Farmers' perceptions of livestock feeding and rangeland management; dynamics of soil, forage and cattle blood serum mineral levels in two communal areas of the Eastern Cape, South Africa

By

Farai Alice GWELO

A dissertation submitted in partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE IN PASTURE SCIENCE

Department of Livestock and Pasture Science, Faculty of Science and Agriculture

University of Fort Hare

University of Fort Hare
Together in Excellence

November 2012

Alice, South Africa

Supervised by:

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Co-supervisor: Prof. V. Muchenje

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Dr S.T. Beyene	**Prof V. Muchenje**
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November 2012

Declaration

I, **Farai Alice Gwelo,** vow that this dissertation has not been submitted to any University and that it is my original work conducted under the supervision of Dr. S. Tefera-Beyene and co-supervision of Prof. V. Muchenje. All assistance towards the production of this work and all the references contained herein have been duly accredited.

______________________________ ____________________

Farai Alice Gwelo **Date**

Livestock production, rangeland management and the mineral levels of soils, grass and cattle blood serum in two communal areas of the Eastern Cape, South Africa.

Abstract

This study was conducted to determine livestock production, rangeland management and the mineral levels of soils, grass and cattle blood serum in two communal areas (Kwezana and Dikidikana). A total of 77 farmers from both Kwezana and Dikidikana were interviewed to determine farmersô perceptions. Soil and grass sampling was done at three sites in each communal area. Soil and grass samples were analysed for N, Ca, Mg, K, P, Fe, Cu, Zn, Mn and Bo. Three, two and half year old Nguni heifers were randomly selected from each communal area and blood samples were collected for the analysis of Ca, Mg, K, Cu and Fe. Soil, grass and blood samples were all collected in two seasons (winter and summer). The results of the study revealed that feed availability was the major constraint in livestock production as indicated by 83% of the farmers at Kwezana and 88% at Dikidikana. At both villages less than 20% practiced supplementation and grazing management. From both villages, 83% of the farmers did not know the forage species preferred by their cattle. The second study revealed significant seasonal variations in soil N in both study areas while forage N exhibited seasonal variations ($P<0.05$) only at Dikidikana. Spatial variation ($P<0.05$) in soil Mn was apparent in both seasons at Dikidikana and in summer at Kwezana. At Dikidikana forage P varied ($P<0.05$) both seasonally and spatially. In both study areas, there was a positive correlation ($P<0.05$) between soil and forage levels of Cu and Zn. The blood serum of animals from both study areas had higher ($P<0.05$) K and Na in winter than in summer.

Farmers do not understand the composition of their rangelands but are concerned about cattle nutrition during winter. Indeed the mineral status of soils, forages and Nguni cattle blood serum tend to vary not only seasonally but also spatially. There is need therefore to assist the farmers to understand these changes in order to find ways of managing the rangelands in a way that will manipulate both seasonal and spatial variations in soil nutrients for the benefit of the grazing livestock. Further research is required to determine the digestibility of the forages and the amount of energy available from these forages for the grazing livestock.

Keywords: Grazing management, supplementation, minerals, winter, summer.

Dedication

I dedicate this work to my mother who has through it all been my guardian angel.

Acknowledgements

I would like to thank Adam Flemming and the Nguni Project Office for funding this project. I am grateful to my supervisors Dr Beyene S.T. and Prof Muchenje V. for all their hard work. My gratitude also extends to Mr Wellington Monwabisi Sibanga and Mr Mweli Nyanga for technical support; Mr Peter Fayemi for coaching during statistical analysis; Prof Michael Pillay and Dr Bethwell Moyo for reviewing the thesis drafts. Many thanks go to the residents of Kwezana and Dikidikana who willingly participated during data collection. My heartfelt thanks extend to my sister Blessing Gwelo, my dear friend Vincent Musekiwa, colleagues, family and friends who kept me encouraged throughout this research. Finally and most importantly, I would like to thank God for this.

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List of abbreviations

AAS	Atomic Absorption Spectrophotometer
ADF	Acid Detergent Fibre
BCMM	Buffalo City Metropolitan Municipality
CEC	Cation Exchange Capacity
CP	Crude Protein
DAFF	Department of Agriculture Forestry and Fisheries
DM	Dry Matter
EDTA	Ethylenediaminetetraacetic Acid
ICP	Inductively Coupled Plasma
IDC	Industrial Development Corporation
IK	Indigenous Knowledge
NDA	National Department of Agriculture
NDF	Neutral Detergent Fibre
SAS	Statistical Analysis System
SPSS	Statistical Package for the Social Sciences

CHAPTER 1: INTRODUCTION

1.1. Background

The rangelands of Southern Africa support diverse and dynamic ecosystems that sustain livestock farming as well as game and wildlife production. A recent report on a livestock census of South Africa showed that the country has 13.8 million cattle, 25 million sheep and 6.4 million goats (Department of Livestock Forestry and Fisheries (DAFF), 2011). The Eastern Cape Province is regarded the ñlivestockò province of South Africa and is a home to 21% of the countryøs cattle, 28% of sheep and 46% of goats (DAFF, 2011). Small-scale production accounts for about 25% of all the beef production in South Africa.

Rangelands are the major source of nutrition for livestock in the arid and semi-arid communal areas of South Africa. Grasses are the major source of nutrients for grazing cattle and sheep and yet forages from natural rangelands rarely satisfy all the essential mineral requirements of grazing livestock throughout the year (Espinoza, Mcdowell, Wilkinson, Conrad and Martin, 1991). It has been reported that mineral concentrations in both soils and plants affect the mineral status and hence the performance of grazing livestock (Espinoza *et al.*, 1991) as it has implications on rates of gain, milk production, reproduction and enterprise profitability (Ball, Collins, Lacefield, Martin, Merterns, Olson, Putman, Undersander and Wolf, 2001). Even under satisfactory forage supply, mineral deficiencies may be present in animals due to low mineral concentrations in soils and forages (Tiffany, Mcdowell, OøConnor, Nguyen, Martin, Wilkinson and Cardoso, 2000).

The performance of livestock on natural rangelands is also affected by the seasonal fluctuation in forage quality and quantity; a common phenomenon on arid and semi-arid rangelands (Berhane and Eik, 2006; Gwaze, Chimonyo and Dzama, 2009). Natural pastures found in the arid and semi-arid environments vary in their chemical composition and structure with season. A number of studies have reported semi-arid rangelands to be characterised by seasonal fluctuations in quality and quantity of forages (Ramirez, Haenlein and Nunezï Gonzalez, 2001; Khan, Hussain, Ashraf and McDowell, 2006; Fardous, Gondal, Shar, Ahmmad, Khan, Ibrahim, Ejaz, Ahmad, Ullah and Valeem, 2010) and this consequently affects the performance of livestock species in the communal areas.

In order to ensure that communal livestock production continues to thrive, the South African government is re-introducing cattle breeds such as the Nguni which perform well under low forage availability and quality and which can survive under droughts (Bester, Matjuda, Rust and Fourie, 2001). The South African Government in recognition of the hardiness of the Nguni breed and its cultural value collaborated with the University of Fort Hare and the Industrial Development Corporation (IDC) to get the Nguni cattle back into rural communities. Therefore, through the Nguni cattle project initiative Nguni cattle production throughout the Eastern Cape, South Africa is expanding throughout the Eastern Cape Province.

Interventions concerning the development and conservation of natural resources in communal rangelands are governed by the belief that communal herders have little technical skills and by the tenets of the ñtragedy of the commonsò paradigm (Hardin, 1968). These are based on the assumption that livestock keepers are selfish, aiming at maximising only short-term off-take and are not embedded in any system of collective norms that might result in a consistent management of the commons (Allsopp, Laurent, Debeaudoin and Samuels, 2007). However, rural communities in different parts of the world have been reported to have a detailed knowledge of grazing lands, forage values of grazing resources, diet selection behaviour of livestock species and nutrient requirements of animals; Oba and Kotile (2001) in three different African countries; Mapinduzi, Oba, Weladji and Colman (2003) in Tanzania and Abate, Ebro and Nigatu (2010) in Ethiopia. According to Abate *et al*. (2010), this knowledge develops through extensive observation and years of herding livestock.

1.2. Problem statement

Farmers throughout the Eastern Cape Province of South Africa continue to benefit from the Nguni Cattle Project. These farmers need to make decisions concerning the feeding of the cattle they receive since they are not given either cattle feed or supplements by the same project. No studies have been conducted to determine the indigenous knowledge and perceptions of the farmers in the communities that are beneficiaries of the Nguni cattle project on livestock feed and rangeland resources management. Furthermore, no studies have been conducted in the Eastern Cape of South Africa, to determine the seasonal and spatial dynamics of forage quantity, crude protein (CP) and mineral levels of the communal rangelands on which these cattle are grazed and the related variation in the mineral levels of Nguni cattle blood serum in the two major seasons, summer and winter.

1.3. Justification

Communal people have been widely reported to rely on their perceptions when making decisions about livestock nutrition and natural resources management (Mapinduzi *et al.,* 2003; Hart, 2007; Abate *et al.,* 2010). This entails that the perceptions of the local people will influence their common resource management strategies and this will in-turn have an influence upon the sustainability of the particular resources. Therefore, an understanding of the perceptions of communal farmers on livestock nutrition and natural resources management is the basic starting point in the prediction of the sustainability of both livestock and rangeland resources under the management of the concerned group. Therefore, this study aimed to determine the perceptions of communal livestock farmers on livestock feeding and rangeland resources management. This study generated information that would be useful in identifying existing and potential challenges pertaining to livestock feeding and rangeland resources management in the communal areas.

The result of the study will be explained in the sections to follow. As already alluded to the study of farmersô perceptions is only a starting point in predicting the sustainability of livestock production and rangeland resources management therefore a second study was conducted to investigate the seasonal and spatial dynamics of forage production and mineral status of soil, forages and Nguni cattle blood serum in the same communal areas. Such information was useful in determining whether the communal rangelands can offer adequate levels of nutrients for the grazing Nguni cattle. The study also provided opportunity to identify possible mineral deficiencies in the soil and plants that may also manifest in the animals. Understanding the seasonal dynamics of forage production and nutrients is vital for the purposes of developing a sound fodder flow and supplementation program to mitigate seasonal scarcity, if any. Ultimately, the study aimed to provide information that would benefit the relevant stakeholders in making informed decisions on the conservation, management and utilization of the rangeland resources to sustain Nguni cattle production, communal farmersô livelihoods and food security.

1.4. Objectives

The objective of this study was to determine perceptions of farmers on livestock feeding and rangeland resources management and the dynamics of the mineral levels of soils, forage and Nguni cattle blood serum in two communal areas of the Eastern Cape, South Africa.

The specific objectives were:

1. To determine the perceptions of communal farmers on livestock feeding and rangeland resources management in two communal areas of the Eastern Cape, South Africa;
2. To determine the seasonal and spatial variation in the mineral content of soil, forage and cattle blood serum in two communal areas.

CHAPTER 2: REVIEW OF LITERATURE

2.1. Introduction

Livestock production in South Africa is an important economic sub-sector contributing about 25ï 30% of the total agricultural output per annum (Musemwa, Mushunje, Chimonyo, Fraser, Mapiye and Muchenje, 2008). The livestock production sector is also important because there is increasing demand for livestock products. Urbanisation and rising income are some of the reasons for the increasing demand for animal source foods. This phenomenon is described as the livestock revolution (Stroebel, Swanepoel and Pell, 2011).

In South Africa, there are two major livestock production sectors, the commercial and communal livestock production. Both sectors face many challenges, but the communal sector is challenged by the complexity of rangeland resources management. It is characterised by multiple ownership of grazing lands by all community members, and keeping different livestock species on the same grazing land (Mapekula, 2009). This makes it quite difficult for the livestock farmers to make decisions for sustainable use and management as discussed in the theory of the tragedy of commons established by Hardin (1968). The Author argued that the tragedy of the commons is a dilemma arising from the situation in which multiple individuals, acting independently and rationally consulting their own selfï interest, will ultimately deplete a shared limited resource, even when it is clear that it is not in anyone's longï term interest for this to happen.

Despite the widely accepted ñTragedy of the commonsò paradigm, it is acknowledged that rural farmers have their own experiences and knowledge which they have used for generations to manage the rangelands (Oba, 2012). Rural communities have a wealth of indigenous knowledge (Ngulube, 2003) and it is crucial to consider the knowledge of the indigenous people regarding their rangelands and welfare of their livestock when planning livestock development and rangeland management strategies and programs. Communal livestock developments undertaken in African countries such as Ethiopia and neighbouring east African countries failed because they disregarded pastoralistsô knowledge and participation in decision making (Abate *et al.*, 2010).

Currently, most rural development initiatives in South Africa are focused on the improvement of rangeland based cattle production and the introduction of communal producers into the main stream commercial beef supply chain (Mapiye, Chimonyo, Dzama, Raats and Mapekula, 2009; Strydom, 2008). One of the major constraints of rangeland beef finishing systems though, is the limited protein supply (less than 50g/kg DM) in the dry season (Mapiye, Chimonyo, Dzama and Marufu, 2010) which is far below the recommended level of between 120g/kg and 150g/kg for beef cattle (National Research Council, 1996). To improve viability and sustainability of rangeland based systems it is important to develop and adopt strategies that can boost beef yield and quality under rangeland conditions in the semiï arid areas (Mapiye *et al.*, 2010).

During the wet season (summer) there is a characteristic abundance of forage of high crude protein and mineral content, which declines as the season progresses towards the dry period. Many studies have reported semiï arid rangelands to be characterised by seasonal fluctuations in quality and quantity of forages and this consequently affects the performance of livestock species in the communal areas (Berhane and Eik, 2006; Gwaze *et al.*, 2009).

2.2. Perceptions of farmers on livestock feeding and rangeland resources management

Several authors worldwide have recognised communal famersô inï depth knowledge and perceptions on livestock husbandry and rangeland management and their influence on resource use and livestock production (Coppolillo, 2000; Oba and Kotile, 2001; Sheuyange, Oba, and Weladji, 2005; Solomon, Snyman, and Smit, 2007). Communal herders have been reported to have extensive knowledge to the extent of being able to classify the grasses as highly desirable, intermediate and least desirable based on their acceptability to livestock (Gemedoï Dalle, Maas, and Isselstein, 2006).

Based on the rich and diverse knowledge that passes through generations, communal livestock keepers in Africa have developed complex resource management systems to allow them to survive under oftenï difficult biophysical environments, which are highly variable in space and /or time. In Southern Africa, Kinlund (1996), Dahlberg (2000) and Thomas and Twyman (2004) investigated the relationship between perceptions about land degradation and change in savannah ecosystems held by scientists and land users. They concluded that a combination of local and scientific knowledge can lead to a more useful assessment of environmental change and its implications for local land users.

