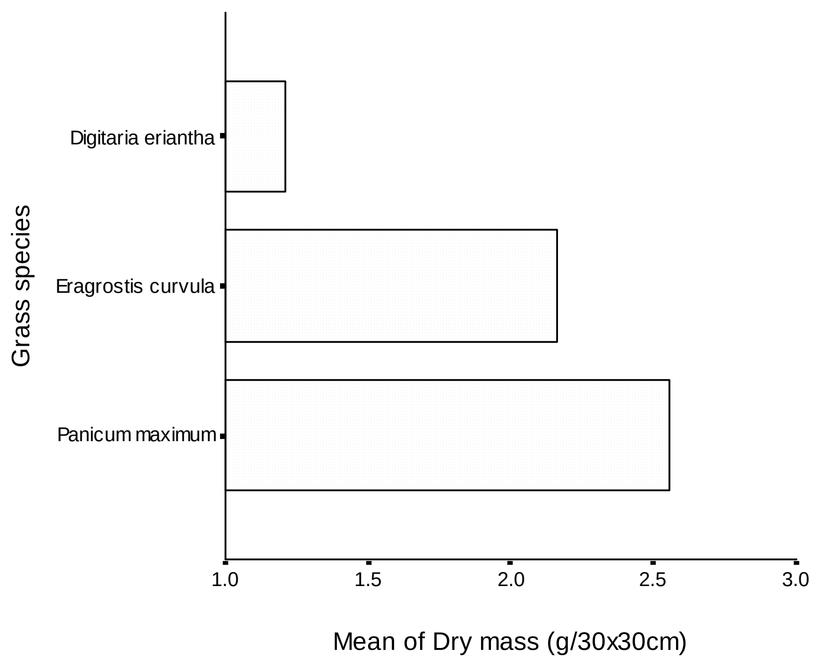

Figure 7.6: Biomass production between *D. erientha*, *E. curvula,* and *P. maximum* under different restoration treatments (F = 1.57, df = 2, $p > 0.05$).

Table 7.5: Multiple comparisons (LSD, $p < 0.05$, SE) between grass species on germination performance, plant density, and biomass production under different restoration treatments (* = $p < 0.05$, NS = $p > 0.05$).

Dependent Variable	(I) Grass species	(J) Grass species	Mean Difference (I-J)	Std. Error
Germination average	*Digitaria eriantha*	*Eragrostis curvula*	-108.64*	39.041
		Panicum maximum	NS	-
	Eragrostis curvula	*Digitaria eriantha*	108.65*	39.041
		Panicum maximum	121.16*	29.099
	Panicum maximum	*Digitaria eriantha*	NS	-
		Eragrostis curvula	-121.16*	29.099
Plant density	*Digitaria eriantha*	*Eragrostis curvula*	-109.58*	39.51
		Panicum maximum	NS	-
	Eragrostis curvula	*Digitaria eriantha*	109.58*	39.51
		Panicum maximum	121.72*	29.45
	Panicum maximum	*Digitaria eriantha*	NS	-
		Eragrostis curvula	-121.72*	29.45
Dry weight	*Digitaria eriantha*	*Eragrostis curvula*	NS	-
		Panicum maximum	NS	-
	Eragrostis curvula	*Digitaria eriantha*	NS	-
		Panicum maximum	NS	-
	Panicum maximum	*Digitaria eriantha*	NS	-
		Eragrostis curvula	NS	-

7.3.3. Soil moisture retention techniques used in rangeland restoration

There was a significant difference ($F = 11.034$, $p < 0.01$) among soil moisture retention practices. The use of brushpack alone was significantly higher ($p < 0.01$) than the control in terms of moisture retention in the soil (Figure 7.7). Soil moisture retention was significantly higher ($p < 0.01$) on the plots covered with brush, under minimal soil disturbance where *P. maximum* seeds (BP/MSD/PaMa/SD) were planted compared to the control. However, the BP/MSD/PaMa/SD was not significantly different ($p > 0.05$) from the plot that had brushpack only. The minimal soil disturbance (MSD) with both *P. maximum* and *E. curvula* seeds were not significantly different ($p > 0.05$) with the control for soil moisture retention.

The plots with microcatchment, brushpack and minimum soil disturbance planted with *D. eriantha* (MC/BP/DiEr/SD) or *P. maximum* (MC/BP/PaMa/SD) were significantly higher ($p < 0.01$) than the control plots in soil water retention. Furthermore, the use of microcatchment and brushpack with both *Paspalum dilatatum* and *Themeda triandra* seedlings was also significantly higher ($p < 0.01$) than the control in soil moisture storage. The soil water storage was significantly higher ($p < 0.01$) on microcatchment without brushpack planted with *Eragrostis curvula* seeds, *P. dilatatum*, and *T. triandra* seedlings than control. Water spreading system plots were significantly higher ($p < 0.01$) compared with the control plots for soil water retention.

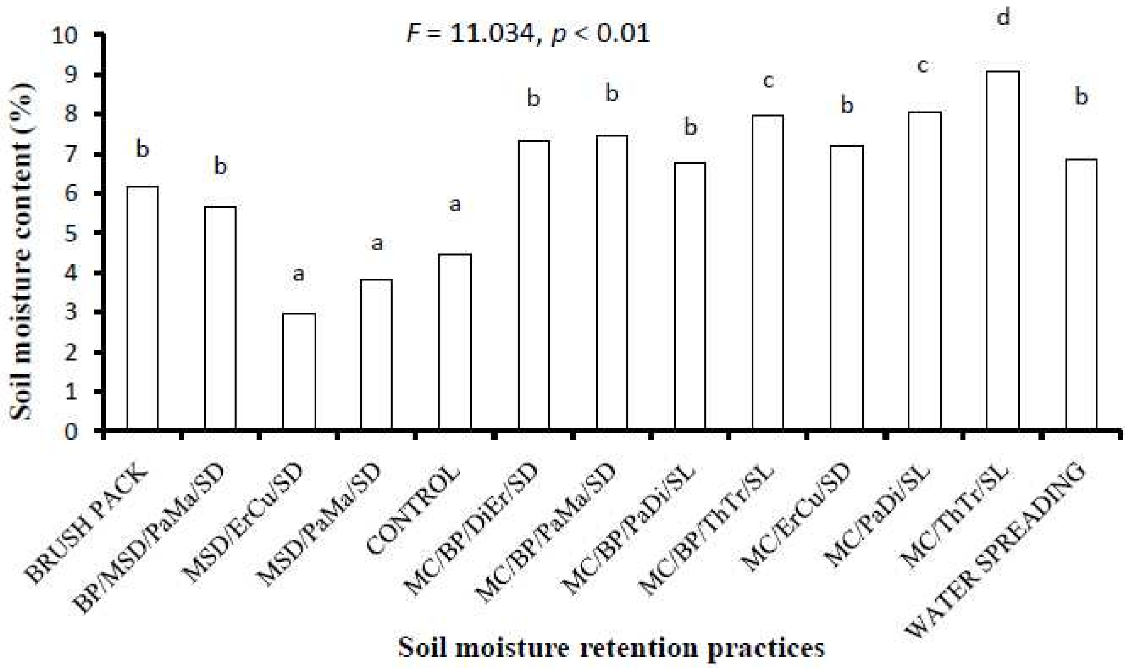

Figure 7.7: Soil moisture content under different rainwater harvesting practices in rangeland restoration (different letters above the bars demonstrate that the means for moisture retention between treatments were different).

BP = Brush park, MSD = Minimum soil disturbance, SD = grass seeds, MC = Microcatchment, SL = Grass seedling, ThTr = *Themeda triandra*, ErCu = *Eragrostis curvula*, DiEr = *Digitaria eriantha*, PaDi = *Paspalum dilatatum*.

7.3.4. Evaluation of soil seed bank on degraded rangelands

The seed bank means were significantly higher ($p < 0.01$) on degraded sites (Amakhuze Tribal Authority) (5.7, $SD = 4.8$) than non-degraded sites (Phandulwazi High School) (1.7, $SD = 1.5$). The minimum seed bank at the degraded sites was (0) with the maximum of (20) while for the non-degraded sites it was (0) and (6) for the minimum and maximum respectively (Table 7.6).

Table 7.6: Seed germination (seedling counts) to estimate soil seedbank measured in 48 days at the interval of 8 days between Amakhuze Tribal Authority and Phandulwazi Agricultural High School ($p < 0.05$).

Site	Seed Germination				
	Mean	SD	Sum	Min	Max
Amakhuze Tribal Authority	5.671[a]	4.827	397.0	0.0	20.0
Phandulwazi Agricultural H S	1.652[b]	1.462	147.0	0.0	6.0

Means with different superscript within the same column are significantly different

7.4. Discussion

7.4.1. Use of grass seedlings under microcatchments and brushpacks on vegetation restoration

The observation that number of tillers and leaves were changing with time indicates that the success of vegetation restoration treatment with grass seedlings depends on duration from transplanting to establishment. This could be ascribed to the fact that tillering process depends on leaf development. The larger the number of leaves the more tillering, this is because tillers start as buds in the leaf axils. In support of the observed behaviour of a number of tillers and leaves, Wolfson and Tainton (1999) reported that tillers arise as buds in the leaf axils; therefore, the potential rate of tillering depends on the rate at which leaves are produced.

The results show that the number of tillers and leaves, and flowering and mortality percentages were different between the restoration treatments, thus, where microcatchment was combined with brushpack and where microcatchment was used without brushpack. The fact that tillering, leaf production and flowering percentages were higher with low mortality rates on the plots with microcatchment combined with brushpack could be attributed to the high moisture retention resulting from runoff collection in the microcatchment and reduced evaporation loss due to shade provided by brushpack. This implies that the integration of vegetative measures with physical structures in vegetation restoration treatment may produce complementary effects resulting in an effective and successful restoration. Structural measures such as microcatchment and brushpack control runoff, sediment transportation and evaporation loss, whilst vegetative measures improve soil cover. This is in agreement with Singh *et al*. (2011) who indicated that physical structures reduce the runoff flow velocity in the channel resulting in an increased infiltration and sediment deposition. Hanke *et al*. (2011)

reported that infiltration rates were increased in the microcatchment and that was explained by the accumulation of coarse sand and organic material in the pits, which also decreased soil surface compaction. Coetzee (2005) highlighted that microcatchment breaks through impervious soil capping and runoff water collects during rainfall resulting in infiltration rather runoff.