Abule (2003) and Admasu, Abule, and Tessena (2010) revealed that the major constraints of livestock production raised by livestock owners, elders and other members in the communal grazing areas of semiï arid Ethiopia were drought, and deterioration of the rangelands that caused a shift in vegetation composition. This issue was of concern since communal people used different grass species found on natural rangelands for feeding their livestock (Abule, Snyman, and Smit, 2005; Lesoli, 2008). Communal farmers also use plants for a wide range of other purposes, other than grazing, and this includes a source of medicine (Makunga, 2009), cosmetics (Dold and Cocks, 2005), thatching (Shackleton, Shackleton, Buiten, E. and Neil, 2007), house furniture, and for rituals (Solomon *et al.,* 2007; Lesoli, 2008).

2.3. Soil and forage nutrients

2.3.1. Soil nutrients

Soil forms the basis for all vegetation growth and plays a key role in the hydrological, carbon and nutrient cycles of ecosystems (Li, Li, Zed, Zhan. and Singh, 2007; Lesoli, 2008). Thirteen minerals found in the soil are recognised as essential for plant growth and reproduction. These are generally divided into macro and microï minerals (Karr, 2003).

Soils are different with respect to the minerals found in them. The factors that affect soil nutrients include soil texture, pH, organic matter content and cation exchange capacity (CEC) (Jones, 2001). Both macro and microï minerals interact with soil pH influencing the availability and solubility of nutrients in a specific way therefore, it is important to consider the level of pH in the soil when performing mineral element analysis. Minerals such as calcium (Ca) and magnesium (Mg) are commonly absorbed in large amounts at pH 6.5ï 8; while at pH 3ï 6 the uptake of nitrogen (N) and phosphorus (P) may be favoured. In soils with higher pH (7 and 7.5) minerals such as iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn) become less available and others such as boron (Bo) become extremely available for assimilation by plants (Matlhoahela, Crammer, Jacobs, and Littlejohn, 2006).

2.3.2. Forage nutrients

Indigenous range plants are indispensable sources of animal feed and mineral nutrition, particularly in areas with arid to semiï arid climates (Juarezï Reyes, Montoya, Nevarez, Cerrillo, and Mould, 2004). Such species can alleviate feed shortages or even fill feed gaps in the winter and especially when grassland growth is limited or dormant due to unfavourable weather conditions (Guerreroï Cervantes, Ramirez, Gonzalezï Rotriguez, Cerrilloï Soto and Juarezï Reyes, 2012). In general, natural grasslands have a good content of crude protein (Moyaï Rodriguez, Ramirez. and Foroughbackhch, 2003) and minerals (Guerreroï Cervantes *et al.,* 2012). However, in some situations they are deficient in one or more minerals (McDowell, 2003).

It seems that nutritional quality of range plants follows plant growth patterns (Huston, Rector, Merrill. and Engdall, 1981) with a peak in forage quality generally occurring during spring when growth is most active, and levels declining steadily reaching the lowest levels during winter (Huston *et al.,* 1981). In a study conducted by Gizachew, Hirpha, Jalata, and Smit (2002) in the western midï altitude of Ethiopia, livestock performance tended to follow the seasonal pattern of forage availability and quality. The poor winter season animal performance led Gizachew *et al.* (2002) to suspect mineral deficiencies in the native pastures.

2.4. Mineral element status of soils, natural pastures and cattle blood serum

The chemical composition of growing plants under different habitats is affected by many factors such as concentration of a given element and the relative concentration of its assimilable forms in the soil. The mineral transmittance from soils to the plants may, however, be affected by environmental conditions such as season, some interacting soil variables and environmental conditions (Shaltout, Keblawy, and Mousa, 2008). Fluctuation in mineral content in soil and plants depends on a number of factors including soil pH, soil texture, variation in ambient temperature and season (Ahmad, Khan, Ashraf and Ejaz, 2012). Mineral contents of natural pasture forages may vary according to species, region, stage of growth (Ball *et al.*, 2001; Biricik, Ocal, Gucus, Ediz and Uzman, 2005). Forage mineral composition can have a significant effect on animal performance and their health as they are often not in balance with the nutrient requirements of the animals (Soder and Stout, 2003). The concentration of individual minerals in forages varies greatly depending on soil, plant and management factors (Ramirez, Haenlein and Nunezï Gonzalez, 2001).

Minerals have many functions in the plants and bodies of animals, including the formation of the body structure, cofactor for enzymes, and transformation of energy (Biricik *et al.,* 2005). Livestock need minerals for skeletal growth, milk production and the maintenance of body fluids and enzyme system. The minerals found in forages include Ca, P, Mg, potassium (K), sodium (Na), sulphur (S) and the trace minerals Fe, Zn, Cu and Mn (Rayburn, 1997). Livestock managers must be aware of the nutritional dynamics of forages to sustain satisfactory growth and reproduction of their animals and be sure that the pasture provides adequate nutrients (Ganskopp and Bohnert, 2003; Hussain and Durrani, 2008).

2.5. Nguni Cattle

In South Africa, the Nguni breed, a subtype of the African Sanga (*Bos Taurus africanus*) is characterised by a small mature size (200ï400kg) hardiness and adaptability to subtropical conditions (Strydom, 2008). Nguni cattle are mainly found in the semi arid communal areas where there is frequent occurrence of droughts (Mapiye *et al.*, 2009; Marufu, Chimonyo, Dzama and Mapiye, 2009) and high prevalence of nematodes (Ndlovu, Chimonyo and Muchenje, 2008). This presents the opportunity for communal farmers to produce organic beef whose demand is ever increasing with increasing health concern among beef consumers.

The Nguni is a hardy breed, uniquely adapted to the South African environment (Bester *et al.,* 2001). The recent recognition of its adaptive traits led to its evaluation and development as a beef breed in the commercial sector. Currently, most rural development initiatives in South Africa are focused on the improvement of Nguni cattle production on rangelands and the introduction of communal producers into the main stream commercial beef supply chain (Strydom, 2008).

2.6. Summary

Livestock production plays a important role in the economy of South Africa. Many rural development initiatives in South Africa are focused on the improvement of livestock production through initiatives such as the Nguni Cattle Project. In the communal areas, cattle production is often done under extensive grazing systems where the cattle rely mainly on natural communally managed rangelands for nutrition. There is need therefore to consider the wealth of indigenous knowledge of the rural communities regarding their livestock and rangeland management when planning these projects. Farmers must be aware of the nutritional dynamics of forages in order to plan strategies to sustain satisfactory growth and reproduction of their animals and be sure that their natural rangelands continue to provide adequate nutrients for their livestock. Therefore, the objective of this study was to determine the indigenous knowledge and perceptions of communal farmers on livestock feeding and rangeland resources management and also to determine the dynamics of mineral levels of soils, forage and Nguni cattle blood serum in two communal areas of the Eastern Cape, South Africa.

CHAPTER 3

Perceptions of farmers on livestock feeding and rangeland resources management in two communal areas of the Eastern Cape Province of South Africa

(The manuscript was submitted to the African Journal of Agricultural Science)

Abstract

The objective of this study was to determine the perceptions of farmers on livestock feeding and rangeland resources management in two communal areas of the Eastern Cape Province of South Africa. Selection of respondents was done on the basis of livestock ownership. All the livestock owners in the two communal areas were selected as respondents. The selected farmers were interviewed by use of a structured questionnaire. At Kwezana 36 farmers (43% male and 57% female) and at Dikidikana 41 farmers (66% male and 34% female) were interviewed. Male farmers owned 99% of the cattle at Dikidikana and 85% at Kwezana. At Kwezana and Dikidikana, 64% and 100% of the farmers, respectively could not name the preferred grass species on their rangelands. Also 69.4% and 97.6% of the farmers at Kwezana and Dikidikana respectively, could not name the dominant grass species on their rangelands. Supplementary feed was offered by 25% and 19.5% of the farmers at Kwezana and Dikidikana, respectively. Only 16.7% and 2.4% of the farmers at Kwezana and Dikidikana, respectively practiced grazing management. Farmers at Kwezana and Dikidikana have little understanding of the rangeland feed resources available for their livestock. Therefore, there is need for interventions to help these farmers to understand their rangeland resources and ways of managing them sustainably for the benefit of their grazing livestock.

Keywords: Forage species, grazing management, supplementary feed, communal rangelands.

3.1. Introduction

In Africa, communal livestock production systems have existed for generations despite the enormous challenges and pressure that have undermined their existence, food security and livelihoods of millions of people. Such challenges include increased population densities, land degradation (Scoones, 1995; Allsopp *et al.,* 2007), land use change and extreme climatic fluctuations (Abule *et al.,* 2005). Extensive livestock production from natural rangelands remains an important aspect of agricultural production and rural livelihoods in many parts of the world (Turner and Hiernaux, 2002; Bennet, 2008).

In the Eastern Cape Province of South Africa, livestock production is an ageï old agricultural activity that historically proved capable of supporting the livelihoods of the rural communal people. The communal livestock production system is sedentary and small scale, mainly based on extensive browsing and grazing on communal rangelands. The key feature of this production system is that the grazing lands are held and administered as a common pool resource (Bennet, 2008) where control of access to these resources is open and each user is capable of subtracting from the welfare of others (Ostrom, Burger, Field, Norgaard and Policansky, 1999).

Communal farmers use both individual as well as common knowledge to sustain their livestock production. Several authors worldwide have recognised the inï depth indigenous knowledge possessed by communal farmers and their perceptions on livestock husbandry and rangeland management and their influence on resource use and livestock production (Sheuyange *et al.,* 2005; Solomon *et al.,* 2007). Based on the rich and diverse knowledge that passes through generations, communal livestock keepers in Africa have developed complex resource management systems to allow them to survive under often difficult biophysical environments, which are highly variable in space and/or time. Kinlund (1996), Dahlberg (2000), Thomas and Twyman (2004) and Twyman, Sporton and Thomas (2004) investigated the relationship between perceptions on land degradation and change in savanna ecosystems held by scientists and land users in southern Africa. They concluded that a combination of local and scientific knowledge can lead to a more useful assessment of environmental change and its implications for local land users.

Human societies have for generations interacted with their environments and over time developed basic knowledge structures (Johnson, 2000; Scherrer, Motti and Weckerle, 2005; Dovie, Witkowski and Shackleton, 2008). The perceptions of indigenous and rural people about biological resources, have often translated into belief systems that have helped over long time periods to protect key natural resources (Kleymeyer, 1994; Dovie *et al.,* 2008). This knowledge, which is often indigenous in nature or in origin, is generally poorly documented (Wickramasinghe, ruizï Perez and Blochus, 1996; Johnson, 2000).

Communal herders can classify the grass species as highly desirable, intermediate and least desirable based on their acceptability to livestock (Gemedoï Dalle *et al.,* 2006). Despite this, several development interventions in the communal livestock production and resource management have continued to undermine their indigenous knowledge and perceptions (Allsopp *et al.,* 2007; Solomon *et al.,* 2007). Indeed, most interventions in Africa and elsewhere are still dominated by the belief that communal herders have little technical skills and are governed by the tenets of ñthe tragedy of the commonsò paradigm (Hardin, 1968) assuming that livestock keepers are selfish, aiming at maximising only shortï term offï take and are not embedded in any system of collective norms that might result in a consistent management of the commons (Allsopp *et al.,* 2007).

Past agricultural interventions which did not embrace the participation of the communal people have proved to show little progress and are not sustainable (Solomon *et al.,* 2007). Moreover, these have contributed to considerable erosion of indigenous knowledge (Ward, Ngairorue, Apollus and Tjiveze, 2000; Abule *et al.,* 2005). The objective of this study was therefore to determine the perceptions of communal farmers on livestock feed and rangeland resources management in two communal Nguni cattle project areas (Kwezana and Dikidikana) of the Eastern Cape Province of South Africa. This study generated information that was useful in identifying existing and potential challenges pertaining to livestock feeding and rangeland resources management in the communal areas.

3.2. Materials and methods

3.2.1. Description of the study area

This study was conducted in two communal areas that recently benefited from the Nguni Cattle Project, namely, Kwezana and Dikidikana located in the Eastern Cape Province of South Africa. The two villages have different climates and landscapes, and are situated at about 50 km distance from one another.

Dikidikana is located on the lower lying plateau of the Eastern Cape Midlands at coordinates of about 33.01ô07.25òS and 27.55ô19.99òE, with an altitude of 518ï 550 m above sea level (Figure 4.1). Dikidikana has a semiï arid climate with mean annual rainfall of 550ï 650 mm (Buffalo City Municipality (BCM), 2007). In summer the temperature ranges between 18^{o}C and 21^{o}C while in winter the temperature ranges from

10ºC to 13ºC (BCM, 2007). Dikidikana soil is predominantly medium textured shallow young soils, generally shale or sandstone with a low moisture retention capacity and high tendency to get waterlogged after heavy rains. Dikidikana falls under the Thornï veld savanna biome. The common grass species are *Themeda triandra, Eragrostis* spp. and *Sporobolus capensis* (Buffalo City Metropolitan Municipality (BCMM), 2011). *Acacia karoo* is the dominant encroaching woody plant which occurs often with other woody species such as *Scutia myrtina*, *Grewia* spp. and *Rhus* spp.

Kwezana (Figure 4.2) is located at coordinates of about 31.58ô59.880òS and 27.41ô60.000òE. The elevation is 1 059 m. Kwezana has a humid (>0.64 p/pet) climate. Annual rainfall falls between 450ï 600 mm. In summer the temperature ranges between 16ºC and 26.9ºC while in winter the temperature ranges from 6.5 to 18 C (World Atlas, 2012). Kwezana has no distinct temperature seasons, the temperature is relatively constant during the year. The soils at Kwezana are calcisols, combisols, luvisols (cl), dominated by calcium carbonate as powdery lime concentrations. The soil is high in lixisols (lx) soil with clay enriched lower horizon, low CEC and high saturated bases (World Atlas, 2012). Kwezana vegetation consists of predominantly falseï thornveld with its landscape dominated by *Acacia Karoo*. The dominant grass species in this area are *Themeda triandra, Panicum maximum and Digitaria eriantha* (Mapekula, 2009).

3.2.2. Selection of farmers

A total of 41 and 36 farmers were selected from Dikidikana and Kwezana villages, respectively. These included all farmers both male and female who possessed any livestock species. Prior to selection, a meeting was held with residents of the villages to introduce the purpose of the study and identify willing farmers.

3.2.3. Data collection

The 77 livestock farmers at Kwezana and Dikidikana were interviewed using structured questionnaires. Trained enumerators administered the questionnaires. Each farmer was interviewed individually in their homestead. The farmers had to sign a consent form before the enumerator could proceed with the interview. The consent form served as proof that the farmer agreed to be interviewed and as reassurance that none of their personal information would be used for any other purposes outside of this study. The questionnaire was structured into three sections with both closed and open ended questions. The first section dealt with demographic information, the second section had questions about livestock production practices and constraints and the third section had questions that sought to investigate the understanding of each farmer concerning the dynamics of livestock feed and rangeland resources management.

3.2.4. Statistical Analysis

Data gathered through the questionnaire were analysed using the SPSS statistical software program (SPSS, 1999). The Pearson Chiï square test was used to determine all possible paired combinations of the response variables to generate a correlation coefficient matrix. Descriptive statistics such as frequencies, means, standard deviations and percentages were also employed where appropriate.