The results imply that the combination of microcatchment and brushpack support higher rate of grass tillering, leaf development, flowering and reduces seedling mortality. These variables (tillering, leave development, flowering, and mortality) could be used as the early indicators of vegetation restoration success in degraded rangelands if the seedlings are to be used. The complete growth of grass plant is directly dependent on the vegetative growth characterised by number of leaves and tillers, which improves the plant's photosynthetic capacity, however, depends on water availability among other factors (Rodriguez-Iturbe and Porporato 2004). The availability and retention of soil moisture captured by microcatchment and brushpack are important factors for vegetation establishment and growth as indicated by vegetative growth (tillering and leaf production) and reproductive growth (flowering) attained on restoration treatment with both microcatchment and brushpack.

Microcatchment and brushpack simulates and enhances infiltration and canopy interception processes resulting in higher moisture retention for the use of transplanted seedlings. Rainwater input into the soils in drylands is determined by infiltration-runoff partitioning and by canopy interception related processes (Noy-Meir 1973). The two methods of restoration, individual or combined improves seepage and reduce evaporative soil water depletion, that results retains increased soil water remaining for plant growth performance as indicated by tillering, leaf development, flowering and reduced mortalities. Loik *et al*. (2004)

indicated that soil water remaining for plant growth might be further reduced by evaporative depletion and seepage.

In the short term, continuous production of tillers and development of leaves could indicate a successful trend in vegetation restoration on degraded rangelands. This is because the larger the number of tillers and leaves the larger the tuft diameter, which in turn reduces the space between the tufts and increase the area covered by individual tufts. Simultaneous increase of tuft diameter and reduction on tuft-to-tuft distance collectively improves basal and aerial cover, which in turn reduces raindrop impact on bare soil and runoff rate. Svejcar *et al*. (1999) pointed that the stage of rangeland retrogression in grassland is characterised by increased rates of runoff. Therefore, improvement of soil cover resulting in reduced runoff presents rangeland restoration progression. Morris and Kotze (2006) indicated that water inputs may either be intercepted by plants, which reduces raindrop impact, improves infiltration rates and reduce runoff. However, that depends on, among other factors, soil characteristics, topography and vegetation cover. While soil characteristics and topography are not underestimated in vegetation restoration success, Malan and Van Niekerk (2005) emphasised that the most important single factor affecting water runoff is the amount and type of vegetative cover.

There was a high flowering rate of *Paspalum dilatatum* planted on microcatchment combined with brushpack compared with the same species planted under microcatchment without brushpack. This could indicate that improved soil moisture retention due to the reduced evaporation rate because of brushpack has an effect on grass reproductive growth. The flowering ability of the plants is an important factor in vegetative growth and development, it signifies maturity of grass plants, and furthermore, seed production indicates vegetation recruitment possibilities, which as well could be an indicator for rangeland restoration success. Noy-Meir (1973) indicated that flowering, seed set, dispersal, and germination is vital especially in the arid systems because the occurrence of times suitable for these processes is highly uncertain. The fact that *Themeda triandra* had higher leaf number compared with *Paspalum dilatatum* under similar treatment of microcatchment and brushpack could be ascribed to the genetic material of the species used for restoration. This implies that when vegetation restoration performance is determined by leaf development, the success of such a treatment is dependent on the species' difference.

The fact that *P. dilatatum* produced more flowers than *T. triandra* under microcatchment with brushpack could be as well ascribed to genetic difference between species, because flowering is genetically induced. Furthermore, flowering is also induced by biochemical process that may require a cold pre-treatment (vernalisation) or a certain day length or series of day lengths (photoperiodism). *T. triandra* has been shown to be one of the species that requires over wintering for it to flower in the next spring. Therefore, its failure to flower could be attributed to the requirement of cold pre-treatment and photoperiodism. Dahl (1995) alluded to the fact that floral initiation is interpreted as a biochemical process that may require a cold pre-treatment, that is photoperiodic, that requires favourable growing conditions and in some plants, it is genetically induced. Wolfson and Tainton (1999) indicated that *T. triandra* requires resting from midsummer of one year for seeding in the following spring. This implies that when flowering is considered as a performance indicator for rangeland restoration, the factors that affect phenological phases of different species should be considered.

The observed mortality percentages on grasses transplanted under microcatchment without brushpack could indicate that the seedlings died due to soil desiccation, which might have been caused by loss of soil moisture through evaporation. The high mortality was observed for *Themeda triandra* on the microcatchments without brushpack. This implies that the establishment of *Themeda triandra* was more dependent on soil moisture content than *Paspalum dilatatum*. Furthermore, this means that the effectiveness of microcatchment and brushpack on degraded rangeland vegetation restoration varies with plant species used. That could be attributed to the adaptation of different grass species to low water supply, which could be due to variation in stomatal conductance. This was in agreement with Wolfson and Tainton (1999) who indicated that the effects of moisture stress on growth and development of grass varies among different plant species, growth stage of the plant, duration of moisture stress period and management prior to and during stress period.

7.4.2. Introduction of grass seeds under microcatchment and brushpack

Germination rate of grass seeds was used as an indicator of restoration performance between the restoration techniques in which microcatchment, brushpack, and minimum soil disturbance and their combinations were used. The results indicate that use of microcatchments in restoring degraded rangelands combined with grass seeds performed better than the use of brushpack, use of microcatchment combined with brush, minimum soil disturbance, and combination of brushpack and minimum soil disturbance on seed germination. The higher germination performance on the use of microcatchment compared with other treatments could be attributed to the ability of microcatchment to hold water and release some through evaporation, which reduces water logging.

Brushpack reduces evaporative soil moisture loss and when combined with microcatchment results in the soil remaining wet for a longer period, which deprives grass seeds oxygen necessary for germination. The introduction of seed and seedlings into overgrazed rangelands could re-establish forage species in an area, which in turn can increase the plant diversity. The use of microcatchment and brush serve as a microsite or microhabitat.

The creation of favourable microhabitats for seed entrapment or planting, germination, and seedling establishment could assist in rehabilitation of grazing induced vegetation change. Artificially created safe sites such as microcatchments and brushpacks can act as traps for water, sediments, litter, and seed resulting in the formation of fertile patches (Noble *et al*. 1997) which facilitate the establishment of seedlings.

On the other hand, the low germination performance on use of minimum soil disturbance alone or combined with brushpack could be ascribed to low soil moisture retention, which deprives grass seeds sufficient soil moisture required for germination. Furthermore, use of brushpack could provide shading which reduces the light intensity sufficient for germination of grass seeds. Snyman (2005) indicated that light intensity serves as one of the important factors influencing germination. The implication of these results is that while in all the treatments there was germination, the degree of germination varied with treatments. Light intensity, moisture availability, amount, and length of time at which soil stay moist, and availability of free oxygen in the soil could affect germination of grass seeds. Snyman (1998) emphasised the importance of soil moisture in seedling germination, which in degraded rangelands is lost due to runoff and evaporation on the bare ground after rainfall.

The similar trend was observed with plant density under different rangeland restoration techniques. Thus, the plant density was high on the plots where microcatchments alone were used, followed by the plot where brush-pack combined with minimum soil disturbance, minimum soil disturbance alone and the least were the plots where microcatchment was combined with brushpack. These results indicate that microcatchment alone could serve as a restoration technique where grass seeds are to be used to attain maximum germination and growth performance. The similar trends between germination rates and plant density between treatments could imply that the larger effect of moisture excess/deficit in terms of both availability and storage provided by combination of brushpack and microcatchment, which controls oxygen availability could be more during germination than post-germination stages.

7.4.3. Complementary role of soil moisture retention techniques in the restoration of degraded communal rangelands

The fact that treatment with brushpack retained more moisture than the control indicates that the brushpack had an effect on soil moisture storage. This implies that brushpack had positive effect on soil water storage. That could be due to a reduced evaporation rate from the soil resulting from shading effect of brushpack. Simons and Allsopp (2007) demonstrated that brushpacks have sheltering effect to the ground from harsh climatic conditions, and trapping of organic material and seeds, in addition to that, brushpack may have increased the soil water content through precipitation combing. Akpo *et al*. (2005), who indicated that in restoration treatments covered and, shaded the soil surface delayed soil water depletion, further reported protection of soil layer from the sun and wind as result of brushpack. The results propose that combination of microcatchment with brushpack on rangeland restoration leads to higher soil moisture retention than the land that does not have both microcatchment and brushpack. Rainwater input into the soil in drylands is determined by infiltration-runoff partitioning and by canopy interception related processes (Noy-Meir 1973). Soil could serve as a water reservoir, nevertheless, on degraded rangelands this property might not be the reality due to factors such as poor soil cover and soil compaction. These factors enhance the rate of runoff and evaporative water loss from the rangeland ecosystems.

Furthermore, the use of microcatchments and water spreading system has higher water retention potential than the land that does not have these structures (control). This could be attributed to the fact that after rainfall, the microcatchment holds rainwater within the catchment, the water spreading system spread water across the wider areas on rangelands, both of these structures reduce water loss through runoff, and brushpack reduces water loss through evaporation. Microcatchments are widely and successfully applied for water and soil conservation throughout Africa (Critchley *et al*. 1994) and microcatchments effectively harvest surface runoff and mitigate water erosion caused by heavier rains. This implies that the use of brushpack, microcatchments, and water spreading system should be considered as the water harvesting techniques and could significantly complement the vegetation restoration techniques.

Microcatchments mimic the role of natural depressions and act as zones of increased soil moisture. Elevated soil moisture levels under brushpack are also encouraging plant growth and this suggests that brush helps to maintain resources such as water within the system, preventing it from being lost as runoff (Simons 2005). Whilst the concept of soil as a reservoir for water is more acknowledged in irrigated areas (Veihmeyer and Hendrickson 1950), for rangeland restoration exercise, it is important that as much water as possible be collected and stored in the soil to support vegetation that is being restored. The improvement of soil property as water reservoir on degraded rangelands in the short to mid-term until the natural capacity to hold the soil has been restored could be achieved with microcatchment and brushpack on restoration of degraded rangeland.

7.4.4. Soil seed bank status of degraded communal rangelands

Degraded rangelands were found to have more seedbank than non-degraded rangelands. This difference could be attributed to lack of or poor rangeland resting practices and prevailing seed germination conditions in non-degraded rangelands. Thus, even if rotational grazing is practiced, if a rangeland-resting plan is not implemented, the chances of available species to produce and shed seeds is reduced. Furthermore, if the conditions of seed germination are conducive, the seeds that were shed could have germinated. Rests designed specifically to benefit individual plant or plant community requirements may vary and aim to meet different requirements such as species composition, plant density, and vigour (Tainton and Danckwerts 1999). Summer rests are aimed primarily at promoting seed production (Tainton and Danckwerts 1999, Trollope 1986), which could result in improved seedling recruitment through germination.

On the other hand, the relatively high seed bank in degraded rangelands indicates the potential for plant recovery if the disturbance is removed and the germination conditions are improved. Bekker *et al*. (1997) pointed out that soil seedbanks indicate a potential pool of propagules for regeneration of grasses after disturbance. Venable and Brown (1988) also indicated that the presence of a seedbank reduces the probability of population extinction of plants. Degraded rangelands have poor vegetation cover, which results in low soil moisture retention in the soil due to high runoff rates. Low soil-moisture conditions in degraded rangelands renders the soil less conducive for germination, and therefore, the seeds may be retained. There are a number of factors, which could serve as barriers to natural recovery of degraded rangelands. These factors could include soil moisture (Snyman 1998), which in degraded rangelands is lost due to runoff and evaporation on the bare ground after rainfall. Storage of viable seeds in the soil and subsequent establishment depend on the degree of disturbance (Thompson 1986). The dry soil conditions may adversely affect the seedling recruitment of the seedbank (Kinloch and Friedel 2005).

This proposes that, for communal rangeland restoration, restoration techniques and practices should be aimed at among other factors improvement of soil moisture retention, which may promote seed germination. Sufficient soil moisture at certain patches of rangelands renders such patches into being favourable microsites for germination. Harper *et* *al*. (1965) indicated that seed germination and establishment in natural and artificial revegetation is due to the number of seeds in favourable microsites or 'safe sites' in the seedbed rather than the total number of available seeds. Therefore, available soil seed bank supported with soil moisture retention techniques could serve as complementary units in communal rangeland restoration. Snyman (1993) and Hayatt (1999) highlighted that the availability of a seedbank could serve as a source in establishing plant communities following environmental changes such as rainfall.

Grazing poses a disturbance in rangelands and affects soil seedbank through continuous consumption of grasses, which deprives the vegetation the chance for reproductive growth. Grazing may also interfere with new vegetation recruitment through continuous defoliation, which results in new recruits being consumed before establishment. This proposes that if rangeland restoration in the communal areas is based on soil seedbank availability and density, and subsequently on germination of available seeds, therefore, grazing and/or defoliation practices should be given a considerable attention. Bekker *et al*. (1997), Solomon (2003), and Snyman (2004) indicated that heavy grazing by livestock introduces a disturbance to grasslands and can negatively affect the size and composition of grasses in the seedbank.

7.5. Conclusion

Abiotic factors such as poor water collection and retention coupled with biotic factors such as poor soil seedbank and disturbance mostly through grazing are the barriers of rangeland natural recovery. Identification and elimination of such barriers are fundamental in the attainment of successful rangeland restoration. Soil moisture availability is essential for rangeland restoration exercise and therefore, restoration techniques that promote collection and retention of water are important for a successful rangeland restoration. Development of microcatchments and brushpack improved soil moisture storage through collection of runoff water and reduction of evaporative soil moisture loss. This was achieved through improved infiltration rates resulting from digging and reduced evaporative loss by shading effect of brushpack. Introduction of plant propagules (seeds and seedlings) addressed the low soil seedbank barrier. Introduction of vegetation on degraded rangelands with the use of microcatchment and brushpack afford the rangeland ecosystem with active and passive protection, and promote forage productivity. Active protection against erosive agents consists of raindrop interception, an increase in water infiltration in soil, thermal regulation, and soil fixation by the root systems. Passive action is provided by trapping and retaining sediment inside the catchment due to its aerial parts.

8. GENERAL DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

8.1. General discussion

Communal rangelands provide services such as maintenance of stable and productive soils, delivery of clean water and sustaining plants, animals, and other organisms that support the livelihoods and, aesthetic and cultural values of people (Grice and Hodgkinson 2002, Teague *et al*. 2009). Based on the economical and ecological value of communal rangelands and on the notion that such areas are threatened by land degradation, an assessment of land degradation characteristics was central for investigation in this study followed by evaluation of vegetation and soil restoration techniques. Land degradation affects primary productivity of rangelands and in turn affects ecosystem biological and economic function (Herweg and Stillhardt 1999).

Communal rangelands are utilised by farmers primarily for grazing livestock, and overgrazing have been blamed for being the root of rangeland degradation. Rangelands are considered salient renewable resource because of the number of ecological functions such as nutrient cycling, deposition of organic matter and infiltration. In addition, there are variety of economic goods and services including meat, fibre, recreation, and wildlife production found from rangelands (Batabyal 2004). Therefore, farmers' perceptual experience on causes and status of communal rangeland degradation and possible restoration techniques were explored. The farmers' perceptions were supported by biophysical investigation on rangeland degradation characteristics, indicators for degradation ranged from soil hydrological, vegetation change and soil loss characteristics. The extent of rangeland degradation in communal areas varies with different areas being affected by a number of biophysical and socio-economical factors (Herweg and Stillhardt 1999).

Grazing distribution pattern was explored to establish whether grazing could be one of the drivers of rangeland degradation. The assessment was based on the key perceptions of farmers and key biophysical characteristics of rangeland degradation. The completion of this study was grounded by an investigation on rangeland restoration techniques. Factors that influence livestock grazing distribution pattern include landscape, vegetation type, land use practice, distance to water points and seasonal variations. Thus, within the rangelands, some landscapes especially low-lying, such as valley bottom and foothills are grazed more severely than higher lying areas. The areas that were experiencing higher grazing intensity were perceived by farmers to be more degraded, and were affirmed through biophysical assessment to be degraded. Farmers cited the non-existence and/or lack of policies for livestock-rangeland management. That was further linked with low individual and/or community obligation and lack of skills on rangeland management. This was conceived to have lead to unplanned grazing distribution pattern, which in turn exert scratchy grazing pressure on certain portions of rangelands and lead to rangeland degradation.

Vegetation change was cited by the farmers and affirmed through biophysical appraisal as the major rangeland degradation characteristics in communal areas. Higher grazing intensity results into vegetation change from productive and stable to unproductive and unstable vegetation structure through the change of species composition. Rangeland degradation resulting from higher grazing pressure leads to changes in vegetation structure, composition, and productivity (Moleele and Perkins 1998; Oztas *et al*. 2003; Maki *et al*. 2007). Thus, degraded portions in communal areas were dominated by increaser II grass species such as *Aristida conjesta, Cynodon dactilon,* and *Eragrostis obtusa.* The dominance of these species indicates low rangeland forage productivity and poor soil protection, and that characterises rangeland degradation. Decreaser species disappear under heavy grazing intensity, and are replaced by increaser II and invader species (Sisay and Baars 2002; Abel 1997, Hays and Holl 2003).

Poor vegetation cover, low hydraulic conductivity, and high-unconfined compressive strength (UCS) of the soil were discovered through biophysical assessment as other characteristics of communal rangelands. These characteristics reflect high livestock grazing intensity, which further suggests soil compaction due to livestock trampling (Milchunas *et al*. 1989). High intensity grazing leads to excessive removal of acceptable species (Anderson and Hoffman 2006) and that opens the space for less acceptable and faster establishing annual grasses. Combination of these variables leads to poor infiltration and higher water loss through run-off and subsequently into soil erosion.

Rangeland degradation occurrence and extent was discovered through farmers' perceptual experience and biophysical assessment to vary between landscapes and vegetation types. Thus, low-lying grassland areas were more degraded than higher lying areas; this suggests variation in vulnerability between the landscapes and vegetation types in communal areas (Bailey 2004; Pinchak *et al*. 1991). The variation in vulnerability could be attributed to the nature of soils, terrain morphology, poor grazing management, and vegetation type. Rangeland degradation is not a spatially uniform process because there are substantial off-site effects. Thus, some lands are more prone to degradation than other lands. This could be because they have erodible soils and acceptable grass species, which attract more grazing activity (Pickup 1998). The fact that rangeland degradation occurrence and extent vary between landscapes implies that the approach to address rangeland degradation should be landscape specific, thus, landscapes that are more vulnerable should be given the highest preference. Warren (2002) and Reynolds *et al*. (2007) emphasised the importance of a place-based approach to rangeland degradation to understand the causal relationships within specific physical and social circumstances. Hoffman and Todd (2000) indicated that the extent of land degradation was found greater on the steeply sloping environments.

Communal Rangeland degradation was characterised by poor vegetation, which leads to low-forage productivity and poor vegetation cover. This low level of forage productivity and soil protection were characterised by the dominance of annual grasses (increaser II) with low forage value and those grass species, which increase with overgrazing. Land degradation is reflected in a decline of land productivity, which has resulted into cyclical causes and effects resulted in a depletion of plant cover, soil exposure to erosion and deterioration of soil structure (Sanchez *et al*. 2002).

Land users indicated that among other factors, rangeland degradation could be attributed to poor grazing management resulting from non-existence and/or lack of implementation of rangeland utilisation policy underlined by lack of fencing. Although farmers acknowledge the fact that rangelands are degraded, they perceive fencing to be some form of panacea. The relationship between livestock-rangeland management and fencing could lead into the hypothesis that there is a controversy between “farmers’ obligation” and “fencing complex” in relation to rangeland degradation. Thus, the fact that animals are neither kraaled nor herded signifies low level of attachment of farmers to their livestock, and that coupled with their need for fencing indicates the complexity on developing communal rangeland management strategies. Moyo *et al*. (2008) argued that the need for fencing by communal farmers was motivated by the benefits of reduced labour and time spent herding, rather than improved grazing management. The perception of famers that fencing could solve rangeland management anarchy coupled with the reasons for fencing cited by Moyo *et al*. (2008) twinned with an irony in communities, which destroyed their fences (Bennet *et al*.

2010), leaves fencing alone as unsustainable solution to communal rangeland degradation and livestock production enhancement.

Fencing of communal rangelands was tried before and was abortive due to among other factors, vandalism by community members (Corney and Farrington 1998). These two aspects, thus low farmers' and/or communities' responsibility and lack of fencing used as the foundation facts for poor rangeland management could indicate the "policy versus infrastructural requirement controversy." However, introduction of an effective policy and fencing in communal rangelands could complement each other, but the cost of fencing communal rangelands might be unbearable considering the extent of communal rangelands and their low level of production. The art of herding is fast disappearing due to low involvement of the youth in livestock production, fencing is considered an alternative to herding by farmers, and however this is not feasible (Niamir 1990) given the extent of communal rangelands and financial requirement for installation and maintenance. However, considering the rate of unemployment, introduction of rangers and/or herders could contribute into job creation and in turn indirectly reduce food insecurity in rural areas.