3.3. Results

3.3.1. Demographic information

In both villages the interviewed farmers were typically smallholder livestock farmers who owned cattle, sheep, goats and/or poultry. All interviewed farmers were not formally employed. They relied on livestock and social grants for livelihood. At

Kwezana, the proportion of female farmers was greater than that of male farmers whilst at Dikidikana the reverse was true (Figure 3.1). Both at Kwezana and Dikidikana the majority of the farmers were older than 50 years and only 6% and 7%, respectively were less than 30 years of age (Table 3.1). All the interviewed farmers had some form of formal education though the majority did not go beyond primary education. Only 3% of the farmers at Kwezana and 15% at Dikidikana had received formal agricultural training (Table 3.1).

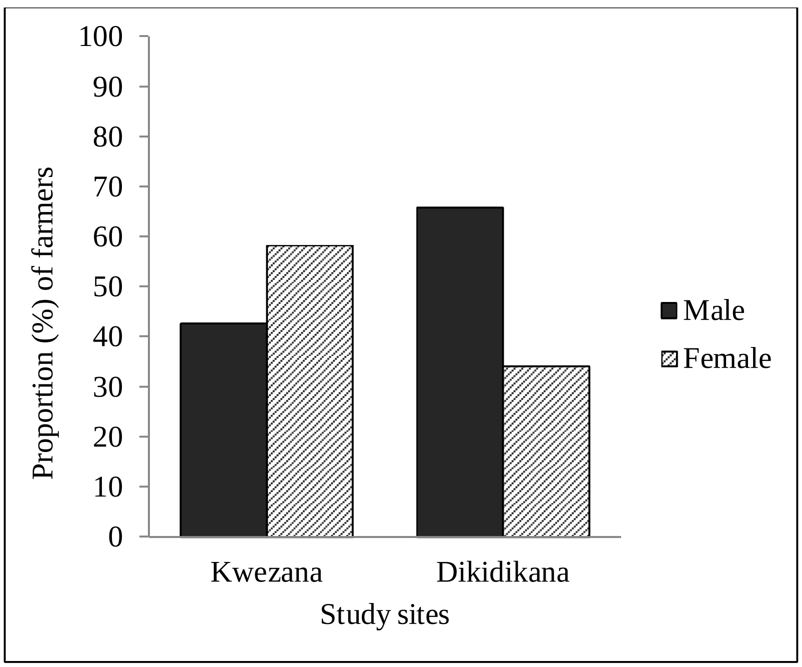

Figure 3.1: Proportion (%) of male and female livestock owners at Kwezana and Dikidikana

Table 3.1: Age distribution, education and agricultural training status of livestock owners at Kwezana and Dikidikana

	Kwezana (%)	Dikidikana (%)
Age distribution		
<30 years	5.6	7.3
30-40 years	8.3	17.1
41-50 years	19.4	17.1
>50 years	66.7	58.5
Education level		
Primary	50	58.5
Secondary	41.7	48.8
College	8.3	4.9
University	0	4.9
Agricultural training		
Formal	2.8	14.6
Informal	97.2	85.4

3.3.2. Livestock numbers and ownership patterns

At Kwezana male farmers owned most of the cattle (Figure 3.2). At Dikidikana almost all the cattle were owned by the male farmers and only 1% was owned by the female farmers. None of the female farmers owned cattle herds of more than 5 cattle at both villages. Goat ownership had a similar trend where males possessed the majority of goats at both study areas. Sheep ownership, however, showed the opposite trend where all the sheep at Kwezana and 96 % at Dikidikana were owned by female farmers. Female farmers owned most of the poultry at Kwezana while male farmers owned most of the poultry at Dikidikana.

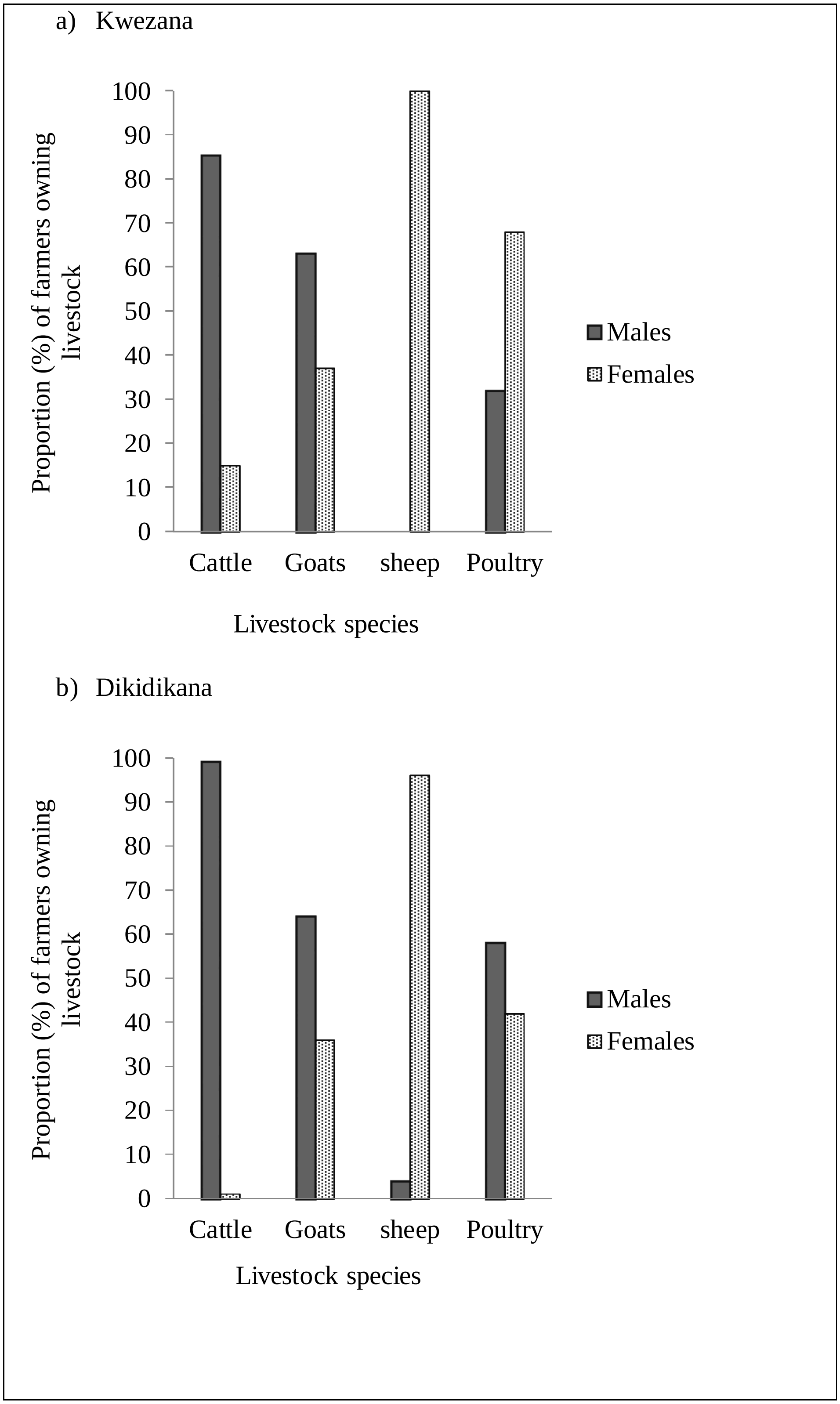

Figure 3.2: Proportion (%) of livestock ownership at Kwezana (a) and Dikidikana (b).

The mean number of livestock owned by each farmer at Kwezana was as follows: 6 cattle; 5 goats; 1 sheep and 8 poultry (Table 3.2). At Dikidikana the mean number of livestock owned by each farmer was: 4 cattle; 5 goats; 1 sheep and 6 poultry.

Table 3.2: Flock characteristics of each livestock species at Kwezana and Dikidikana

	Kwezana mean (se)	Dikidikana mean (se)
Cattle		
Bulls	0.28 (0.10)	0.24 (0.09)
Cows	1.39 (0.38)	1.49 (0.36)
Heifers	1.61 (0.36)	1.15 (0.34)
Oxen	1.83 (0.33)	0.27 (0.31)
Calves	0.44 (0.15)	0.51 (0.14)
Herd size	5.55 (1.03)	3.66 (0.96)
Goats		
Bucks	0.28 (0.14)	0.51 (0.13)
Does	1.81 (0.50)	1.68 (0.47)
Young females	0.78 (0.29)	1.15 (0.27)
Wethers	0.78 (0.24)	0.83 (0.22)
Kids	0.92 (0.25)	0.98 (0.24)
Flock size	4.55 (1.16)	5.15 (1.09)
Sheep		
Rams	0.08 (0.15)	0.17 (0.14)
Ewes	0.22 (0.38)	0.45 (0.36)
Wethers	0.14 (0.12)	0.13 (0.11)
Young females	0.08 (0.13)	0.15 (0.12)
Lambs	0.14 (0.19)	0.23 (0.18)
Flock size	0.67 (0.94)	1.13 (0.89)
Poultry		
Cockerels	0.81 (0.21)	0.71 (0.20)
Hens	1.86 (0.53)	2.00 (0.50)
Young males	1.78 (0.34)	0.68 (0.32)
Young females	1.72 (0.40)	1.20 (0.38)
Chicks	1.39 (0.51)	1.07 (0.48)
Flock size	7.56 (1.78)	5.66 (1.67)

3.3.3. Socio economic importance of livestock

Of the farmers interviewed at Dikidikana and Kwezana, 59% and 50% of the farmers respectively, indicated that the most important reason for keeping livestock is store of wealth. The percentages of farmers who regarded food production as the most important reason for keeping livestock were 34% and 22% at Dikidikana and Kwezana, respectively. At Kwezana and Dikidikana, 25% and 7.3% of the farmers respectively kept livestock mostly for income generation. All interviewed farmers at both villages reported that they did not use their livestock for draught power. Indeed, none of the interviewed farmers practised any form of cropping beyond vegetable gardening, and they stated lack of inputs as the main reason. At Dikidikana an association was found between age and farming objective (χ^2=19.81, p=0.02), with 50% of the farmers who were less than 30 years of age keeping livestock only as a hobby, but at Kwezana this association was found to be insignificant ($\chi^2=6.69$, p=0.35).

3.3.4. Farmers' understanding of the composition and condition of rangelands

About 69% and 98% of the farmers at Kwezana and Dikidikana respectively, did not know which grass were currently most dominant on the rangelands. About 83% of farmers at Kwezana and 100% at Dikidikana agreed that there was evidence of rangeland degradation on certain parts of the rangelands though they did not mention the observable indicators of rangeland degradation. When asked about the grass species that were dominant 5–10 years ago, 37.2% of the farmers at Kwezana mentioned uqaqaqa (*Cynodon dactylon*) and iqunde (*Themeda triandra*) and while the rest did not know. At Dikidikana 15% mentioned iqunde was the most abundant species and the remaining farmers did not know.

3.3.5. Farmers' perceptions on forage availability and supplementation

About 83% of the farmers at Kwezana and 88% at Dikidikana indicated that feed availability was the major constraint of livestock production. About 19% of the farmers at Dikidikana and 25% at Kwezana indicated that they offered supplementary feed to their livestock. The most common feed supplements used in both villages were barley and lucerne. Regarding the supplementary feed that the farmers were giving cattle 5ï 10 years ago, 100% of the farmers mentioned either or both, lucerne and barley. There was also no significant association between gender and supplementation at Kwezana (X^2= 0.038, p=0.85), but at Dikidikana there was significant association between gender and supplementation (X^2= 5.15, p= 0.023), where 100% of the female farmers and 69% of the male farmers did not offer their cattle, sheep or goat any supplementary feed.

3.3.6. Farmers' perceptions on grazing management

At Kwezana, 17% of the farmers agreed to practicing grazing management. When prompted to specify the kind of grazing management practised, farmers began by explaining that the cattle were not herded but left on the rangelands to feed unattended, neither were the cattle housed at night. They further explained that the cattle were moved at the turn of the seasons from the mountain tops where the cattle are left to spend their winter to the slopes where they were left for the summer; to the bottom lands in autumn and back to the mountain tops in winter. The cattle were moved closer to the watering points in summer but were still left to graze day and night unattended. The herders only gather the cattle for vaccination or dosing or other such practices.

At Dikidikana 2% of the farmers agreed to practising grazing management though they did not specify the kind of grazing management practiced. The cattle at Dikidikana were herded during the day and kraaled at night. Of all the farmers at Kwezana and

Dikidikana combined, 71% of those who practised some form of grazing management were older than 50 years and 71% did not go beyond primary education. All the farmers (100%) at both study areas claimed that there was no overstocking on their rangelands.

3.3.7. Farmers' perceptions on livestock foraging behaviour and diet selection

In the present study, 68% of the farmers at Kwezana did not know the grass species most preferred by their cattle or sheep, and 64% could not indicate the preferred browse species. At Dikidikana, 100% lacked knowledge on the preferred browse species and 98% on the preferred grass species. Regarding the forage species most preferred by goats, the farmers in both study areas unanimously agreed that *Acacia Karroo* was the most preferred. When asked which bush species was most preferred by cattle, the 100% of the farmers at both Kwezana and Dikidikana did not know.

Farmers at Dikidikana explained that different herd men herded the different herds of cattle. Nguni cattle were grazed separately from the other nonï descript breeds and they tended to move together as a group . At Kwezana, the farmers explained that though the cattle grazed unattended, the Nguni cattle herd tended to move away from the other cattle and to graze as a separate group. At Kwezana, there was no control of cattle movement during the day while at Dikidikana the herd men led the cattle to the chosen part of the rangeland where they grazed until 14:00 hrs when they were led to graze near and around the homesteads before they were kraaled at 17:00 hrs. In summer, the cattle grazed on the part of the rangelands nearer to the homesteads, while in winter the cattle grazed further from the homesteads closer to dams and water sources.

3.4. Discussion

Livestock production constitutes an important component of the social, economic and agricultural values for the resource poor communal farmers of Kwezana and Dikidikana. Nthakheni (2006) and Stroebel *et al.* (2011) also reported that livestock, especially cattle and their products, provide cash income and financial security for many smallholder farmers in South Africa. Livestock is a source of livelihood for rural farmers in numerous African countries. Livestock production generates roughly half of the rural household income in pastoral areas of Kenya (McDermott, Staal, Freeman and Van De Steeg, 2010) and over 80% of incomes in pastoral areas of Ethiopia, Niger and Burkina Faso (Barrett, Osterloh, John, McPeak, Mahmoud, Luseno, Little and Gebruf, 2003). Besides being a source of income and/or wealth, the farmers interviewed in the present study also cited food security as one of the reasons for keeping livestock.

Esenu, Sserunkuna and Ossiya (2005) reported that gender imbalance in livestock production is one of the major hurdles for the success of livestock restocking programs in the Teso farming system in Uganda. Kwezana and Dikidikana recently benefited from one such livestock reï stocking program, namely, the Nguni cattle project. In this project too, gender inequalities in ownership do exist. Gender inequalities extended to other livestock species such as goats and poultry. Mapiye *et al*. (2009a) reported similar findings in 18 communal areas of the Eastern Cape where 75% of the cattle owners across all production systems and rangeland types were men.