Farmers' and community responsibility in livestock – rangeland management could be installed through establishment and/or reintroduction of livestock herding practices. Livestock herding refers to the art of guarding and conducting livestock (Niamir 1990) to, from, and within a grazing area. Herding consists of moving animals against the wind so that they can smell predators, night grazing, controlling livestock in a grazing area and drinking times especially during dry season and learning all the signs, cries and songs needed to communicate with livestock (Ba 1982). Introduction of herders in communal rangelands could improve livestock productivity and reduce land degradation. This could be achieved if herders are trained on the basic livestock production and rangeland management practices including breeding, nutrition, health, animal adaptation to environment and grazing management. However, this should be based on the farmer and/or community objectives for livestock-rangeland management.

The role of herding in livestock-rangeland monitoring and management is significant especially in communal areas, that could improve livestock productivity and should therefore, be rationalised. Herding-kraaling practices and their effect on rangeland management could be demonstrated by Liliefontein Commons of Namaqualand (Allsopp *et al*. 2007) and communal rangeland system of Lesotho and Sterkspruit (Magwiji) (Moyo *et al*. 2008; Moyo 2009), the Wodaabe Fulani and the Fulani of northern Nigeria (Niamir 1990), and Northern Kenya and Southern Ethiopia (Pavanello and Levine 2011). That could be used to demonstrate the individual farmer and community responsibility on livestock-rangeland management. Herders closely monitor their livestock and environment for signs that indicate a need to move and the best direction to go (Niamir 1990). At Amakhuze Tribal Authority and even the whole of central Eastern Cape Province (Bennett *et al*. 2010), the communal rangelands are not fenced and herding is not practiced. Thus, livestock select areas on which to graze and that would be based on their preference, this subject areas that are more livestock preferred to overgrazing and subsequently to land degradation.

Uncontrolled grazing distribution pattern in communal rangelands is influenced by factors such as landscape, altitude, land use practices, distance to water points and seasonal variations. This indicates the fact that other areas are more attractive to grazing animals than others are and that subject selected areas to overgrazing. Thus, low-lying areas are grazed approximately three times more intensely than associated uplands due to easy access by animals (Senft *et al*. 1985). Therefore, grazing management should consider the variation between landscapes, altitudes, land use practices, water points, and seasons. Grazing distribution pattern could therefore, be managed through introduction of fencing or herding. This proposes that landscape and other factors that are responsible for heterogeneity in rangelands should be considered if any interventions in grazing management or restoration activities are to be practiced in communal areas. However, the complete cost benefit analysis between fencing and herding-kraaling practices and their separate or combined effect on improving and sustaining communal rangelands should be given a priority. The analysis should emphasise on establishing the equilibrium between the economic and ecological benefits from the ecosystem. Rangeland degradation in the communal rangelands could be driven (Figure 8.1) by social and biophysical drivers and any intervention should consider such factors. Rangeland degradation is a complex phenomena, it could be caused by complex set of factors. Its extent varies with different areas being affected by number of biophysical and socio-economic factors (Herweg and Stillhardt 1999).

Where herding-kraaling system is considered as means to control livestock movement, overgrazing can be minimised. That could be achieved through an effective control of livestock grazing distribution, thus animals will be guided to the grazing area and stay there for determined period. The idea of livestock grazing management brings the three identified social deficient factors (lack of skills, lack individual and/or community responsibility and ineffective policies) and uneven livestock-grazing pattern together in addressing the problem of rangeland degradation. The relationship between herders, livestock, and rangeland management could be demonstrated by the responsibility taken or assigned to herders. The presence of herders in communal grazing systems would address both animal production and rangeland management requirements. Thus, animal safety from predators, toxicity, theft, injuries etc, temporal and spatial nutritional management by selecting where animals will graze during different seasons, provision of other grazing support elements such as access to drinking water and finally the state of grazing area would be monitored daily and the decision to move animals could be made. Thus, among other issues, herders classify grazing areas according to the complex set of criteria and consider these when deciding seasonal and daily herding patterns (Allsopp *et al*. 2007). These include (i) the safety criteria - when there are young animals in the herd, animal safety is compromised by the presence of toxic plants, predators, steep or rough terrain, and cold weather; (ii) animal intake is dependent on season and amount of rainfall. Thus different seasons and areas vary with grazing quality depending on plant composition; (iii) grazing strategies must consider water availability, presence of croplands and other herds, and try to guarantee herder's needs for minimum comfort (Allsopp *et al*. 2007). Based on the mentioned criteria, herders' responsibilities are to select a "target zone" for grazing and the routes through which animals should move to these "target zones."

The perception that communal farmers do not have skills in livestock and rangeland management and their requirement for capacity building could improve community utility of the unemployed rural area dwellers as rangers and/or herders. Everson *et al*. (2007) also highlighted lack of skills as the challenge; they mentioned that the challenge in addressing the problem of rangeland degradation in communal areas is the introduction of conservation measures and making people aware of their benefits through education. Therefore, capacity building would improve the understanding of communal farmers on management of the ecosystems and that will subsequently improve the chances of some village members for employment as herders at household, or user group and/or community levels. Fratkin and Roth (2004) indicated that the low level of knowledge, capacity, and resources from the farmers has prevented them from voicing their views and perceptions. Traditional herder systems have not been used in the development context; this could be because they did not fit into the classical fenced "commercial" model. However, their effectiveness enhanced with modern livestock - rangeland management techniques and relatively low cost of hiring herders as local range monitors are advantages that can form an integral part of more effective rangeland management and restoration interventions.

Rangeland forage quality has spatial and temporal variations (Laughlin and Abella 2007). Herders direct animals on temporal (daily or seasonal) and spatial bases (landscapes, land use, water points and vegetation type). Thus, where to graze in the morning, in other areas they even chose the route with consideration that animals cause degradation with trampling if one route is overused. This rather demonstrates an objective interaction between herders, livestock, and rangeland ecosystems, and such is not the case at Amakhuze Tribal Authority and many other communal rangelands especially in the central Eastern Cape Province. Allsop *et al*. (2007) highlighted that one of the basic advantages of herders is that they direct the herd in the morning so that the same route is not taken on consecutive days to avoid excessive trampling which they perceive will destroy vegetation and increase soil disturbance."

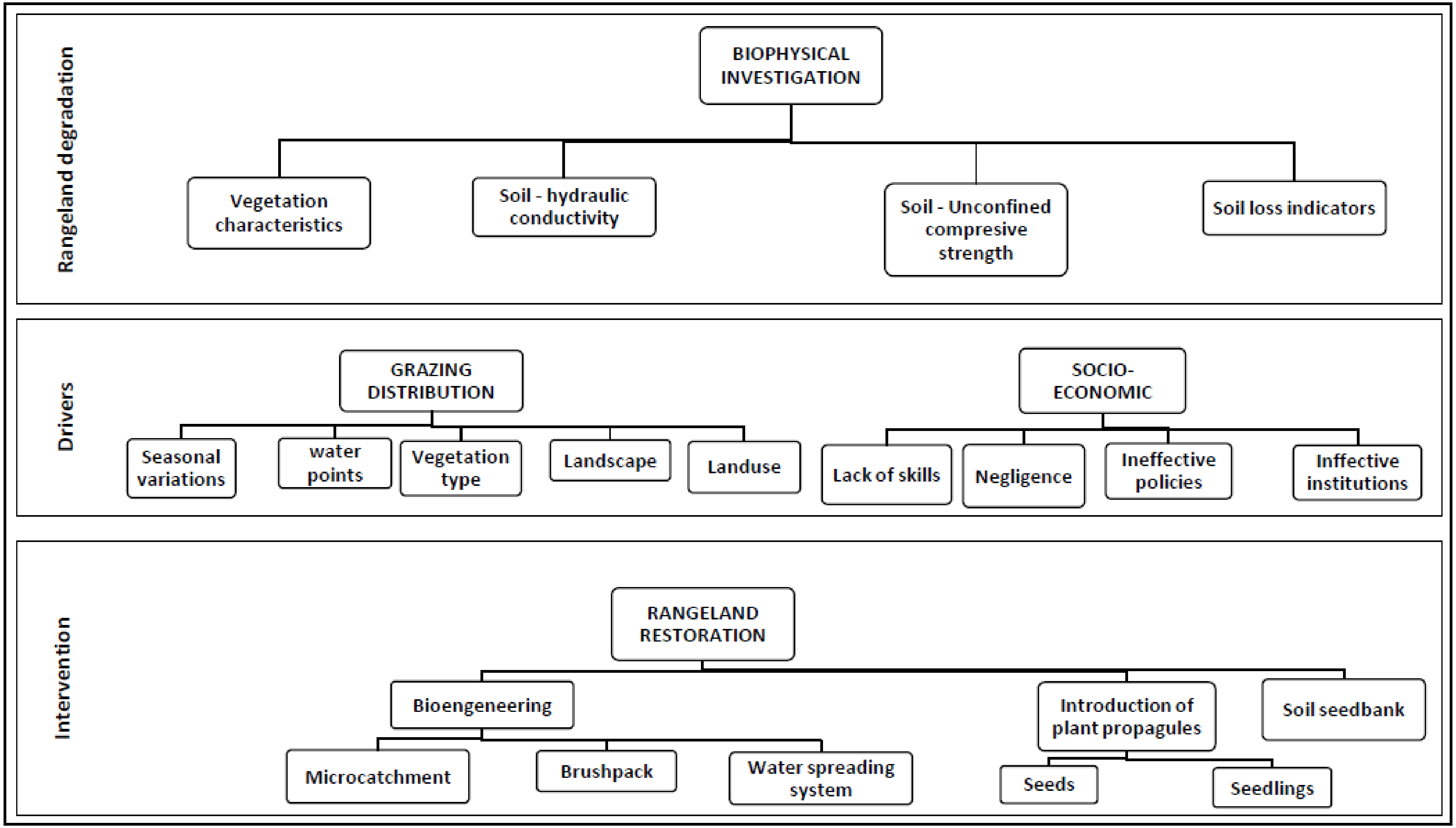

Figure 8.1: Conceptual framework on characterisation of rangeland degradation, grazing distribution pattern, and rangeland restoration.