The male dominance in poultry ownership observed at Dikidikana in this study is unlike the situation reported in The Gambia and Tanzania where Okitoi, Ondway, Obali and Murekefu (2007) found chicken keeping a domain of women but the author went on to report that an increasing trend towards men keeping poultry was likely because of economic change of attitudes of men towards the enterprise. From the results of this study, poultry keeping is no longer marginalised as an enterprise for women only. Shackleton, Shackleton and Cousins (2001) also reported that households in the communal areas of South Africa are eager to keep livestock for the multiple benefits they provide rather than for the social status it provided in the past (Duvel and Afful, 1996).

In the present study, women were more engaged in small ruminant production than in cattle production. The reason for greater involvement of women in sheep production may be the result of the Xhosa concept that results in ownership of cattle being strongly male dominated in that society (Lent and Hebinck, 2007). In addition, sheep do not have the same cultural significance as cattle, and sheep production has the advantage of ease of husbandry as compared to cattle. The proportions of ownership of small stock by females in the present study were slightly higher than the findings of Jaitner, Sowe, Seckaï Njie and Demptle (2001) in The Gambia. The case of female farmers being more engaged in small ruminant production is not only an African scenario but was also reported in Turkey by Budak, Darcan and Kantar (2005).

According to Lesoli (2011) the youth in the Eastern Cape villages demonstrated low interest and commitment to agriculture and also lacked participation in livestockï rangeland management. The results of this study also revealed a similar lack of interest and commitment to agriculture among the youth as substantiated by the findings that all of the farmers who practiced grazing management were elderly farmers (older than 50 years) and none of the younger farmers practiced any form of grazing management. Poor youth participation implies a breakdown in the transfer of indigenous skills from the elders to the youth as suggested by Lesoli (2011). Lwoga, Ngulube and Stilwell

(2010) suggested that indigenous knowledge that is not documented but kept in the memories of the elders, is at risk of becoming extinct due to memory lapses and death. This presents a challenge for sustainable livestock production in the rural communal areas. Dung, Antonssonï Ogle and Uden (2012) found contrary results in Vietnam where livestock farmer knowledge on pasture management was extensive and effectively transferred from the elders to the young generation.

In the present study, while livestock farmers perceived their rangelands to be degraded, they still made little effort to regulate the intensity and frequency of grazing on their communally owned pastures. Lesoli (2011) reported similar findings in the communal areas of the Eastern Cape. All livestock farmers in both Kwezana and Dikidikana agreed that animals tend to lose condition in winter and regain condition in summer. This is in agreement with the work of Mengistu (2012) in Ethiopia who reported that seasonal feed shortages cause loss of body weight gain during the more unfavourable season. Feed availability seems to be the major limiting factor to livestock production in semiï arid communal areas (Stares, Sarid and Kategile, 1992). The farmers in the present study also agreed that livestock feeding was the major constraint in livestock production but few farmers offered their cattle supplementary feed in the dry season.

Crop residues are an important source of livestock feed across small holder mixed systems in (sub) tropical Africa and Asia (Valbuena, Erestein, Tui, Abdaulaye, Claessens, Duncan, Gerard, Rufino, Teufel, Rooyen and van Wijk 2012). However, in this study, the farming system lacked the crop component such that the farmers did not have crop residues with which to supplement their livestock during times of feed scarcity. Farmers who did offer their livestock supplementary feed revealed that they had to buy the supplementary feeds (lucerne and barley), which were not always available from commercial producers. Farmers who did not offer their livestock supplementary feed indicated that they were constrained by the unaffordable cost of the supplements.

Similar to the report by Mengistu (2012), all stock in the two study areas grazed together with no attempt to provide special treatment for the different classes of livestock. It is evident from the present study that farmers do not have in-depth knowledge of the natural forage species, their grazing and browsing value and livestock preferences. In contrast Solomon *et al.* (2007) and Kassahun, Snyman and Smit (2008) in Ethiopia and Dung *et al.* (2012) in Vietnam reported that many communal farmers have in-depth knowledge on naming and grazing values of natural forage and browse species.

3.5. Conclusion

This study showed that livestock played a great role in the livelihoods of the resource poor farmers at Kwezana and Dikidikana who regarded their livestock highly as a source of wealth and income. Livestock farmers did not only have the challenge of feeding their livestock during the dry season but they also exhibited little knowledge of their rangeland resources by failing to name or identify any of the forage species found on their rangelands. The farmers need to be educated on the sustainable use and management of rangeland resources for livestock production. Farmers also need assistance in coming up with strategies to cope with the reported feed scarcity during winter but before much can be prescribed, there is need to follow up the perceptions of farmers with a scientific investigation of the nutritional status of the rangelands and its effects on the livestock. Hence, the second study to determine the mineral status of the two communal rangelands and the implications on the mineral status of Nguni cattle in the two major seasons, summer and winter.

CHAPTER 4

Seasonal and spatial dynamics in mineral levels of forage, soil and cattle blood serum in two communal areas of the Eastern Cape, South Africa

Abstract

The objective of this study was to determine the seasonal and spatial dynamics of the mineral levels in soil, forage and Nguni cattle blood serum in two communal areas of the Eastern Cape Province of South Africa. In each study area, the rangelands were divided into three study sites for grass and soil sampling. Soil and forage samples were collected from each study site at the end of winter and summer and analysed for Ca, Mg, K, P, Fe, Cu, Zn, Mn, Bo and N. Blood samples were obtained from two and a half year old heifers in winter and summer and analysed for Ca, Mg, K, Cu and Fe. There was significant ($p<0.05$) seasonal variability in the soil levels of Ca, N, Mg, Fe and CP. There was also significant ($p<0.05$) seasonal variation in the concentrations of forage K, Mg and Fe. Spatial variability was found in soil Fe, Mn, Ca, Mg, P, Bo and K concentrations ($P<0.05$) and no significant seasonal variations in the soil S, Na, Cu and Zn ($P>0.05$). Forage CP, Mg, Ca, K, Zn, Fe and Cu concentrations showed some seasonal and spatial variations ($P<0.05$) while there were no significant seasonal variations in forage Mn, Bo and P. In summer, significant correlations were found at Kwezana between soil and forage Cu ($r=0.34$, $p<0.05$) and Zn ($r=0.38$, $p<0.05$) and at Dikidikana Cu ($r= 0.43$, $p<0.01$) and Zn ($r=0.38$, 0.02). Soil, forage and cattle blood serum mineral levels varied seasonally and/or spatially. Further study could determine similar variations in the minerals that were not investigated in this study and also consider other sources of minerals such as water that could affect the mineral status of grazing livestock.

Keywords: Macroï minerals, microï minerals, summer, winter, rangelands.

4.1. Introduction

Rangelands are the main source of livestock feed for resource poor communal farmers (Lesoli, 2008). Though natural forage provides essential minerals to grazing livestock (Hussain and Durrani, 2008), it rarely meets all the mineral requirements, especially during the dry periods (McDowell, 1992; Khan, Hussain, Ashraf, Koyro, Huchzermeyer, Yousaf and Akhtar, 2004). Both forage biomass and mineral availability in rangelands can vary according to soil (Ramirez, Haenlin, Carciaï Castillo and Nunezï Ganzales, 2004), season (Scholes and Walker, 1993; McDonald, Edwards, Greenhalgh and Morgan, 1996), species composition (Tefera, Mlambo, Dlamini, Koralagama and Mould, 2009) and topography (Gizachew *et al.,* 2002).

Soil properties of natural rangelands may vary greatly in space and time due to natural and anthropogenic disturbances (Starr, Parkin and Meisinger, 1995; Kariuki, Schroder, Zhang, Hanks, Mcgrath and Payton, 2010). On natural rangelands, soil nutrient variability may result from the absence of tillage (Fisher, Thornton, Hudson and Edwards, 1998) and the irregular deposition of cow dung and urine (Drewes *et al.*, 1999). The mineral concentrations of natural pasture forages are also affected by season and topography.

Loganathan, Mackay, Lee and Hedley (1995) and Gizachew (2002) reported that during the wet season, the mean concentrations of most minerals in natural pasture forage tend to be higher for low lying areas than uplands. They further reported that the high mineral concentrations of pastures in the bottom land is due to the relatively higher soil mineral and organic matter levels at lower slopes and the predominance of species adapted to high fertility environments. Seasonal variability in natural pasture mineral concentrations was also reported by Minson (1990), Espinonza *et al.* (1991), Pastrama, McDowell, Conrad and Wilkinson (1991) and Grings, Haferkamp, Heitschmidt and Karl (1996). Such variability in the quantity and quality of available forage is widely reported to affect cattle production on semiï arid communal rangelands of Africa (Angassa and Oba, 2007; Mapiye *et al.,* 2010).

The objectives of this study were to determine the spatial and seasonal variability of soil, forage and Nguni cattle blood serum mineral concentrations in two communal grazing areas and secondly to determine any correlations between soil and forage mineral levels.

4.2. Materials and methods

4.2.1. Description of the study area

The study area is described in Chapter 3.2.1.

4.2.2. Site selection and layout

In each study area, extensive grazing land surrounding a homestead was identified for vegetation and soil sampling. Three sites representing the near, middle and further sites from homestead were selected at Dikidikana (Figure 4.1) and bottom, slope and top at Kwezana (Figure 4.2). Dikidikana is set on a plain and topographical differences along the distance gradient from the homesteads were minimum, and therefore the rangeland was simply divided according to the distance from the homesteads into near (<2.5km), middle (2.5ï 3.5km) and far (>3.5km) sites. Kwezana on the other hand is situated in a valley and the grazing lands extend from the bottomlands through gently sloppy land to the mountain top.

4.2.3. Vegetation sampling and chemical analysis

In each site (distance) of both study areas, four 20 m x 100 m homogenous vegetation units/plots (HVU) were marked to serve as replicates. In each HVU, Three $0.25m^2$ quadrants were randomly placed for grass sampling. Grasses within the each quadrant were harvested at stubble height and bulked and ovenï dried for 48 hours at 80^oC. Dried samples were weighed to estimate the biomass yield. The dried samples were then sent to the Western Cape Department of Agriculture for N and mineral element analysis. Collection of plant samples was done once at the end of winter (July) winter and at the end of summer (February).

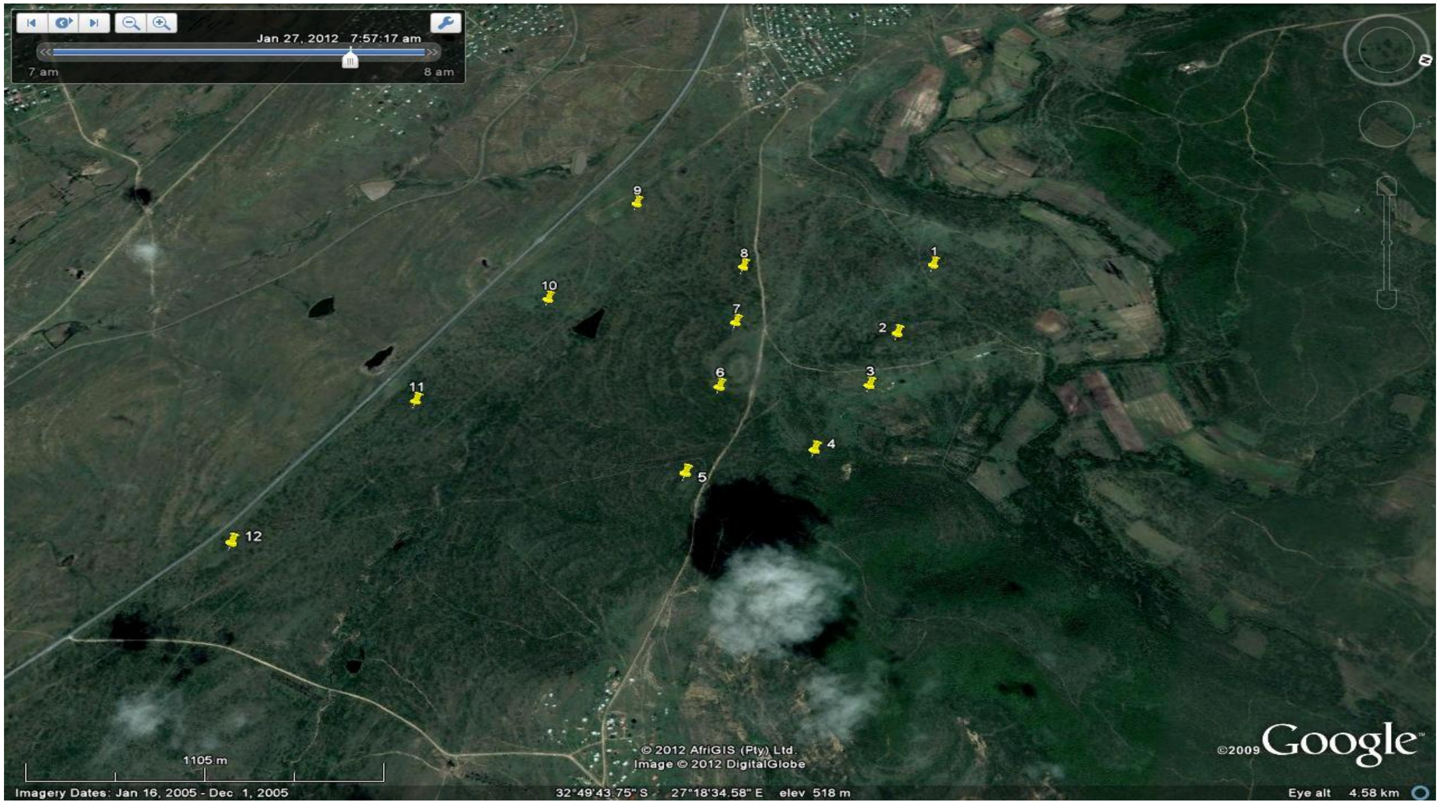

Figure 4.1: Layout of experimental sites at Dikidikana

Source: Google earth (2009). The points 1, 8, 9 and 7 constitute the near site (nearest to the homesteads). The points 2, 3, 6 and 10 constitute the middle sites and the points 11, 12, 4 and 5 constitute the far site (furthest from the homesteads).