The lack of effective policy, low level of responsibility in livestock movement and the extent of rangeland degradation, together with the fact that there was no attempt in restoring degraded portions of the rangelands could suffice to characterise communal rangeland system as negligent and degradative. Nunow (2000) criticised communal system as irrational, ecologically destructive, and economical inefficient. The irrational nature, ecological destructiveness, and economic inefficiency could therefore, be invoked as the characteristics of communal rangelands. This could propose the tragedy of commons as outlined by Hardin (1968), which portrays African pastoralism as a destructive and maladaptive system and calls for system change before disaster strikes.

The lack or low level of involvement of farmers on rangeland livestock-management and the response of communal rangeland ecosystems to grazing pressure could thus, be associated with the concept of the tragedy of commons (Hardin 1968) and equilibrium theory of vegetation change (Ellis and Swift 1988). The consideration of social factors, thus, ineffective policy, low individual, and/or community obligation underpinned by ineffective institutions on communal rangeland management at Amakhuze Tribal Authority could align with the concept the tragedy of commons. In support of the foregoing assertion, the response of vegetation to grazing distribution could be aligned with the equilibrium model propositions. Thus, the equilibrium theorem is based on the analogy that rangeland ecosystem dynamics could have the elements of stability, resilience and a domain of attraction (Walker 1980). Stable systems are those that when subjected to outside pressure (e.g. grazing) changes in species composition and production. Rangeland degradation as indicated by vegetation change, which in turn leads to low production and poor vegetation cover both, which subsequently result into loss of soil through run-off are the consequences of poor grazing management.

The concept of equilibrium is in accord with principles of the succession model of rangeland vegetation change. According to this model, grazing pressure is balanced against the successional trend of an orderly and predictable process where plants replace each other to maintain a stable sub-climax (Stoddart *et al*. 1975). Equilibrium theory narratives are based on the three basic assumptions. (i) That communal rangeland ecosystems are potentially stable systems; (ii) are frequently destabilised by improper use on the part of pastoralists and (iii) alterations of system structure are needed to return these systems to an equilibrium and more productive state (Ellis and Swift 1988).

Although the social factors direct the comprehension of communal rangeland degradation towards the tragedy of commons, Hardin's paradigm has been explicitly acknowledged to be failing because of its confusion of common property with "open access" (Ciriacy-Wantrup and Bishop 1975). The social factors identified as deficiencies or courses of deficiencies in livestock – rangeland management, which results into uneven and negligent grazing distribution pattern thus together serve to be components responsible for communal rangeland degradation. The rampant grazing management practices precede communal rangeland degradation and could be dependent on community organisation. Community organisation would predominately be in terms of establishment of local level institutions to govern rangeland resource utilisation. The major question would be "could the failure of Hardin's paradigm as described by Ciriacy-Wantrup and Bishop (1975) for the communal system be corrected through institutionalisation?" The recognition of the failure of Hardin's paradigm has subsequently influenced development of the "new institutionalist" paradigm. This paradigm recognises the fact that the commons can be managed sustainably on communal bases and formally defines the social and institutional environment necessary to facilitate this (Berkes *et al*. 1989, Ostrom 1990).

Land users indicated that there are no institutions governing rangeland utilisation, however, little acknowledgement of the existence of institutions such as the chief and the tribal council was given, however, they were sceptical about their functionality. Lack and/or ineffectiveness of local institutions to govern communal rangeland resources would prove it difficult to plan, implement, and monitor communal rangeland management or any other intervention to halt and reverse rangeland degradation. The lack of effective institutions charged with overseeing rangeland management has been reported as one of the main limitations to the existence of functioning common property resources (CPRs) (Ainslie 1999, Bennett and Barrett 2007; Moyo *et al*. 2008). Bennett *et al*. (2010) further indicated that the communal grazing lands of central Eastern Cape Province, struggle in most areas both within and between communities, over the management of common pool grazing resources. Moyo *et al*. (2008) highlighted the absence and ineffectiveness of the local-level institutions and structures monitoring access and use of rangeland in most villages of Eastern Cape.

The perception that the local institutions are partially or non-existent, accompanied by the uneven grazing distribution pattern could suffice the social and ecological drivers for communal rangeland degradation. Communal farmers perceive that the solution to rangeland degradation lies on fencing. Institutionalism could work very well in improving communal rangeland management propositions compared to the perceived fencing panacea. Moyo *et al*. (2008) emphasised the need for local-level institutions and supported that with the fact that fences are being stolen suggesting a need for strong local-level institutions. The perception of fencing as a solution to enhance rangeland management and reduce rangeland degradation articulated by land users especially based on the reasons for fencing could practically be counteracted and/or complemented by introduction of local institutions. Rohde *et al*. (2006) illustrates how the promotion of Rangeland Management Associations (RMAs) in Lesotho without fencing is the culmination a century of livestock development and rangeland management policies. Some of the results of local institutions in rangeland management as observed in Lesotho's RMAs include improvement of species composition and accumulation of organic matter. The community members in Lesotho attributed the improvement on rangeland condition at the RMAs to proper monitoring of the rotational grazing system that had allowed recovery and regeneration of some species (Rohde *et al*. 2006). On the other hand, Marake (2000) indicated that there were higher levels of organic matter on soils in the RMA compared to off-RMA and that was attributed to the greater levels of erosion in off-RMA areas. RMAs were promoted by USAID, based on the model used for Native American Reserves in the USA (Quinlan 1990).

To address rangeland degradation problem, livestock production and rangeland management should be objectified if both economic and ecological functions of communal rangelands are to be earned. The concept of unmanaged grazing distribution pattern combined with low level of farmers' and community accountability underlined by lack of effective institutions and policies has lead to poor degree of interaction between farmers, livestock, and rangelands. That has subsequently resulted into degradation of rangeland resources, therefore, this emphasises the need for rationalisation of utilisation and management of communal rangelands in order to increase rangeland ecological and economical efficiency. Rohde *et al*. (2006) present the proponent where introduction of local level institutions was used in rationalisation of livestock production and communal rangeland degradation management in Lesotho. The Lesotho RMA's were designed to promote commercial livestock production and communal rangeland improvement based on the idea that high animal stocking rates drove rangeland degradation and lead to low productivity.

The RMA concept had number of objectives centred on the improvement of rangeland management through a formation of grazing associations, animal improvement through the establishment of an association stud service and livestock extension activities, and promotion of higher levels of market off-take of livestock products (Rohde *et al*. 2006). Rationalisation of communal rangeland utilisation and management could therefore, be achieved through and should be based on the participatory development principles and practices. In this study, the suggestions in approaching rationalisation of communal rangeland utilisation and management are that: (i) there should be clearly set rangeland utilisation and management objectives and such should be aimed at promoting both community livelihoods and primary productivity. (ii) Identification of rangeland management activities, which would help in attaining the set objectives. (iii) Establishment of strategies for implementation and monitoring of selected activities. (iv) Evaluation procedures for the output in the short, medium and long- term. (v) Finally, the establishment of procedures and strategies for sustaining favourable output and long term institutional, economic and ecological development of the whole community.

Degraded communal rangelands have lost their vegetation structure and that could be expressed by few vegetation species with low ecological status. That has lead to the loss of ecosystem functions such as forage productivity, soil protection, nutrient cycling, and rangeland hydrological properties. Land degradation is reflected in a decline of land productivity and that because of cyclical causes and effects result in a depletion of the plant cover, soil exposure to erosion, reduction of soil organic matter and nutrient content, and deterioration of soil structure (Sanchez *et al*. 2002). Despite recognition and acknowledgement of the fact that communal rangelands are degraded, there was no attempt to restore these areas by the land users. However, farmers perceive that degraded rangelands can recover if grazing practices such as rotational resting, introduction of plant propergules, introduction of plants that can hold soil particles together such as agave, building catch dams and fencing of the rangelands could be installed. Improvement in grazing management as indicated in the above sections can yield remarkable recovery of degraded rangelands and that could restore their ecological functions. However, natural recovery of degraded rangelands supported by proper management could take longer to occur. Thus, ecosystem functions cannot recover solely through-improved management strategies within practical-relevant time span and hence, active rehabilitation techniques are sought (Dregne 2002). Therefore, to hasten the vegetation and soil recovery on degraded rangelands, restoration should be considered. Restoration is commonly considered as an accelerated succession (Hilderrbrand *et al*. 1993).

Therefore, management of communal rangelands to reduce the impact of land degradation should consider strongly the preventative and restorative measures. Both sets of measures could be successful if the socio-economic and ecological drivers for land degradation could be identified and used as the background for decision support system. Thus, elimination of the causes of rangeland degradation could remedy the scourge in communal areas. Preventative measures are related to the causes of land degradation (Young 2000), thus, identification of the causes of degradation is based on rangeland degradation preventative theories.

Preventative strategies to communal rangeland degradation should therefore, consider the installation of local level institutions, skilling of the farmers and communities on livestock-rangeland management and development and/or review of local policies to be used for utilisation and management of these ecosystems. This should further consider the fact that areas such as valley bottom, grassland vegetation, closer proximity to homesteads and water points, and wet season are more attractive to livestock and therefore, subject to overgrazing and susceptible to rangeland degradation. This therefore, calls for the control of livestock grazing distribution pattern, thus there are areas that are vulnerable to overgrazing due to their physical characteristics. Although an amendment of rangeland management with consideration of the foregoing assertions can improve rangeland productivity, natural recovery would alone take longer time to get to the required stage through successional processes. Therefore, rangeland restoration practices should be considered in the enhancement of rangeland vegetation production recovery and soil conservation. Successful rangeland restoration will result in an improved productivity and environmental conditions (Hai *et al*. 2007).

Rangeland restoration should consider the use bioengineering techniques such as brushpack, microcatchments, and water spreading systems. These are intended to collect and store soil water through increased infiltration and reduced evaporative loss (Thurow 2000). In the absence of soil seedbank, the use of bioengineering techniques will not hasten recovery, therefore, it is important to introduce plant propagules, which will utilize the retained soil water for germination, establishment, and growth. Seed germination and/or seedling establishment depends on the development of "microsites" and that could be in the form of brushpacks or microcatchments or their combination. The objective of various methods of vegetation restoration among others is creating favourable microsites to enable seeds to germinate and establish successfully (Gebremeskel and Pieterse 2008).

In rangeland restoration, it is important to pre-set the target ecosystem condition, which should be done with consideration of the fact that degradation process could have taken longer to occur. However, it is important to note that restoration is aimed at stimulating recovery faster than natural and therefore, identification of barriers of natural recovery becomes fundamental. Rangeland restoration may not need to follow the entire sequence of degradation stages to reach the target ecosystem, but may skip partially degraded portions. Restoration exercise may need to use bypasses to reach a particular referenced ecosystem and thus additional efforts may be required especially when aggradative and degradative trajectories vary (Cortina *et al*. 2006). It is important to further note that, although additional efforts for restoration will increase the rate of recovery such efforts are costly and depend on climatic and biological factors. These factors constrain the rates of passive recovery on degraded rangelands (Milton and Dean 1995).