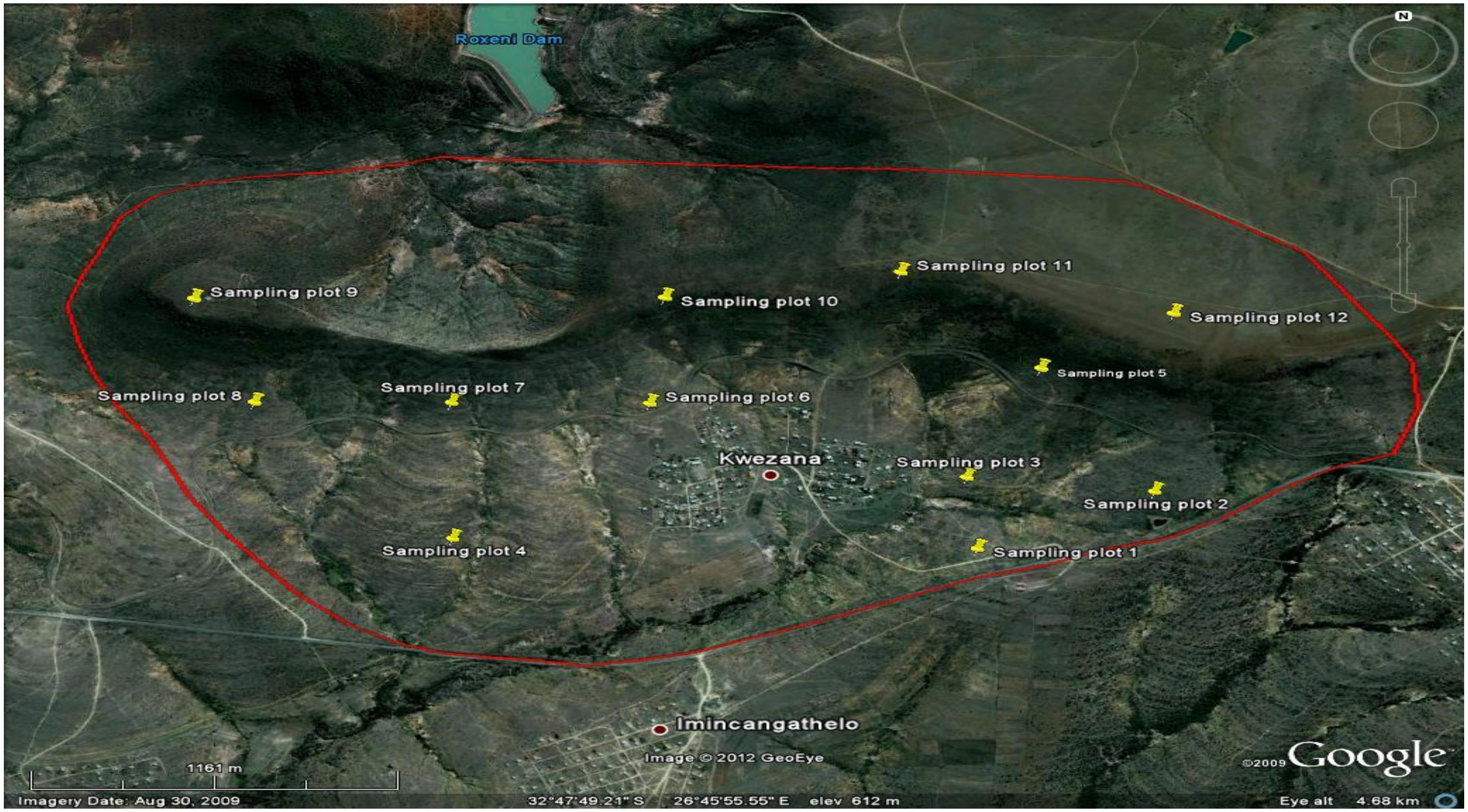

Figure 4.2: Layout of experimental sites at Kwezana

*Source: Google earth (2009).*The sampling plots 1, 2, 3 and 4 constitute the bottom site. The sampling plots 5, 6, 7 and 8 constitute the slope sites and the sampling plots 9, 10, 11 and 12 constitute the top sites.

Plant samples were analysed for the minerals elements phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), copper (Cu), zinc (Zn), manganese (Mn), boron (Bo) and iron (Fe). Phosphorus, K, Ca, Mg, Na, Cu, Zn, Bo Mn and Fe levels were determined using the dry ashing macro and trace minerals method for feeds and plants (ALASA, 1998). Forage N content determination was done using the Kjeldahl digestion method (ALASA, 1998). Forage CP was calculated by multiplying the N value by 6.25.

4.2.4. Soil sampling and chemical analysis

Soil samples were collected at the time of forage sampling at a depth of 20cm using a soil auger next to each quadrant. The soil samples were air dried for 14 days and then milled to pass through a 2mm sieve. Soil samples were analysed for N, Ca, Mg, K, P, Fe, Cu, Zn, Mn, Bo and pH. Total soil N was determined using the standard Kjeldahl method using a block digester (Bremner and Breitenbeck, 1983). Available soil P was detemined by the Inductively Coupled Plasma (ICP) analysis of extracts of soil with 1% citric acid (ALASA, 1998). Exractable Ca, Mg and K were determined by ICP in the same 1% citric acid extractions (ALASA, 1998). Determination of soil Cu, Zn and Mn was ICP in 0.02 M Diï ammonium EDTA soil extracts (ALASA, 1998). Boron was determined by ICP in hot water soil extracts. Soil pH was determined in 1M potassium chloride (KCl) 2.5 KCl: 1 soil (ALASA, 1998).

4.2.5. Nguni cattle blood sampling and analyses

4.2.5.1. Selection of study animals

Three Nguni heifers raised on the communal rangelands and aged 2.5 years were randomly selected each season. Due to technical and logistical complications, different heifers were used in each season. Only three animals were used per village due to limited research funds.

4.2.5.2. Collection and preparation of blood samples

Blood samples of the Nguni heifers were obtained at the end of July 2011 and February 2012. Cattle were restrained in a cattle race where the head was held in a head gate. Blood samples were collected into 10ml vaccutainer tubes using the tail bleeding method (Kramer, 1962). Following collection, the serum was separated by centrifuging the samples at 3220 rpm for 20 minutes. The serum samples were frozen and sent to the University of Pretoria where they were analysed for Ca, Mg, K, Cu and Fe. Due to limited research funds blood samples could only be analysed for the five macro minerals listed above. All the determinants were done on the serum. Calcium, Mg, Na and K were done on the serum diluted with a dilute lanthanum chloride solution and analysed on a GBC Atomic Absorption Spectrophotometer (AAS) using the standard conditions set by the manufacturer (Pye Unicam Limited, York street Cambridge, Great Britain). Copper, Fe, Mn and Zn analyses were done on the deï proteinised serum, using 12% trichloroï acetic acid, resulting in a 1:1 dilution and analysed by AAS. The inorganic phosphate was determined using acid ammonium molybdate to develop the blue colour complex. The method was based on Technicon: Automation in Analytical Chemistry (Jordan, 1967).

4.2.6. Statistical analysis

Data on soil and forage minerals as well as forage biomass were analysed using the General Linear Model (GLM) procedure of SAS (2007). Analysis was done separately for the two areas because of their great variation in topography, mean annual temperatures and vegetation type. A 3 x 2 factorial arrangement was used in a Completely Randomised Block Design was used. The two treatments were the two seasons and the three levels were the distances from the homesteads.

The following statistical model was used:

$Y_{ijk} = \mu + S_i + A_j + (S \times A)_{ij} + E_{ijk}$

Where Y_{ijk} = the dependent variable

μ = overall mean

S_i = the effect of the i^{th} season

A_j = the effect of the j^{th} site (Bottom, slope, top for Kwezana and near, middle, far for Dikidikana)

$(S \times A)_{ij}$ = interaction between i^{th} season and j^{th} site

E_{ijk} = the random error

Mean separation was conducted using the PDIFF option of SAS (2007). Relationship between soil and forage minerals was investigated using the PROC CORR procedure of SAS version 9.1.3 (2007).

4.3. Results

4.3.1. Soil pH, nitrogen and macro–minerals

Soil pH at both Kwezana and Dikidikana did not show any significant seasonal or spatial differences (Figure 4.3). The nitrogen and macroï element status of the soils collected from the two study areas are presented in Table 4.1. At Kwezana, soil N exhibited seasonal variations with summer having higher ($P<0.05$) CP level than winter. There was no significant difference in soil N between bottom, slope or top sites. Similarly, at Dikidikana soil N also showed seasonal variations with higher levels ($P<0.05$) recorded in summer and there was no significant spatial variation.

At Kwezana, soil Ca levels were higher ($P<0.05$) in summer than winter on the bottom and top sites but no spatial variations were found. Dikidikana, on the other hand showed no significant seasonal or spatial variations. Soil Mg was higher ($P<0.05$) in summer than winter on the bottom and top sites at Kwezana but no spatial variation were observed. At Dikidikana, there were neither spatial nor seasonal variations in soil Mg. All the sites at Kwezana showed higher ($P<0.05$) K levels in summer than in winter. However, there were no significant spatial variations. At Dikidikana, no significant seasonal or spatial variations in soil K were observed. At Kwezana there were no seasonal or spatial variations in soil P ($P>0.05$). At Dikidikana, however, soil P showed spatial differences in summer with the higher ($P<0.05$) levels being found in soils collected from the near sites.

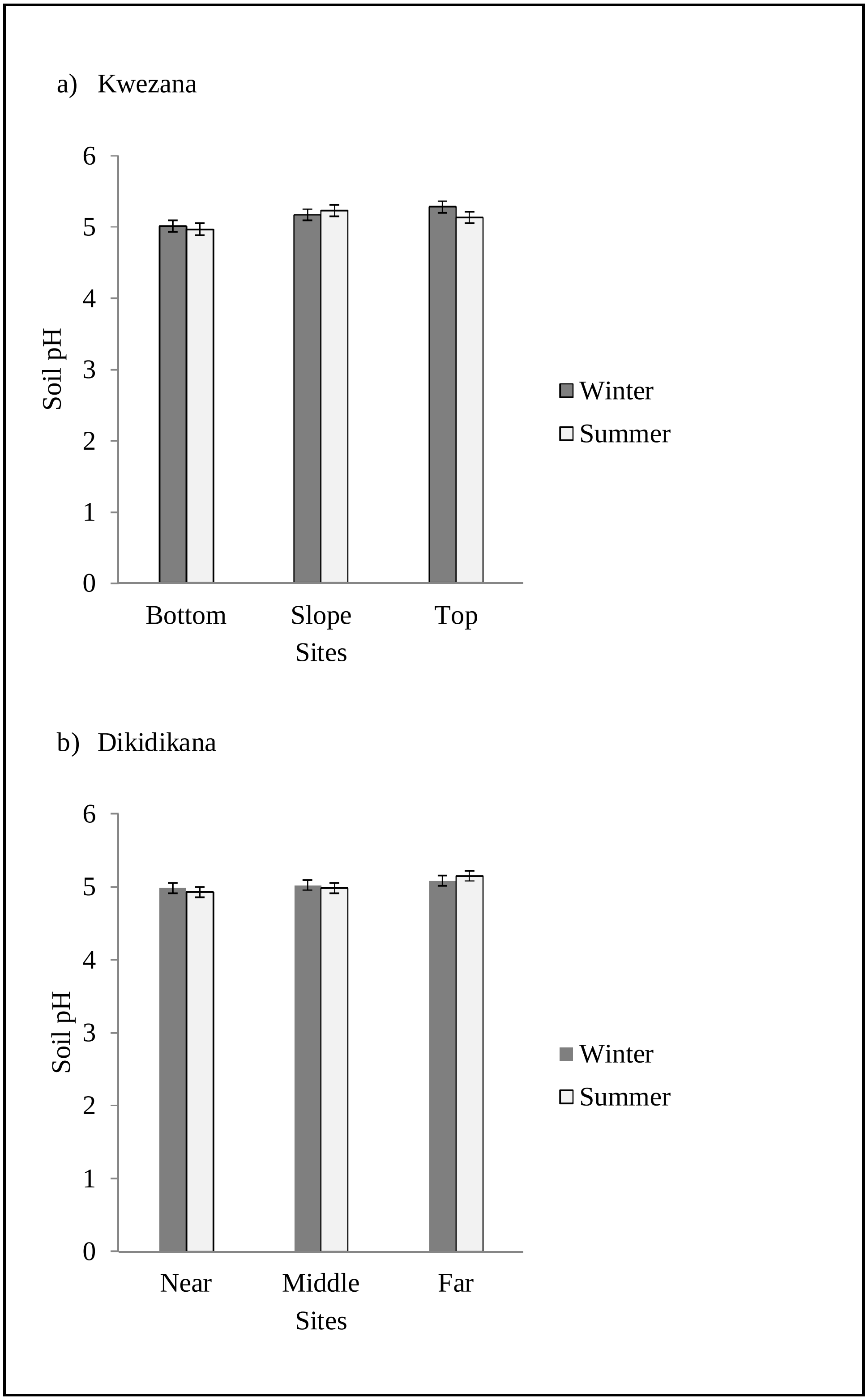

Figure 4.3: Spatial differences in the pH of soil samples collected from three sites at Kwezana (a) and Dikidikana (b) in summer and winter

Table 4.1: Nitrogen and macroï minerals of soil sampled from Kwezana and Dikidikana in summer and winter

Areas/site	**N (%)**		**Ca (cmol/kg)**		**Mg (cmol/kg)**		**K (mg/kg)**	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Kwezana								
Bottom	0.53^{a}	0.14^{b}	3.35^{b}	5.22^{a}	1.81^{b}	2.42^{a}	82.7^{b}	153.1^{a}
Slope	0.51^{a}	0.12^{b}	3.38^{a}	4.14^{a}	1.70^{a}	2.00^{a}	104.8^{b}	170.1^{a}
Top	0.50^{a}	0.14^{b}	3.03^{b}	5.10^{a}	1.59^{b}	2.43^{a}	118.8^{b}	167.9^{a}
SE	0.07		0.41		0.22		20	
Areas/site								
Dikidikana	**N (%)**		**P(mg/kg)**					
Near	0.50^{a}	0.11^{b}	8.00^{aA}	14.00^{bA}				
Middle	0.49^{a}	0.12^{b}	6.58^{aA}	8.00^{aB}				
Far	0.50^{a}	0.12^{b}	7.41^{aA}	9.08^{aB}				
SE	0.05		2.5					

Lowercase superscripts are used to compare means between seasons within each site, while uppercase superscripts are used to compare site means within each season. Means with different superscripts differ significantly ($P < 0.05$).

4.3.2. Soil micro–mineral status

Table 4.2. presents the microï mineral status of soils at Kwezana and Dikidikana rangelands in summer and winter. The Fe concentrations of soils from the Kwezana rangelands showed no significant seasonal variations on the bottom and slope sites but on the top sites, it was higher in winter ($P<0.05$). There was no spatial variation in soil Fe in winter but in summer spatial variations were observed between the bottomlands and the top lands with the bottomlands having higher Fe levels ($P<0.05$) in both seasons. At Dikidikana, neither seasonal nor spatial variation in soil Fe ($P>0.05$) was observed.

At Kwezana, soil Bo showed no seasonal variations but some spatial variations were observed, with the bottomlands having higher Bo level ($P<0.05$) than the top lands in both seasons. Dikidikana showed no significant seasonal or spatial variations in soil Bo.

Soil Mn levels at Kwezana showed seasonal variations ($P<0.05$) only on the bottomlands. There was no spatial variation ($P>0.05$) in soil Mn in winter though significant spatial differences was apparent in summer with the bottomlands exhibiting significantly ($P<0.05$) higher levels. At Dikidikana, seasonal variations in soil Mn was only present on the near sites where the soil Mn was higher in winter ($P<0.05$). Statistically significant spatial variation was apparent in both seasons at Dikidikana. In winter, the far sites had lower ($P<0.05$) Mn concentrations than both the near and middle sites. In summer, Mn levels on the middle sites were marginally higher than the far sites.

Table 3.2: Microï element status (µg/kg) of soils sampled from Kwezana and Dikidikana in summer and winter

Areas/site	Fe		Bo		Mn		Cu	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Kwezana								
Bottom	15050^{A}	14450^{A}	31^{A}	35^{A}	17270^{bA}	28980^{aA}	165^{bA}	390^{aA}
Slope	13000^{A}	11850^{AB}	28^{AB}	31^{AB}	14490^{A}	21220^{B}	137^{A}	156^{B}
Top	13880^{aA}	10740^{bB}	22^{B}	27^{B}	17240^{A}	14550^{B}	137^{A}	183^{B}
SE	1090		3		2470		40	
Dikidikana	**Mn**							
Near	27862^{aA}	19734^{bAB}						
Middle	25697^{A}	22877^{A}						
Far	17498^{B}	15886^{B}						
SE	2588							

Lowercase superscripts are used to compare means between seasons within each site, while uppercase superscripts are used to compare site means within each season. Means with different superscripts differ significantly (P < 0.05).

Copper levels at Kwezana showed significant seasonal and spatial variations. On the bottomlands, Cu levels were higher (P<0.05) in summer than in winter. The spatial variations were not apparent in winter but in summer, bottomlands showed significantly higher Cu levels than both the slope and the top lands. At Dikidikana, there were neither spatial nor seasonal variations in soil Cu (P>0.05). There were no seasonal or spatial variations (P>0.05) in soil Zn both at Kwezana and Dikidikana.

4.3.3. Forage nitrogen and macro–mineral status

Forage N at Kwezana showed neither seasonal nor spatial variations (P>0.05), while at Dikidikana there were both seasonal and spatial variations (P<0.05) in forage N (Table 4.3). Seasonal variation was apparent on the middle sites where the summer N level was higher (P<0.05) than the winter level. In summer at Dikidikana there were spatial differences in forage N with middle sites having higher N levels than the near sites (P<0.05).

Forage sampled from Kwezana showed statistically significant (P<0.05) seasonal and spatial differences in Ca levels. Seasonal variation was present on the bottomlands where the forage Ca was higher (P<0.05) in winter than in summer. Spatial variations were only apparent in winter when forage Ca level was significantly (P<0.05) higher on the bottomlands than on the slopes and top lands. At Dikidikana, forage Ca level showed seasonal differences but no significant spatial differences. The seasonal differences were apparent on the near sites where Ca level was higher (P<0.05) in winter than in summer.

Table 4.3: Nitrogen (%) and macroï mineral status (g/kg) of forage sampled from Kwezana and Dikidikana in summer and winter

Areas/site	**Ca**		**K**		**P**		**N**	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Kwezana								
Bottom	5.3^{aA}	3.6^{bA}	6.8^{b}	9.8^{a}				
Slope	4.1^{aB}	3.3^{aA}	6.1^{b}	10.7^{a}				
Top	4.1^{aB}	3.6^{aA}	5.9^{b}	9.2^{a}				
SE	0.41		0.98					
Dikidikana								
Near	4.49^{a}	3.17^{b}	6.74^{aA}	7.96^{aA}	0.96^{bA}	1.17^{aA}	1.07^{aA}	0.98^{aB}
Middle	3.81^{a}	3.08^{a}	6.21^{bA}	14.11^{aB}	1.01^{bA}	1.36^{aAB}	1.03^{bA}	1.22^{aA}
Far	4.50^{a}	3.67^{a}	5.87^{bA}	11.76^{aA}	0.98^{bA}	1.45^{aB}	1.00^{aA}	1.11^{aAB}
SE	0.39		0.99		0.09		0.06	

Lowercase superscripts are used to compare means between seasons within each site, while uppercase superscripts are used to compare site means within each season. Means with different superscripts differ significantly ($P < 0.05$).

Both at Kwezana and at Dikidikana, Mg showed neither seasonal nor spatial variation. The K level of forage sampled from Kwezana did not show marked spatial variations. However, seasonal variations were apparent on all the three sites with the summer K levels being significantly higher than the winter levels. Dikidikana on the other hand exhibited both seasonal and spatial variations in forage K. The seasonal differences were apparent on the middle and far sites where K levels were higher ($P<0.05$) in summer than in winter.

The P levels in Kwezana forages showed neither seasonal nor spatial differences, while forage sampled from Dikidikana showed both seasonal and spatial differences. The seasonal differences were apparent on all the sites where P was higher in summer ($P<0.05$). The spatial differences were between the near and the far sites in summer only with the forage P level being marginally higher on the far sites ($P<0.05$).

4.3.4. Forage micro–mineral status

Table 4.4 presents the microï mineral status of forages sampled from the two study areas. At Kwezana, marked seasonal and spatial variations were found in forage Fe. The winter Fe level was significantly higher than the summer across all the sites. Spatial variations were only found in winter when the bottomlands had higher Fe levels than the slope and top lands ($P<0.05$). Forage sampled from Dikidikana showed marked seasonal differences but no spatial differences in Fe levels with the winter forage Fe levels being significantly higher than the summer Fe levels across all the three sites.

Table 4.4: Microï mineral (µg/kg) status of forage sampled from Kwezana and Dikidikana in summer and winter

Areas/site	Fe		Mn	
Kwezana	Winter	Summer	Winter	Summer
Bottom	16000^{aA}	4000^{bA}	1000^{a}	900^{a}
Slope	12000^{aB}	2000^{bA}	1100^{a}	800^{b}
Top	10000^{aB}	3800^{bA}	1000^{a}	700^{b}
SE	2000		100	
Dikidikana				
Near	16400^{a}	6300^{b}		
Middle	14800^{a}	4500^{b}		
Far	17800^{a}	6400^{b}		
SE	2800			

Lowercase superscripts are used to compare means between seasons within each site, while uppercase superscripts are used to compare site means within each season. Means with different superscripts differ significantly ($P < 0.05$).

At Kwezana there were no seasonal differences in the forage Bo though spatial differences were present in winter with the bottom sites having a higher ($P<0.05$) level. Forage sampled from Dikidikana on the other hand showed neither seasonal nor spatial variation ($P>0.05$). There were marked seasonal differences in forage Mn at Kwezana on the slope and top sites with winter Mn level being significantly higher. No spatial differences in forage Mn were found at Kwezana. At Dikidikana, there were no significant seasonal variations neither were there spatial differences.

Forage sampled from both Kwezana and Dikidikana showed neither seasonal nor spatial variation in the levels of Cu and Zn.

4.3.5. Forage dry matter yield and crude protein content

The DM yield of both Kwezana and Dikidikana rangelands showed neither seasonal nor spatial variation. Similarly, the CP contents of forages did not appear to show variations both at the spatial and seasonal gradients (Figure 4.4).

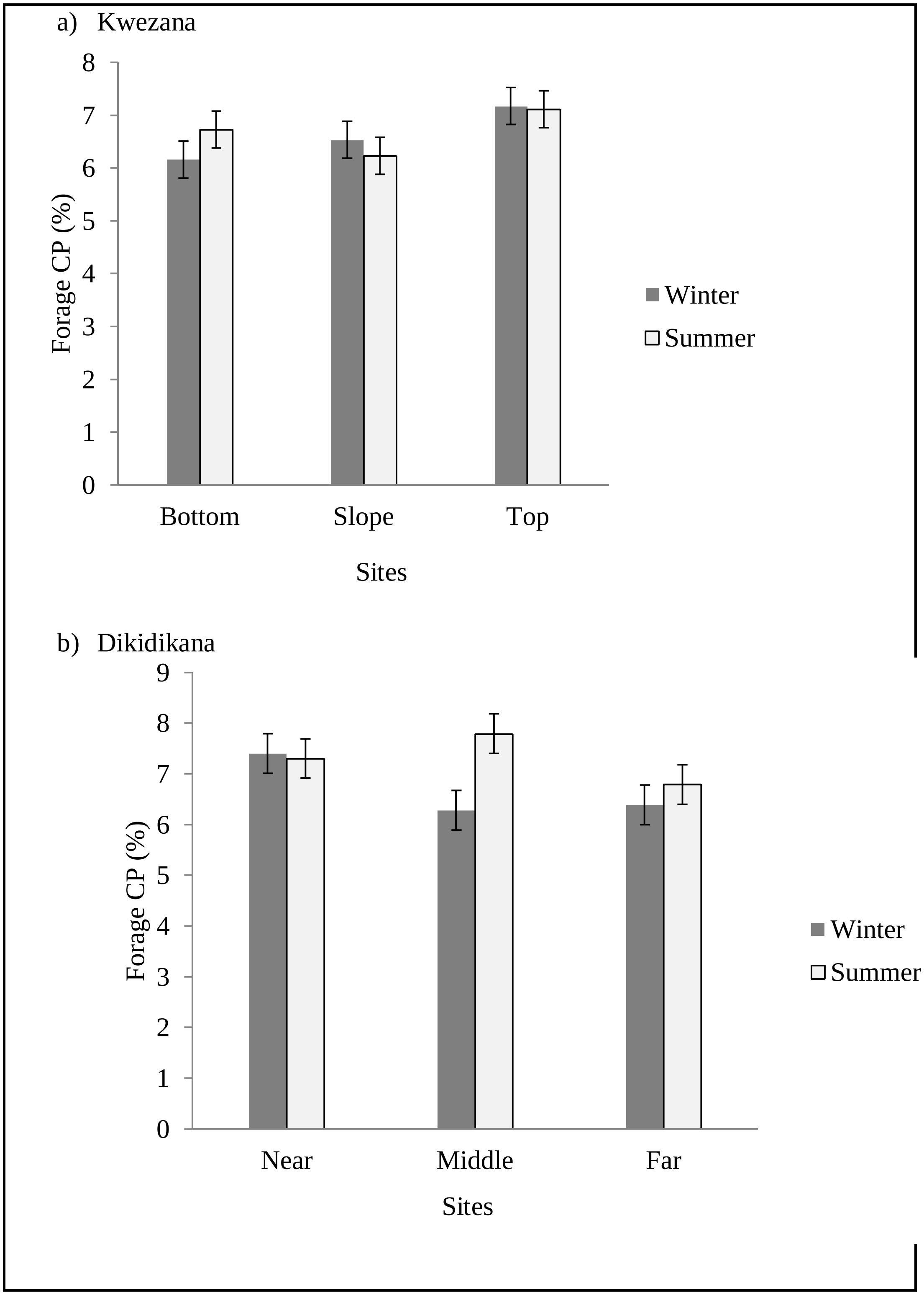

Figure 4.4: Spatial differences in the crude protein content of forage samples collected from three sites at Kwezana (a) and Dikidikana (b) in summer and winter

4.3.6. Correlations between soil and forage minerals

Table 4.5 presents the correlation coefficients between soil and forage micro minerals in winter. In winter, there were no significant correlations between the macro mineral levels of soil and forage sampled from both Kwezana and Dikidikana ($P>0.05$) (Appendices 3, 4 and 5). while there were positive correlations for the micro minerals Cu and Zn ($P<0.05$) at both study areas. In summer, there were no significant correlations between soil and forage levels of either macro or microï minerals.

Table 4.5: Correlations between soil and forage microï mineral levels in winter at Kwezana and Dikidikana

Microï minerals	Fe	Cu	Zn	Mn
Kwezana				
Fe	ï 0.10(0.57)			
Cu		0.34(0.04)		
Zn			0.38(0.02)	
Mn				0.18(0.30)
Dikidikana				
Fe	0.18(0.28)			
Cu		0.43(0.01)		
Zn			0.38(0.02)	
Mn				0.18(0.30)

Numbers in Parentheses indicate the level of significance

4.3.7. Mineral status of Nguni cattle blood serum in summer and winter

Table 4.6 presents the mineral concentrations of Nguni cattle blood serum sampled from Kwezana and Dikidikana. The blood serum Ca, Mg, Cu and Fe levels of animals were slightly higher in winter than in summer. Animals from both sites had remarkably higher K and Na blood serum contents in winter than in summer. In summer, the serum from cattle sampled at Kwezana had Fe and K levels that were below the recommended levels while at Dikidikana Fe levels in both seasons were below the recommended levels.

Table 4.6: Blood serum mineral levels (mean values) of Nguni cattle in summer and winter

Mineral elements	Winter	Summer	SE	Recommended levels (Puls, 1994)
Kwezana				
Ca (mmol/l)	2.95*	2.41	0.19	1.97–2.7
Cu (ppm)	0.87	0.7	0.89	0.41–1.51
Mg (mmol/l)	1.08	0.95	0.12	0.74–1.23
K (mmol/l)	36.13*	4.02**	3.3	4.1–5.5
Fe (ppm)	1.83	1.01**	0.08	1.3ï 2.5
Dikidikana				
Ca (mmol/l)	2.69	2.49	0.03	1.97–2.7
Cu (ppm)	0.98	0.71	0.27	0.41–1.51
Mg (mmol/l)	1.09	0.96	0.04	0.74–1.23
K (mmol/l)	42.04*	4.15	0.57	4.1–5.5
Fe (ppm)	1.28**	0.78*	0.03	1.3ï 2.5

*Values are above the recommended level. **Values are lower than the recommended level.

4.4. Discussion

4.4.1. Soil nitrogen and macro–mineral status

The biological activity responsible for N accumulation in the soil depends on moisture availability; therefore, the level of soil N is strongly influenced by the available soil moisture (Rasaei, Ghobadi, Jalaliï Honarmand, Ghobadi and Saeidi, 2012). In this study, the expectation therefore was higher N levels in the wet summer but marginally higher soil N was found in winter. The reason for the higher soil N in winter was not clear but may be attributed to the high soil moisture content during the winter sampling period as observed during sampling (Appendices 6 and 7). The moisture could have been due to some rains that were experienced during the winter sampling period. It could also be due to the organic matter from dead plant material that accumulates during winter.

Calcium is quite essential to reduce soil acidity and is also a major nutrient for normal plant growth (Ashraf, Khan, Ashraf and Zafar, 2006). Ashraf *et al.* (2006), in a study conducted in Pakistan found seasonal variation in soil Ca as found in the present study where soil Ca was higher in winter. Seasonal variations in soil Ca concentrations have also been reported by Khan *et al.* (2004) in Pakistan and Tiffany *et al.* (2000) in North Florida but contrary to the findings of this study, these two researchers found higher levels of soil Ca in summer.

The seasonal variability of soil Mg found at Kwezana was similarly reported by Khan, Ashraf, Ahmad, McDowell and Valeem (2008) in the semiï arid regions of Pakistan. The nonï significant spatial variation of soil K found in the current study concurred with the reports of Fardous *et al.* (2010) who conducted a similar study on the semiï arid rangelands of Pakistan.