It is significant to identify the rangeland ecosystem functions and select of the functions to be restored first. Degraded rangelands are normally poor in hydrologic conductivity with higher unconfined compressive strength, that results into poor water retention and subsequently poor vegetation cover, which in turn leads to high run-off and soil erosion. Thus, the rangeland soil protection function (vegetation cover) becomes impaired because of degradation. The other important ecosystem function would be forage production, which translates to animal production and nutrient cycling. Restoration success indicated by improved soil cover, soil moisture retention, would lead into reduced soil erosion and subsequently into the improved forage production.

It is fundamental in rangeland restoration to establish the relationship between ecosystem structure and function. Thus, when the ecosystem structure is poor the functions will also become affected and the opposite is true. The logical implication is that, if the vegetation structure is improved through restoration, the functions of the ecosystem will be improved as well. Bradshaw (1984) and Cortina *et al*. (2006) indicated that the linear structure and function (LSF) model for reclamation of derelict land assumes a linear increase in ecosystem function with an increase in complexity of its structure. Thus, when the structure of an ecosystem is improved then linearly the function will be improved.

Although rangeland degradation could be caused by uncontrolled grazing distribution pattern that is presided by lack of effective policies, lack of obligation from the farmer and/or community and lack of local institutions, climatic variations such as drought and/or flood could be also predisposing factors. It is therefore, important to consider that there are no straight away connections of rangeland degradation to grazing without considering the effects of climatic variations. The causes of rangeland degradation could therefore, be considered complex and multi-linked, the underlying causes occur at larger scales than can be influenced by the actions of land users alone (Kerven *et al*. 2003).

8.2. Conclusions

The null hypothesis that communal farmers have skills in rangeland management, take livestock grazing pattern as their obligation, have effective policies governing utilisation of rangeland resources, and have effective local institutions overseeing rangeland management was rejected. Thus, communal farmers have no skills on livestock-rangeland management, they do not take livestock grazing management as their obligation, and they do not have effective policies and institutions for rangeland management.

The null hypothesis that communal rangeland degradation occurrence is not different compared to controlled grazing areas, is not different between landscapes within communal rangelands, is not characterised by poor forage production and vegetation cover, high soil compaction with low infiltration rate and soil loss was rejected. Thus, communal rangelands were more degraded than controlled grazing areas, degradation within communal areas varied between landscapes, communal rangelands are characterised by poor forage production and vegetation cover, high-unconfined compressive strength, low hydraulic conductivity and soil loss.

The null hypothesis that grazing distribution pattern in communal areas is not affected by landscape, vegetation type, land use practices, seasonal climatic changes and grazing distance from drinking points was rejected. Grazing distribution pattern was affected by landscape, vegetation type, land use practices, distribution of water points and seasonal variations. Thus, animal grazing concentration was high at the low-lying grassland areas closer to water points and they were concentrated into larger herds during wet season. This implies that grazing pressure was not distributed evenly, thus there were areas that were grazed more compared to the adjacent areas, and therefore, rangeland degradation can be associated with poor grazing distribution.

The null hypothesis that rangeland restoration exercise is not dependent upon water availability in the soil and therefore, could not be improved by restoration techniques that promote collection and retention of water and introduction of plant propagules was rejected. Successful rangeland restoration treatment is dependent on ability of the restoration techniques to collect and retain soil water to be utilised by introduced plant propagules.

Rangeland degradation in communal areas is characterised by poor forage production and soil protection resulting from vegetation change, which successively results from change in species composition, and reduced vegetation cover. Rangeland degradation was further indicated by poor soil hydraulic conductivity and high-unconfined compressive strength. This in turn resulted into soil loss, which was characterised by the presence of pedestals, terracettes, rills, and gullies. Rangeland degradation characteristics indicate high run-off rate, which could be attributed to poor vegetation cover, low soil hydraulic conductivity, and high-unconfined compressive strength resulting from overgrazing and trampling. Communal rangeland degradation is preceded by poor grazing management, which could be explained by the set of social and biophysical factors. The social factors include lack of skills on livestock-rangeland management for farmers, lack of individual and/or community obligation on rangeland management, lack and/or ineffective policies and institutions governing rangeland utilisation and ensuring proper communal rangeland management.

These social factors subsequently resulted into undefined grazing distribution pattern, thus animal movement within and between rangeland portions were not managed, therefore, animals were selecting areas to graze based on their preference. That has resulted into preferred areas being utilised more than their adjacent areas and that resulted into areas of higher utilisation being degraded. Farmers perceived that low-lying areas were more degraded than higher-lying areas. This was confirmed with biophysical assessment for grazing pattern and degradation occurrence. Thus, low-lying areas experienced higher grazing intensity and therefore, became more degraded. The major factors that influence grazing distribution pattern in communal areas include landscape, land use, proximity to homestead and water points, and seasonal variations.

Improvement of rangeland management in communal areas of Eastern Cape can be achieved through capacity building of the farmers on livestock-rangeland management, introduction of livestock movement control measures, development of effective rangeland management policies, and introduction of local level institutions. The lack institutional structures result in lack of rules or difficulties in enforcing grazing management rules (Ainslie 1998; Bennett *et al*. 2010). Whilst the foregoing social factors are important in improving communal rangeland management, the biophysical factors such as landscape, land use, distribution of water points within rangelands and the proximity of rangeland portions to homesteads should be considered in any communal rangeland management plan.

However, the improvement of rangeland management through incorporation of social and biophysical factors alone would take a longer time for the recovery of degraded communal rangelands. Therefore, restoration of rangelands should be considered if the quick recovery should be realised. Restoration should target at improving both ecosystem structure and function. The major ecosystem functions of communal rangeland could be categorised into economical and ecological. Therefore, restoration should address both functional categories, thus, it should emphasise on the improvement of forage productivity and soil protection, which leads to enhanced livestock productivity. If these ecosystem functions are restored, ecological functions such as improved rangeland hydrology and nutrient cycling could be attained.

Rangeland restoration should utilise the bioengineering techniques and such techniques should be selected based on their ability to collect and store rainwater for the use by introduced plant propagules. The bioengineering techniques include the use of bruchpack, microcatchment, and water spreading systems. The use of brushpack and microcatchment and/or their combination has been found to yield successful restoration output.

In conclusion, it is important that any interventions aimed at improving communal rangeland management, controlling rangeland degradation in the communal areas, or restoring degraded rangelands to consider the social factors driving rangeland management and biophysical factors influencing grazing distribution. Rangeland restoration techniques for communal areas should be centred on their ability to collect and retain water to support introduction of plant propagules.

8.3. Recommendations

It is recommended that communal rangeland management be rationalised. This can be achieved by objectifying livestock production and rangeland management. Thus, objective rangeland management should consider four important prospects. These are; (i) establishment of an objective rangeland management program, which should include community setting of livestock-rangeland management objectives; (ii) identification of activities that can aid in attainment of the set objectives; (iii) monitoring strategies of the progress and measurement of the rangeland management output; and (iv) finally, restoration of the degraded rangeland, this should begin with identification of barriers of vegetation natural recovery and restoration should target addressing such barriers.

The development of rangeland access and utilisation policies, capacity building of farmers on livestock-rangeland management, strengthening farmers' responsibility on livestock grazing movement and institutionalisation of communal system could assume some positive results. Farmers' responsibility could be strengthened through introduction of kraaling and herding and in turn, this can influence the practicality of rotational grazing in the communal areas.

Consideration of employment of people for herding could improve livestock production and rangeland management compared to fencing. Considering the wideness of communal rangeland areas in South Africa, it will be unbearably and unsustainably expensive to fence and maintain fences. Furthermore, with the evidence of vandalism from the side of community residents experienced from the previous fencing in some areas, fencing exercise might be a waste. In contrast, with consideration of the rates of unemployment and low livestock productivity in communal areas, employment of people for herding might be relatively beneficial and that would address local household income, livestock production improvement, and rangeland management. Thus, with the proposed capacity building, livestock herders would be trained on basic livestock and rangeland management practices and that will improve the interaction between herders, herders and livestock and herders and rangeland ecosystems. This interaction will help in identifying early livestock production related problems and rangeland condition trends. The improvement of livestock-rangeland responsibility of farmers would influence the grazing distribution pattern and that will reduce grazing pressure on areas that are more susceptible. That will subsequently result into resting some areas and will lead in recovery of degraded rangelands and will subsequently result in reduced rangeland degradation.

It is further recommended that restoration of degraded rangelands be introduced in communal rangeland management policies in South Africa if the quick recovery is to be attained. Disturbance (grazing) has been identified, as one of the major barriers of natural recovery and in the absence of fencing, the control of disturbance brought by grazing might be impossible. However, an introduction of herding and daily kraaling practices can reduce the intensity of disturbance on restored areas. Furthermore, because of poor vegetation cover in degraded rangelands predisposes the land to accelerated runoff, which in turn results in water and soil loss from the system. Therefore, restoration techniques that improve soil water collection and retention such as development of microcatchment, use of brushpack and water spreading system (diversion/conversation furrows) could lead to a successful restoration in communal rangelands.

Further avenues for research include:

- Rangeland degradation has been caused by certain predisposing factors; however, poor management largely contributes. Such factors could still exist after restoration and therefore, might still pose a challenge on restored rangelands. Therefore, a follow up research on post rangeland restoration management is recommended.

- Recovery of degraded rangelands and their sustained productivity largely depends on the ability of the ecosystem to collect and retain water. Therefore, it recommended that further research on rangeland water dynamics in communal rangelands be conducted. This will result in developing management practices that promote healthy rangeland hydrology.

- Rangeland restoration results ought to indicate stability and sustainability. These variables can be recognised after a long time in the natural ecosystem and can provide succession trend over time and that warrant a need for follow up research. Therefore, it is recommended that restoration-monitoring research be conducted.