The higher levels of soil K in summer at Kwezana concur with the findings of Ashraf *et al.* (2006) and Fardous *et al.* (2010) in Pakistan, and Xin, Long, Guo, Irvine, Ding, Ding and Shang (2011) in China.

The spatial variation in soil P at Dikidikana may be the result of the inputs and outputs of the livestockï pasture system that includes excretion by animals, phosphorus loss into soils and eventual harvest by animals (Sigua, Coleman, Albano and Williams, 2011). As they spend time on the rangelands, animals tend to prefer certain parts of the rangeland than others. This causes an uneven distribution of urine and faeces thereby concentrating nutrients obtained from a large area on a smaller area through urination and defecation (Drewes, Rethman and Donaldson, 1999). Sigua *et al.* (2011) also reported livestock grazing to play an important role in soil P dynamics as it affects P cycling because of the return of P through mineral excretion.

4.4.2. Seasonal and spatial variation in soil micro–mineral status

While in the present study all soil samples except the bottom sites at Kwezana did not show seasonal variation in soil Cu, Rhue and Kidder (1983) in Florida and Khan *et al.* (2006) in Pakistan reported a marked seasonal variation in soil Cu concentrations with summer Cu concentrations being much higher than the winter concentrations. Soil Cu concentrations for all sites were above the critical level of 0.3 mg/kg suggested for the normal plant growth (Rhue and Kidder, 1983) in both seasons. Seasonal variations in soil Zn have also been reported by Ahmad *et al.* (2012) in Pakistan. The levels of soil Zn in this study were below the critical level of 1 mg/kg (Rhue and Kidder, 1983) on most of the sites in both seasons. Season had no effect on soil Mn except on the bottom sites at Kwezana and near sites at Dikidikana. Fardous, Ahmad, Gondal, Khan, Ejaz and Valeem (2011) also found a nonï significant effect of season on soil Mn in the semiï arid regions of Pakistan. All the sites had Mn levels adequate for normal plant growth (5 mg/kg) during both seasons (Rhue and Kidder, 1983).

4.4.3. Forage nitrogen and macro–mineral status

Despite the marked seasonal variation in soil N, there was no significant seasonal variation in forage N on most sites and this may be explained by the fact that when N supply to the roots is not limited, N uptake by plants closely matches the growthï related demand of the plant (Von Wiren, Gazzarrini and Fronmmer, 1995). Forage calcium levels in both study areas were above the requirements of 2.7 g/kg for beef cattle (NRC, 2000) in both seasons. Forage Mg in both study areas maintained levels above the cattle requirement of 1.0 g/kg (NRC, 2000). These results contradict previous reports of Mg deficiencies on rangelands of the Eastern Cape by Drewes *et al.* (1999).

Potassium uptake is most rapid on warm, moist soils that are well aerated and have a slightly acidic to neutral pH. As soil temperature increases, plant metabolic activity increases which increases root growth and root activity (McKafee, 2008). As such, in this study, forage K was much higher in the wet summer when all the three conditions were met. In China, Xin *et al.* (2011) also reported much higher forage K in summer. In summer, forage K was well above the NRC recommendations of 6.5 g/kg for beef cattle (NRC, 2000). Forage P in this study was below the cattle requirements of 2.3 g/kg in both seasons and both study areas. Phosphorus is the most limiting mineral for the productivity of grazing animals throughout the world because of its low availability to range plants and loss through soil erosion (Hussain and Durrani, 2008). Similar P deficiencies have been reported on South African rangelands (Drewes, *et al.,* 1999).

4.4.4. Seasonal and spatial variation in forage micro–mineral status

The total quantity of a microï nutrient in most soils is generally not a good indicator of its availability to plants (Gupta, Kening and Siyuan, 2008). Soil available Fe is not related to the total Fe content hence the apparent seasonal variations in forage Fe despite the absence of seasonal variation in soil Fe. The forage Fe levels were much higher in winter on all the sites similar to the findings of Ahmad *et al.* (2012) on the semiï arid rangelands of Pakistan. Drewes *et al.* (1999) reported that Fe content reaches a peak in the post rainy season, which is in this study the winter season. The mean values of forage Fe were all above the recommended 50 mg/kg (Fardous *et al.,* 2011) for grazing animals. While in this study there were no seasonal variations in forage Bo, Gizachew and Smit (2012) reported a marked seasonal variation in forage Bo on the Vertisols of Ethiopia.

Ramirez *et al.* (2001) reported seasonal variations in forage Zn but in this study the levels of forage Zn showed no significant seasonal variations. It is pleasing though to note that forage Zn levels on all the study sites fell within the recommended range of 0.02ï 0.05 g/kg (McDowell, 1985). In the present study, forage Mn remained unaffected by season across all the sites quite contrary to the findings of researchers such as Pastrama *et al.* (1991) in Colombia, Khan *et al.* (2006) in different regions of the world and Fardous *et al.* (2011) in Pakistan. Mean Mn values in the present study, were above the critical level of 20 mg/kg (McDowell, 1985) for grazing livestock.

4.4.5. Forage dry matter yield and crude protein content

Dry matter content of natural rangelands in the low rainfall savannas is largely determined by precipitation (Abusuwar and Ahmed, 2010). In the present study no seasonal variations were apparent in both forage DM and CP. Also, in both seasons, the forage CP was within the critical threshold level of 6ï 8% (Humphreys, 1991).

4.4.6. Mineral element levels in Nguni cattle blood serum

Though the forage Ca levels were within the recommended levels in both seasons, cattle blood serum Ca was slightly higher than the recommended range in winter. Blood serum Ca may not accurately reflect the actual amount absorbed from the feed consumed by the cattle. The large stores of Ca in bone and the homeostatic mechanism regulate blood Ca concentrations (Herdt, Wilson and Braselton, 2000).

Though low serum Cu concentrations indicate deficiency, adequate serum Cu levels do not necessarily indicate adequate Cu status of the forage because the liver accumulates Cu and releases it to meet physiological demands when intake is insufficient (Hertd *et al.,* 2000; Guidry, 2009). According to Para, Ojeda, Combellas, Gabaldon, Escobar, Martinez and Benezra (1999), serum Mg concentrations reflect daily intake rather than reserves, which are not quickly available. In this study, the Nguni cattle blood serum Mg levels were within the recommended levels in both seasons suggesting that the forage provided sufficient dietary Mg for the cattle.

Blood serum K levels in this study were higher than the recommended levels in winter and slightly lower than the recommended levels in summer. A number of factors may have caused K deficiency in cattle blood serum. Inadequate dietary supply as suggested by McDowell (2003) of K may not have been a possible cause of the K deficiency since the forages supplied sufficient K in both seasons. The other possible causes may be gastroï intestinal losses or endocrine malfunction (NRC, 1984). Though forage Fe levels were above the normal animal requirements, blood serum analysis revealed Fe deficiency in winter at both study areas and also in summer at Dikidikana. The level of Fe in animal blood is influenced by external parasites such as ticks, especially in the hot seasons (summer) as external parasites can cause blood loss and subsequently reduce Fe concentrations (Marufu *et al.*, 2010).

4.7. Conclusion

Most soil samples did not show seasonal and spatial variability in the levels of Ca, Mg, K and Zn in both study areas while the spatial variability of P and micro minerals depended on season and study area. Only soil N showed seasonal variations in both study areas. In the forage, the minerals Mn, Cu and Zn did not show any spatial or seasonal variations while Ca, Mg, K and Bo did vary seasonally and/or spatially. Forages sampled from Dikidikana and Kwezana in wet summer and in wet winter contained adequate levels of Ca, Mg, K, Mn, Cu, Zn, Fe and Bo according to the requirements for grazing cattle. However, the forage contained levels of P lower than the dietary requirements for beef cattle though this mineral was not deficient in Nguni cattle blood serum. The minerals found deficient in Nguni cattle blood serum were Fe and K. Therefore, supplementation of these minerals may be necessary during the summer season in both study areas. There is need for further investigation into the causes of these deficiencies ways of preventing future deficiencies in these minerals. Soil, forage and cattle blood serum mineral levels have been found to vary both seasonally and/or spatially.

CHAPTER 5: SUMMARY

5.1. General

The objective of the study was to determine the indigenous knowledge and perceptions of communal farmers on livestock feeding and rangeland resources management; dynamics of mineral levels of soils, forage and Nguni cattle blood serum in two communal areas of the Eastern Cape, South Africa. In Chapter 3, 77 livestock farmers from two communal areas were interviewed using a structured questionnaire in order to determine their indigenous knowledge and perceptions on livestock feeding and rangeland resources management. The results of the questionnaire survey revealed that farmers lacked inï depth knowledge of the natural forage species, their grazing and browsing value neither did they show knowledge of the dynamics of the rangeland resources and livestock preferences. The livestock all grazed on the communally owned natural rangelands without any supplementation even during the dry season. Therefore, the livestock at Kwezana and Dikidikana rely on the natural rangelands for nutrition. Education did not seem to have an effect on the indigenous knowledge neither did it influence livestockï range management practices at Kwezana and Dikidikana.

The finding that livestock at Kwezana and Dikidikana relied mainly on the natural rangelands for nutrition necessitated the second study in Chapter 4 that sought to determine the dynamics of the mineral status of soils, forages and Nguni cattle blood serum and two communal rangelands. The aim of the study was to determine whether the newly introduced Nguni cattle were getting adequate supplies of minerals from the natural rangelands both in winter and in summer. There were no strong correlations between soil and forage mineral levels, implying that mineral levels in soils may not have direct implications on the mineral status of the forage. Forages were found to have adequate levels of Ca, Mg, K, P, Mn, Cu, Zn, Fe and Bo for grazing cattle. As such, the Nguni cattle blood serum analysis revealed normal Cu concentrations though this may not accurately reflect the mineral status in the Nguni cattle as adequate. The reported adequate serum Mg concentrations in this study are a direct reflection of Mg absorption from the gut, implying adequate Mg supply from the diet. The serum Ca levels in this study were adequate and concur with the levels reported by Ndlovu (2008) and Mapiye *et al.* (2010).

Only two minerals were found to be deficient in the Nguni cattle blood serum. The natural forage contained adequate levels of K for grazing beef cattle therefore the reason for the deficiencies in the Nguni cattle blood serum were not clear. The Fe deficiencies noted in cattle blood serum could not have resulted from dietary lack since the forage analysis revealed more than adequate amounts of Fe in the forage. Therefore, the Fe deficiency in the Nguni cattle blood serum could have been influenced other factors such as external parasites such as ticks, especially in the hot seasons (summer) as external parasites can cause blood loss and subsequently reducing Fe concentrations (Marufu *et al.*, 2009).

5.2. Conclusions

The resource poor farmers at Kwezana and Dikidikana regard their livestock highly as a source of wealth and income, but face the challenge of feeding their livestock. Despite the fact that their livestock mainly relies on the natural communally owned rangeland for nutrition the livestock farmers lack knowledge on the forage species found on their rangelands. The Nguni cattle showed adequate levels of most of the minerals in both summer and winter. Seasonal and spatial variations were noted in the levels of soil Fe and Mn and forage DM, CP, Mg, Ca, K, Zn, Fe and Cu. These seasonal variations did not result in mineral deficiencies in the cattle except for the minerals Fe and K that were found deficient in the Nguni cattle blood serum.

5.3. Recommendations

There is need for interventions to help the communal farmers at Kwezana and Dikidikana to better understand their rangeland resources and ways of managing them sustainably for the benefit of their grazing livestock. There is also a need to find ways for the youth to gain interest in livestock production and rangeland resources management. Until the real cause of the Fe and K deficiency has been determined, farmers could provide Fe and K supplements for their cattle in the summer.

5.4. Further Research

- This study only investigated dynamics of selected minerals and CP of the two communal rangelands therefore there is still opportunity for further study to determine the dynamics of the other minerals and the digestibility of the forage.
- Further study could also consider other sources of minerals for livestock such as water and how these also contribute to the mineral status of the grazing livestock.
- Due to limited technical support and logistical challenges during data collection, a small sample size was used during collection of blood samples therefore, future studies may consider a bigger sample size.

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Appendix 1: Questionnaire

THE DYNAMICS OF THE COMMUNAL FEED RESOURCE BASE, PASTORALIST PERCEPTIONS AND NGUNI CATTLE FEEDING BEHAVIOUR

Questionnaire number: __________ Enumeratorôs name: _________________________

All information provided by interviewee will be treated as STRICTLY CONFIDENTIAL for mutual benefit of both the researcher and the farmers.

A.GENERAL HOUSEHOLD INFORMATION

A1 Name of village/community____

A2 District____

A3 Size of household____

A4 Name of cattle farmer____

A5 Age of cattle farmer: <30_____ 30 ï 40 ______ 40 ï 50______ >50_______

A6 Level of education:

Primary_____Secondary_____ College_____ University______ Postï graduate_____

A7 Training in Agriculture: Formal___________ Nonï formal___________

A4 Highest level of education attained by each member of the family_____________

A5 Main source of income____

A6 Type and number of livestock owned:

Type of livestock	Numbers	Years owned
Goats		
Sheep		
Cattle		
Poultry		

Other :		

A7 List the main objectives for livestock farming in order of importance:

- Goats:____
- Sheep____
- Cattle____
- Other ____

A8 How long have you been keeping livestock? ___________________________

A9 Which breeds are you using?____

A10 How did you acquire your livestock?________________________________

A11 Composition of your livestock:____________________________________

Type of livestock	Male	Female	Young
Goats			
Sheep			
Cattle			
Poultry			

A12 What constraints do you experience in rearing the animals?

Management	Y / N
Feed	Y/ N
Marketing	Y / N
Other	Y / N

A13 Where do you sell your animals?

Open market	Y / N
Auction	Y / N
At home	Y / N
Other	Y / N

A14 How do you perceive the cattle population has changed over the past ten years?

Decreased	Y / N
Increased	Y / N
Remained the same	Y / N

A15 Herd structure:

CATEGORY	NUMBERS
COWS	
BULLS	
HEIFERS	
BULL CALVES	
HEIFERS	
OXEN	
TOTAL	

A16 Do you use your livestock for draft power?

Tick the correct choice	
OXEN	
DONKEYS	
COWS	
GOATS	

A17 Indicate Socioï economic importance of animals?

Animal	Most important use	Important	Least important
Cattle			
Goats			
Sheep			
Pigs			
Poultry			
Others			

A18 Who looks after your livestock? Tick the correct answer

Type of Animal	Family member	Worker	Other
Cattle			
Goats			
Sheep			

A19 Indicate the socioï economic importance of livestock compared to crops, giving reasons for each.

Level of Importance	Reason
Less important	
Equally important	
More important	

A20 Do you provide any form of animal housing? For :

Cattle	Y / N
Sheep	Y / N
Goats	Y / N

A21 What materials do you use for the housing? ___________________________________

A22 What time do animals go out in the morning?_________________________________

A23 What time do animals come in at night? _____________________________________

B. THE DYNAMICS OF FEED RESOURCE BASE

B1 Major feeds in order of importance

Animal	Most important feed	Important feed	Least important feed
Cattle	*Winter*		
Goats			
Sheep			
Cattle	*Summer*		
Goats			
Sheep			

B2 Supplementary feeds

CATTLE		GOATS		SHEEP	
Feed type	Source	Feed type	Source	Feed type	Source

B3 Water

	CATTLE	GOATS	SHEEP
River			
Dam			
Other			

B4 Do you have any communal grazing areas? _______________________________

B5 What is the distance to grazing areas? __________watering point?___________

B6 Do you practice grazing management? ___________________________

B7 Do you have overstocking problems in the area? __________________________

B8 What are the advantages of overstocking? _______________________________

B9 Suggest solutions to overstocking? _____________________________________

B10 Is there a problem of land degradation in parts of the rangeland? ____________

B11 How does the different livestock species graze together? Give details__________

____

B12 how do you deal with issues of feed security during the dry season? __________

____

B13Which grass species are most dominant? List them in order of importance______

____

B14 Which grass species were most dominant 5ï 10 years ago?__________________

____

B15 What feed supplements were you giving animals 5ï 10 years ago?____________

____

B16 What changes occur on the rangelands and feed resource base in:

winter____

summer____

B17 In your own opinion what causes these changes on the rangelands and the feed resource base?____

B18 What are the observable effects of these changes on the animals________________

____

C. CATTLE FORAGING BEHAVIOUR AND DIET SELECTION

C1 Which grass species are most preferred by each of the following?

Nguni cattle____

Sheep____

Goats____

C2 How much time do each livestock species spend in grazing per day?

Nguni Cattle:____________Goats:_______________Sheep:______________________

C3 Which bush species are most preferred by each of these species?

Nguni cattle:____

Goats:____

Sheep:____

C5 How much time does each livestock species spend on browse?

Nguni cattle:_____________Goats:_____________Sheep:________________________

C6 How much time do each species of livestock spend resting?

Nguni cattle:____________Goats:_____________Sheep:__________________________

C7 How much time does each livestock species spend watering?

Nguni cattle:_______________Goats:_______________Sheep:_________________

C8 Describe the patterns of grazing of the following livestock species e.g. solitary, gregarious e.t.c.:

Nguni cattle_______________Goats:_______________Sheep:______________

C9 Describe cattle movement and distribution during feeding times in

winter:____

summer:____

C10 Describe cattle movement and distribution throughout the day in

winter:____

Summer:____

C11 How do you control cattle movement and distribution during feeding times in

winter:____

Summer:____

C12 how do you control cattle movement and distribution throughout the day in

winter:____

Summer:____

Appendix 2: Consent Form

CONSENT FORM

Ié é é é é é é é é é é é é I.Dé é é é é é é é é é é é ..willfully agree that my cattle be observed and bled once every three months for a period of 12 months. The research project is conducted by name of the researcher of Fort Hare University.

Number of cattle to be observed and bledé é é é é ..é é é é ..

Signature of the:

1) Farmeré é é é é é é é é é é é é é é Dateé é é é é é é

2) Project Implementeré é é é ..é é é é é é .Dateé é é é é é é

3) Witness 1é é ..é é é é é é é é é é é é ..Dateé é é é é é é

4) Witness 2é é é é é é é é é é é é é é Date..é é é é é é ..

Appendix 3: Plant and soil mineral ANOVA tables

Kwezana plant ANOVA tables

Dependent Variable: N

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	0.00222222	0.00222222	0.04	0.8345
Site	2	0.10295278	0.05147639	1.02	0.3667
Season*Site	2	0.18305278	0.09152639	1.81	0.1715

Dependent Variable: Po

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	3.12500000	3.12500000	2.12	0.1497
Site	2	3.59527778	1.79763889	1.22	0.3011
Season*Site	2	4.59083333	2.29541667	1.56	0.2176

Dependent Variable: K

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	229.3368056	229.3368056	19.72	<.0001
Site	2	9.5433333	4.7716667	0.41	0.6651
Season*Site	2	8.9644444	4.4822222	0.39	0.6817

Dependent Variable: Ca

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	16.43555556	16.43555556	6.76	0.0115
Site	2	7.32194444	3.66097222	1.51	0.2294
Season*Site	2	4.94361111	2.47180556	1.02	0.3674

Dependent Variable: Mg

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	0.05013889	0.05013889	0.54	0.4671
Site	2	0.04111111	0.02055556	0.22	0.8036
Season*Site	2	0.45777778	0.22888889	2.44	0.0947

Dependent Variable: Fe

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	16.14066806	16.14066806	33.54	<.0001
Site	2	1.42240833	0.71120417	1.48	0.2355
Season*Site	2	1.02491944	0.51245972	1.07	0.3506

Dependent Variable: Cu

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	0.00001901	0.00001901	10.14	0.0022
Site	2	0.00001233	0.00000617	3.29	0.0435
Season*Site	2	0.00000478	0.00000239	1.27	0.2865

Dependent Variable: Zn

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	0.00015901	0.00015901	2.69	0.1060
Site	2	0.00023836	0.00011918	2.01	0.1416
Season*Site	2	0.00031936	0.00015968	2.70	0.0748

Dependent Variable: Mn

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	0.00954501	0.00954501	4.46	0.0384
Site	2	0.00250011	0.00125006	0.58	0.5603
Season*Site	2	0.00097011	0.00048506	0.23	0.7977

Dependent Variable: Bo

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	0.00000501	0.00000501	0.35	0.5572
Site	2	0.00005853	0.00002926	2.03	0.1392
Season*Site	2	0.00001186	0.00000593	0.41	0.6642

Dependent Variable: DM

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	70650.4050	70650.4050	0.81	0.3711
Site	2	155390.8525	77695.4263	0.89	0.4148
Season*Site	2	98571.9675	49285.9838	0.57	0.5707

Dependent Variable: CP

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	0.10503472	0.10503472	0.05	0.8189
Site	2	8.49316406	4.24658203	2.14	0.1261
Season*Site	2	2.44542101	1.22271050	0.62	0.5435

Dikidikana plant ANOVA tables

Dependent Variable: N

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	0.07933472	0.07933472	1.68	0.2000
Site	2	0.12983611	0.06491806	1.37	0.2610
Season*Site	2	0.24561944	0.12280972	2.59	0.0824

Dependent Variable: Po

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	2.10125000	2.10125000	21.14	<.0001
Site	2	0.31583333	0.15791667	1.59	0.2119
Season*Site	2	0.20083333	0.10041667	1.01	0.3697

Dependent Variable: K

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	450.0000000	450.0000000	37.88	<.0001
Site	2	94.9725000	47.4862500	4.00	0.0230
Season*Site	2	140.8225000	70.4112500	5.93	0.0043

Dependent Variable: Ca

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	16.72347222	16.72347222	9.08	0.0037
Site	2	5.01194444	2.50597222	1.36	0.2634
Season*Site	2	1.20361111	0.60180556	0.33	0.7223

Dependent Variable: Mg

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	0.76055556	0.76055556	5.95	0.0174
Site	2	0.03083333	0.01541667	0.12	0.8866
Season*Site	2	0.00194444	0.00097222	0.01	0.9924

Dependent Variable: Fe

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	20.20360556	20.20360556	25.27	<.0001
Site	2	0.76673611	0.38336806	0.48	0.6212
Season*Site	2	0.05893611	0.02946806	0.04	0.9638

Dependent Variable: Cu

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	0.00001513	0.00001513	3.89	0.0528
Site	2	0.00000578	0.00000289	0.74	0.4798
Season*Site	2	0.00000100	0.00000050	0.13	0.8796

Dependent Variable: Zn

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	0.00034235	0.00034235	4.82	0.0317
Site	2	0.00011869	0.00005935	0.84	0.4382
Season*Site	2	0.00011969	0.00005985	0.84	0.4352

Dependent Variable: Mn

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	0.00013339	0.00013339	0.04	0.8516
Site	2	0.00450469	0.00225235	0.60	0.5542
Season*Site	2	0.01408603	0.00704301	1.86	0.1634

Dependent Variable: Bo

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	0.00002689	0.00002689	1.53	0.2208
Site	2	0.00001878	0.00000939	0.53	0.5890
Season*Site	2	0.00001011	0.00000506	0.29	0.7512

Dependent Variable: DM

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	676633.4450	676633.4450	5.27	0.0248
Site	2	178666.5353	89333.2676	0.70	0.5020
Season*Site	2	965405.8808	482702.9404	3.76	0.0284

Dependent Variable: CP

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	9.47938368	9.47938368	4.91	0.0302
Site	2	4.32942708	2.16471354	1.12	0.3323
Season*Site	2	5.60590278	2.80295139	1.45	0.2418

Kwezana soil ANOVA tables

Dependent Variable: N

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	453.0050000	453.0050000	7449.75	<.0001
Site	2	0.2133333	0.1066667	1.75	0.1810
Season*Site	2	0.2233333	0.1116667	1.84	0.1674

Dependent Variable: pH

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	0.03125000	0.03125000	0.37	0.5429
Site	2	0.72333333	0.36166667	4.33	0.0171
Season*Site	2	0.12000000	0.06000000	0.72	0.4914

Dependent Variable: Ca

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	44.21133889	44.21133889	22.37	<.0001
Site	2	3.32446944	1.66223472	0.84	0.4359
Season*Site	2	6.04755278	3.02377639	1.53	0.2242

Dependent Variable: Mg

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	6.10168889	6.10168889	10.88	0.0016
Site	2	0.83361944	0.41680972	0.74	0.4795
Season*Site	2	0.91995278	0.45997639	0.82	0.4448

Dependent Variable: K

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	68326.72222	68326.72222	14.23	0.0003
Site	2	8529.19444	4264.59722	0.89	0.4162
Season*Site	2	1473.86111	736.93056	0.15	0.8580

Dependent Variable: Po

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	0.347222	0.347222	0.00	0.9847
Site	2	1031.444444	515.722222	0.55	0.5798
Season*Site	2	510.777778	255.388889	0.27	0.7626

Dependent Variable: Cu

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	16.90711250	16.90711250	8.64	0.0045
Site	2	24.92777500	12.46388750	6.37	0.0030
Season*Site	2	15.04390833	7.52195417	3.84	0.0264

Dependent Variable: Zn

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	0.72200139	0.72200139	0.64	0.4279
Site	2	1.16125833	0.58062917	0.51	0.6018
Season*Site	2	0.14396944	0.07198472	0.06	0.9386

Dependent Variable: Mn

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	49717.55556	49717.55556	6.77	0.0114
Site	2	67056.01083	33528.00542	4.57	0.0139
Season*Site	2	64124.20861	32062.10431	4.37	0.0166

Dependent Variable: B

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	0.02683472	0.02683472	3.52	0.0649
Site	2	0.08201944	0.04100972	5.39	0.0068
Season*Site	2	0.00048611	0.00024306	0.03	0.9686

Dependent Variable: Fe

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	4785.680556	4785.680556	3.36	0.0712
Site	2	9087.750000	4543.875000	3.19	0.0475
Season*Site	2	2145.861111	1072.930556	0.75	0.4746

Dikidikana soil ANOVA tables

Dependent Variable: pH

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	0.00013889	0.00013889	0.00	0.9638
Site	2	0.33250000	0.16625000	2.49	0.0909
Season*Site	2	0.05527778	0.02763889	0.41	0.6630

Dependent Variable: Ca

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	1.13753472	1.13753472	0.69	0.4075
Site	2	1.35676944	0.67838472	0.41	0.6624
Season*Site	2	0.90660278	0.45330139	0.28	0.7590

Dependent Variable: Mg

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	0.02383472	0.02383472	0.07	0.7865
Site	2	1.07163333	0.53581667	1.66	0.1976
Season*Site	2	0.07591111	0.03795556	0.12	0.8891

Dependent Variable: K

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	8192.00000	8192.00000	1.23	0.2714
Site	2	17514.75000	8757.37500	1.32	0.2754
Season*Site	2	8118.25000	4059.12500	0.61	0.5466

Dependent Variable: Po

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	165.0138889	165.0138889	2.19	0.1433
Site	2	177.8611111	88.9305556	1.18	0.3129
Season*Site	2	79.6944444	39.8472222	0.53	0.5911

Dependent Variable: Cu

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	9.03125000	9.03125000	7.60	0.0075
Site	2	8.33924444	4.16962222	3.51	0.0356
Season*Site	2	0.48923333	0.24461667	0.21	0.8145

Dependent Variable: Zn

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	0.10656806	0.10656806	0.42	0.5203
Site	2	0.97861944	0.48930972	1.92	0.1550
Season*Site	2	0.26070278	0.13035139	0.51	0.6023

Dependent Variable: Mn

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	31266.66889	31266.66889	3.89	0.0528
Site	2	86380.18861	43190.09431	5.37	0.0069
Season*Site	2	14407.16694	7203.58347	0.90	0.4131

Dependent Variable: B

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	0.00000139	0.00000139	0.00	0.9894
Site	2	0.01135278	0.00567639	0.72	0.4884
Season*Site	2	0.02978611	0.01489306	1.90	0.1575

Dependent Variable: Fe

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Season	1	1283.555556	1283.555556	0.88	0.3521
Site	2	2062.111111	1031.055556	0.71	0.4976
Season*Site	2	824.777778	412.388889	0.28	0.7551

Appendix 4: Correlations between soil and forage macroï elements in winter and summer

Macro-minerals	N	Ca	Mg	K	P
Winter					
Kwezana					
N	ï 0.12(0.50)				
Ca		ï 0.25(0.14)			
Mg			ï 0.18(0.30)		
K				0.04(0.83)	
P					ï 0.03(0.87)
Dikidikana					
N	ï 0.14(0.40)				
Ca		ï 0.01(0.96)			
Mg			0.25(0.14)		
K				ï 0.23(0.17)	
P					ï 0.01(0.98)
Summer	**N**	**Ca**	**Mg**	**K**	**P**
Kwezana					
N	ï 0.08(0.63)				
Ca		ï 2.26(0.12)			
Mg			0.0003(0.99)		
K				0.22(0.20)	
P					0.02(0.90)
Dikidikana					
N	ï 0.24(0.16)				
Ca		ï 0.25(0.14)			
Mg			ï 0.18(0.30)		
K				0.22(0.20)	
P					0.02(0.90)

Key: Values in parentheses indicate the level of significance at $p = 0.05$.

Appendix 5: Correlations between soil and forage microï elements in summer

Microï Minerals	Fe	Cu	Zn	Mn
Kwezana				
Fe	ï 0.07(0.68)			
Cu		ï 0.05(0.76)		
Zn			0.02(0.90)	
Mn				ï 0.16(0.37)
Dikidikana				
Fe	ï 0.10(0.57)			
Cu		ï 0.09(0.59)		
Zn			ï 0.08(0.65)	
Mn				0.18(0.30)

Key: Values in parentheses indicate the level of significance at $p = 0.05$.

Appendix 6: Puddles on the rangelands during the winter sampling period at Dikidikana (a) and Kwezana (b)

a) Dikidikana rangelands (*Taken by:* Farai Alice Gwelo on 22 July 2011)

b) Kwezana rangelands (*Taken by:* Farai Alice Gwelo on 22 July 2011)