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APPENDIX 1: COMMUNITY VISIT PROGRAMS AT AMAKHUZE TRIBAL AUTHORITY

Village	Date	Activity
	09-04-2008	**Meeting with the Amakhuze Tribal council** ➢ Introduction of the project ➢ Setting dates for community meetings
Guquka	23-04-2008	**Participatory rural appraisal (PRA)** 1. Introduction of the project to the village members 2. Identification of the expectations of community members from the project 3. Identification and mapping of community resources 4. Focus group discussions (Youth, Women, and Men) 5. Transect walk
Makhuzeni	14-05-2008	**Participatory rural appraisal (PRA)** 1. Introduction of the project to the village members 2. Identification of the expectations of community members from the project 3. Identification and mapping of community resources 4. Focus group discussions (Youth, Women, and Men) 5. Transect walk
Gomro	11-06-2008	**Participatory rural appraisal (PRA)** 1. Introduction of the project to the village members 2. Identification of the expectations of community members from the project

		3. Identification and mapping of community resources 4. Focus group discussions (Youth, Women, and Men) 5. Transect walk
Mpundu	02-07-2008	**Participatory rural appraisal (PRA)** 1. Introduction of the project to the village members 2. Identification of the expectations of community members from the project 3. Identification and mapping of community resources 4. Focus group discussions (Youth, Women, and Men) 5. Transect walk
Gilton	23-07-2008	**Participatory rural appraisal (PRA)** 1. Introduction of the project to the village members 2. Identification of the expectations of community members from the project 3. Identification and mapping of community resources 4. Focus group discussions (Youth, Women, and Men) 5. Transect walk
Sompondo	13-08-2008	**Participatory rural appraisal (PRA)** 1. Introduction of the project to the village members 2. Identification of the expectations of community members from the project 3. Identification and mapping of community resources 4. Focus group discussions (Youth, Women, and Men) 5. Transect walk

APPENDIX 2: PARTICIPATORY RURAL APPRAISAL (PRA) AND FOCUS GROUP DISCUSSION AT AMAKHUZE TRIBAL AUTHORITY

Program

1. General introduction of the project

Objectives of the research project

Benefits to communities from the project

Responsibilities of community members on the project

Expected output from the project

Duration of the project

2. Identification of the expectations of community members from the project

Identification of the strengths of the communities

Identification of opportunities that the communities have

Identification of the community weaknesses

Identification of community threats

3. Identification and mapping of community resources

4. Focus group discussions (Youth, Women, and Men)

Subjects for discussion at different focus group meetings

- Socio-economic issues

    - Community sources of income
    - Farming practices
    - Food availability
    - Community financial spending
    - Institutions/ community governance structures
- Policy issues
    - Community rules and regulations
    - Rules governing use of resources in the community
    - Access to community resources
- Farming practices
    - Crop production
    - Animal production
    - Rangeland management
- Rangeland management, degradation and restoration

5. Transect walk

General view of the village infrastructure (Schools, churches, community halls, crop production fields, livestock handling facilities, rangeland, dams, and rivers).

APPENDIX 3: SUMMARY OF PARTICIPATORY RURAL APPRAISAL (PRA) AND FOCUS GROUP DISCUSSION AT AMAKHUZE TRIBAL AUTHORITY

	Makhuzeni	Gomro	Mpundu	Gilton	Guquka	Sompondo
Youth	15	9	7	10	12	8
Women	23	16	18	15	16	14
Men	29	17	19	21	25	22
Total attendance	**67**	**42**	**44**	**46**	**53**	**44**
Identification of the expectations of community members from the project						
Identification of the strengths of the communities	Cattle production Sheep production Availability of water Availability of rangelands	Cattle production Availability of water Availability of arable land	Cattle production Availability of water Availability of arable land	Cattle production Availability of water Availability of arable land	Cattle production Vegetation gardens Indigenous chicken Availability of water Availability of rangelands	Cattle production Sheep production Availability of water Availability of rangelands
Identification of opportunities that the communities have	Getting better cattle breed through Fort Hare Nguni Project	Collaborating with Fort Hare to use arable land	Collaborating with Fort Hare to use arable land	Collaborating with Fort Hare to use arable land	Getting better cattle breed through Fort Hare Nguni Project	Getting their sheep breed improved through Ram program
Identification of the community	Lack of rangeland	Lack of rangeland	Lack of rangeland	Lack of rangeland	Lack of rangeland	Lack of rangeland

weaknesses	fencing. Laziness. Lack of knowledge.	fencing. Lack of arable land fencing. Lack of knowledge.	fencing Lack of arable land fencing Lack of knowledge	fencing. Lack of arable land fencing. Lack of knowledge.	fencing. Poor commitment of the youth in agriculture. Lack of knowledge.	fencing Poor commitment of the youth in agriculture Lack of knowledge
Identification of community threats	Stock theft Rangeland burning Land degradation Livestock diseases	Rangeland burning Stock theft Livestock diseases	Rangeland degradation Rangeland burning	Rangeland degradation Rangeland degradation	Stock theft Rangeland burning Land degradation Livestock diseases	Stock theft Rangeland burning Livestock diseases
Identification and mapping of community resources						
Water sources	Rivers, dams	Rivers, dams	Rivers, dams	Dams	Dams	Wetlands, Rivers, dams, natural wells, water falls
Active crop production avenues	Arable land in use	Arable land in use	Arable land in use	Home gardens Arable land in use	Home gardens, Arable land in use	-
Abandoned arable lands	+	+	+	+	+	+
Mountains	+	+	+	+	+	+
Roads	+	+	+	+	+	+
Schools and churches	+	+	+	+	+	+
Crave yards	+	+	+	+	+	+

Rangelands		+	+	+	+	+	+
Forest		-	-	-	-	+	+
Focus group discussions (Youth, Women, and Men)							
Youth	**Socio-economic issues**						
	Sources of income	Farming (animal and Crop), employed brothers and sisters	Farming (animal and Crop), employed relatives	Farming (animal and Crop), part time jobs	Farming (animal and Crop), dress making, selling food items	Farming (animal and Crop), selling food items	Farming (animal and Crop), part time jobs
	Source of food	Farming	Farming	Farming	Farming	Farming	Farming
		Govenment food packages	Govenment food packages	Govenment food packages	Govenment food packages	Govenment food packages	Govenment food packages
	Policy issues	No rules govening use of natural resources	No rules govening use of natural resources	No rules govening use of natural resources	No rules govening use of natural resources	No rules govening use of natural resources	No rules govening use of natural resources
	Farming practices	Animal production (Cattle, sheep, goats)	Animal production (Cattle, sheep, goats)	Animal production (Cattle, sheep)	Animal production (Cattle, sheep)	Animal production (Cattle, sheep, goats)	Animal production (Cattle, sheep, goats)
		Field crop production	Vegetation production	Vegetation production	Vegetation production	Vegetation production	Vegetation production
Women	**Socio-economic issues**						

	Source income	Social grants Selling chicken and eggs, From employed children	Social grants Selling chicken, From employed relatives	Social grants Selling vegetables	Social grants Selling vegetables From employed children	Social grants Selling chicken and eggs	Social grants Selling vegetables From employed relativs
	Source of food	Purchase food	Purchase food	Purchase food	Purchase food	Purchase food	Purchase food
		Govement food package	Govement food package	Govement food package	Govement food package	Govement food package	Govement food package
	Policy issues	The are rules gonerning the use of natural resources	The are rules gonerning the use of natural resources	The are rules gonerning the use of natural resources	The are rules gonerning the use of natural resources	The are rules gonerning the use of natural resources	The are rules gonerning the use of natural resources
		Rangelands access by every recident	Rangelands access by every recident	Rangelands access by every recident	Rangelands access by every recident	Rangelands access by every recident	Rangelands access by every recident
		Controlled by tribal counsil	Controlled by tribal counsil	Controlled by tribal counsil	Controlled by tribal counsil	Controlled by tribal counsil	Controlled by tribal counsil
	Farming practices	Vegetable production (home garden)	Vegetable production (home garden)	Field crop production (maize)	Vegetable, field crop production	Vegetable production	Vegetable production
		Cattle, sheep and goats	Cattle, sheep and goats	Cattle, sheep and goats	Cattle and goats	Cattle, sheep and goats	Cattle, sheep and goats
Men	**Socio-economic issues**						

	Source income	Livestock sale, wool, vegetable sale, piece jobs, social grants,	Livestock sale, vegetable sale, piece jobs, social grants,	Livestock sale, vegetable sale, piece jobs, social grants,	Livestock sale, vegetable sale, social grants,	Livestock sale, wool, vegetable sale, piece jobs, social grants,	Livestock sale, vegetable sale, social grants,
	Source of food	Not enough, buy food	Not enough, buy food	Not enough, buy food	Not enough, buy food	Crop and animal production, buy food	Not enough, buy food
	Policy issues	There are rules for natural resources	No rules for natural resources	No rules for natural resources	No rules for natural resources	There rules for natural resources	There are rules for natural resources
	Farming practices	Animals production - Cattle, sheep, goats	Animals production - Cattle, sheep, goats	Animals production Cattle, sheep, goats	Animals production Cattle, sheep, goats	Animals production – Cattle and goats	Animals production - Cattle, sheep, goats
Youth	**Rangeland management, degradation, restoration**						
	Rangeland management	There are rules for rangeland management	No management, no rules, no restrictions	No management, no rules, no restrictions	No management, no rules, no restrictions	No management, no rules, no restrictions	No management, no rules, no restrictions
	Rangeland degradation	Rangelands are degraded Indicators are presence of gullies	Rangelands are not degraded good vegetation (green)	Rangelands are degraded Indicators are presence of poor vegetation species	Rangelands are degraded Indicators are presence of gullies	Rangeland are not degraded	Rangelands are degraded Indicators are presence of patches and gullies

	Rangeland restoration	Cannot be restored	Can be improved – by management	Cannot be restored	Cannot be restored		Cannot be restored
Women	Rangeland management	There are rules but not implemented	There are no rules	There are rules but not implemented	There are rules but not implemented	There are rules but not implemented	There are rules but not implemented
	Rangeland degradation	Rangelands are degraded Indicators are bare vegetation patches, gullies, rills	Rangelands are degraded Indicators are gullies,	Rangelands are degraded Indicators are gullies, rills	Rangelands are degraded Indicators are gullies, rills	Rangelands are degraded Indicators are poor grass species, rills	Rangelands are degraded Indicators are gullies, rills
	Rangeland restoration	Can be restored by planting trees	Can be restored by planting agave	Can be restored by planting trees	Can be restored by building stone walls	Can be restored by planting trees	Can be restored by planting trees
Men	Rangeland management	There are rules and are implemented by the tribal council	There are rules and are implemented by the tribal council	There are rules but are not implemented	There are rules but are not implemented	There are rules and are implemented by the tribal council	There are rules and are implement by the tribal council
	Rangeland degradation	Rangelands are degraded Indicators are vegetation change, bare patches, gullies, rills	Rangelands are degraded Indicators are bare patches, gullies, rills	Rangelands are degraded Indicators are vegetation change, gullies	Rangelands are degraded Indicators are vegetation change, bare patches, gullies, rills	Rangelands are degraded Indicators are vegetation change, bare patches, rills	Rangelands are degraded Indicators are vegetation change, bare patches, gullies, rills

	Rangeland restoration	Planting agave, building stone structure, making divesion farrows	Planting agave, building stone structure, making divesion farrows	Planting agave, building stone structure, making divesion farrows	Planting agave, building stone structure, making divesion farrows	Planting agave, building stone structure, making divesion farrows	Planting agave, building stone structure, making divesion farrows
Transect walk		1hr walk across the rangelands with the community members	1hr walk across the rangelands with the community members	1hr walk across the rangelands with the community members	1hr walk across the rangelands with the community members	1hr walk across the rangelands with the community members	1hr walk across the rangelands with the community members

Note: + = Identified on the map by the community, - = Not identified on the map by the community

APPENDIX 4: QUESTIONNAIRE SURVEY ON COMMUNAL RANGELAND DEGRADATION AT AMAKUZE TRIBAL AUTHORITY

Enumerator's name ______________________ Date ______________ Village ______________________________.

Name of respondent_________________________________ Questionnaire reference number_______________

A. HOUSEHOLD DEMOGRAPHIC INFORMATION

	Relation to head	Age	Gender	Marital status	Education	Occupation	Involvement in rangelands
*A1.1							
A1.2							
A1.3							
A1.4							
A1.5							
A1.6							
A1.7							
A1.8							
A1.9							

Codes:

Relation to head: **1** Head, **2** Spouse /husband, **3** Child, **4** Grandchild, **5** Father or mother, 6 Other
Marital status**:** (**S**) single (**M**) married (**D**) divorced or separate **(W) w**idow
Education: **1** Preschool, **2** Up to STD 5, **3** STD 6-9**, 4** STD 10, **5** Tertiary, **6** None
Status: (**F**) farming (**H**) household wife, (**E**) employee (**P**) pensioner (**B**) business (**N**) no occupation (**S**) student

A2 Household size_________ Adults __________ Children (less than 13 years) ____________________

A3 Gender of the household head _________________

B. LIVESTOCK PRODUCTION

B1. Numbers and livestock species kept (Tick if kept & Put down the numbers)

Cattle		Sheep		Goats		Donkeys		Pigs		horses	

B2. Infrastructure for cattle (livestock handling)

Infrastructure	**A**	**N/A**	**Present condition**	**X**
Handling Facilities			Good	
Dipping Facilities			Fair	
Sale pens			Poor	
Stock Watering Facilities			Very poor	

B3. Comment on the availability of grazing in the different seasons of a year

Season	**Enough**	**Too little**	**Moderate**	**Too much**
Wet season				
Dry winter:				

B24. Do you give any supplementary feed to your animals? Yes☐ No☐ If yes:

(a) At which time of the year? ____
(b) How often do you feed animals with supplementary feed? _________________________________

B4. Who decides when to allow livestock in the arable fields/ home gardens? ________________________________
____

B5. What impact has this practice on the fields/ gardens? ______________________________________
____

B6. Do men consult women on livestock development programmes? ______________________________
____

B7. Do men and women work together on livestock development programmes? _____________________
____

B8. How do women cope with the additional responsibilities of keeping livestock?______________________
____

B9. Are female farmers involved in farmers associations/ organizations? Yes☐ No☐

B10. What is the role of females in farmers associations? _______________________________________

D11. Are the youth involved in livestock production? Yes☐ No☐ If yes, how:

____

B40. How can institutions, such as UFH, assist in livestock production? ____________________________
____

C. RANGELANDS/GRAZING

C1. Do you have access to rangeland? Yes☐ No☐

C2. How did you obtain access?

By virtue of being resident in this community	
Through an application to the Tribal Authority	
Through an application to the village committee	
Local Authority	
Other (specify)	

C3. What threat do the neighbouring communities put to your rangeland? ___________________________
____

C4. How is access to the grazing land controlled? By whom?

Tribal Authorities		Farmers Association	No one		Other(specify)

C5. Do you have grazing rules on your rangelands? Yes ☐ No☐

C6. Who formulates the grazing rules for the community? _______________________________________

C7. Who monitors that users of the grazing land adhere to the rules and regulations? __________________

C8. Rangeland is accessed for?

Uses	Yes/ No	Season of access(summer, winter, year round)
Grazing/browsing of animals		
Collecting fire wood		

Collecting wood and grass for building and fencing		
Collecting plants for medicinal purposes		
Collecting dry dung for cooking		
Other (specify)		

C9. Are there times of restricted access to rangelands Yes ☐ No ☐

C10. If Yes, Which month/s____

C11. Are there any restrictions to quantities of harvested resources ____________________________________

C12. Frequency of kraaling animals (tick appropriate) and state reasons, benefits & disadvantages

	Cattle		Sheep		Goats		Donkeys		Horses	
	Time kraal	Time release	Time kraal	Time release	Time kraal	Time release	Time kraal	Time release	Time kraal	Time release
Daily										
Once a week										
Only on dipping days										
Other (specify)										

C13. How do you minimise neighbouring communities from utilising your resource excessively? _______________
____

C14. At what time of the year would you experience a shortage in grazing?
____

C15. What could be the cause of such a shortage?
____

C16. Does your community have grazing camps? Yes☐ No☐

C17. If yes, what is the purpose of camps? ____

C18. Do you manage livestock movement during grazing?

a) Permanently (daily) Yes ☐ No ☐ if yes, who? ____________________________
b) Monthly Yes ☐ No ☐ if yes, who? ____________________________
c) In Summer Yes ☐ No ☐ if yes, who? ____________________________
d) In Winter Yes ☐ No ☐ if yes, who? ____________________________
e) When rain comes? Yes ☐ No ☐ if yes, who? ____________________________
f) Free ranging? Yes ☐ No ☐ if yes, who? ____________________________

C19. What are the sources of water for your animals? (Tick one or more)

Borehole ☐ Dam/pond ☐ River ☐ Water well ☐ Spring ☐
Others (specify) ______________

C20. What is the distance to the farthest water point from the grazing area?

At household ☐ < I km ☐ 1 to 5 km ☐ 6 to 10 km ☐ > 10 km ☐

C21. Do you have a problem of water for livestock drinking? Yes☐ No☐

C22. Does location at which animals are grazing change with seasons? Yes ☐ No☐ Not sure ☐

C23. Within the rangelands, where do the animals graze in?

Winter ____

Summer____
Autumn ____
Spring ____

C24. Which species of animals are observed to be moving a lot with seasonal changes?
Cattle ☐ Sheep ☐ Goats ☐ horses☐, donkeys ☐

C25. What influences the seasonal movement of animals within the rangelands? ______________________________
____

C26. Which areas are normally preferred for grazing? Mountaintop ☐ mountainside ☐Foothills ☐Valleys ☐

C27. How is the landform for the areas that are selected mostly by animals? Linear (flat) ☐ , Sloppy☐

What influence does the grazing preference of the different areas within the rangelands? ________________________
____

C28. What control measures need to be put in place to ensure a sustainable utilization of the grazing resource?
____
____

C29. What problems or constraints do you face in management of grazing areas?
____
____

C30. Do you receive any advice from extension services on rangeland management? Describe the type of advice.
____
____

C31. How has this advice influenced the grazing management in the community?
____
____

C32. Do you use arable land/home gardens for grazing purposes? Yes☐ No☐
If yes when and why?
When ____ Why____

C33. Are your grazing lands fenced? Yes☐ No☐
C34. If **yes**, who did the fencing ____?

C35. If **no**, do you need fences? Yes☐ No☐

C36. How would you describe the state of fencing in your grazing lands? Good☐ Bad☐. If bad why?
____
____

C37. Is the community doing any repairs on fencing? Yes☐ No☐
If yes what type of repairs____

C38. Who provides resources for repair of fences? ____

D. RANGELAND DEGRADATION

D1. Are the rangeland regularly burned? Yes☐ No

D2. Who decides on burning of rangelands? ____

D3. Why are the rangelands burned? ____

D4. How would you describe the condition of the rangeland?

Very- Poor Condition Little Grass	
Poor Condition, but Some Grass	
Fair - Reasonable Amount of Grass	
Good - Plenty Grass	
Very Good-a lot of grass	
I don't know	

D5. What has led to the current state of rangelands (tick one or more)?

Grazing practices		Burning		Bush encroachment	
Soil quality		Land formation		Climate variation (e.g. drought)	

D6. What is the reason for your answer above? ____

D7. What quality status can you assign to your soil?

Very good		Good		Fair		Poor		Very poor	

D8. What is the reason for your answer above? ____

D9. Are the rangelands in your area degraded? Yes☐ No☐ if yes why do you say so ____________________
____

D10. To what level is degradation in your rangeland?

High		Average		Low		None	

D11. If high, do you apply any erosion control measures on your grazing lands? Yes☐ No☐

D12. What soil erosion control measures do you currently use? ______________________________
____

D13. Is the control measure effective? Yes☐ no☐

D14. Which land degradation indicators have observed in the rangelands?

Galleys		Rills		Pedestals		Vegetation change		Soil deposition	

D15. What type of soil erosion is dominant in your grazing areas?

Sheet erosion		Gully erosion		Rill erosion		Other	

D16. What shape of areas that are mostly degraded in the rangelands?

Flat areas		Sloppy areas		Valleys		other	

D17. Where is most of the degradation located within the grazing areas?

Mountaintop		Mountain side		Foothills		other	

D18. How far are the degraded grazing areas from the home states?

Around homesteads		Not very far		Far		Very far	

D19. On what vegetation type are degraded rangelands mostly found within the grazing area?

Grassland		Shrubland		Grass/trees		Forest		other	

D20. Do you think the rangelands can recover from degradation? Yes☐, No ☐

D21. What do you think are the possible methods for rangeland recovery? ______________________________
____

D22. How do you think the rangelands have to be managed in other to prevent land degradation? ______________
____
____

D23. How would gauge your knowledge on rangeland management?

High		Average		Low		None	

D24. Where did you gain this knowledge? ____
____

D25. Have you or the community ever had any training on rangeland management? Yes ☐ No ☐

D26. What kind of training would you or the community like to receive? ______________________________
____

D27. Give five suggestions, which in your opinion can improve communal grazing areas? __________________
____
____
____