EVALUATION OF RANGE CONDITION, SOIL PROPERTIES, SEED BANKS AND FARMER'S PERCEPTIONS IN PEDDIE COMMUNAL RANGELAND OF THE EASTERN CAPE, SOUTH AFRICA

By

Mndela Mthunzi

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Faculty of Science and Agriculture

University of Fort Hare

P/Bag X 1314

Alice 5700

Supervisor: Dr K Mopipi

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DECLARATION

I declare that "**Evaluation of range condition, soil properties, seed banks and farmer's perceptions in Peddie communal rangeland of the Eastern Cape, South Africa**" is my research under the supervision of Dr K. Mopipi and it has not been submitted for any degree in any institution. All the information sources used in this thesis have been cited properly without any manipulations.

Mr Mndela Mthunzi **Date**

Approved as to style and content by:

Dr K. Mopipi
(Superviser)

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ABSTRACT

South African rangelands in combination with their surrounding homesteads occupy 13% of the entire land surface in South Africa. These rangelands are a source of forage for communal livestock. The rangelands in communal tenure system are degraded due to high human population and livestock numbers. The rangeland of Peddie was never evaluated since the introduction of Nguni Cattle Empowerment Project. Therefore, socio-ecological evaluation was conducted in order to interlink farmer's perceptions and scientific data to recommend appropriate rangeland management and restoration programme.

Two structured questionnaires consisting of close and open ended questions were used to investigate farmer's perceptions on rangeland condition, dynamics, and their causes. Sixty households were randomly selected on the bases of livestock ownership and the membership in Nguni Cattle Project. In each household, any respondent of 20 years or greater, and a key informant of age greater than 40 years were selected. For scientific assessment of range condition, three homogenous vegetation units namely grassland, scattered and dense bushland were demarcated into four 100m x 50m replicates. In each replicate, two 100m transects were laid parallel to each other with 30m equidistant apart. The step point and harvesting method along each transect were employed for herbaceous species composition and biomass production. The point-to-tuft distance was also determined as a proxy for basal cover. Woody density, species composition and tree equivalents were determined in $200m^2$ belt transects in each HVU replicates. The germination method for soil seed bank evaluation was also employed to find plant species composition and density. The soil nutrients (OC, N, P, K, Na, Ca, Mg, Zn, Cu and Mn) and pH were analysed through solution preparation and observation under photospectrometer to determine functional capacity of the soil of Peddie rangeland.

The farmer's perceptions comprised of 63% females and 37% males (n = 120) with a mean household of 8 people, 5 adults and 3 children. It was perceived by 93.3% respondents that the rangeland of Peddie have undergone changes over two decades. These changes were perceived by 83% respondents to be accompanied by decline in livestock numbers. Woody encroachment and overgrazing were perceived to be the major attributes of these vegetation changes. The scientific rangeland condition assessment confirmed that these changes were more pronounced as bush density increases. Dense bushland had a significantly high (p<0.05) encroached condition with 6650 trees ha^{-1} and 4909.5 TE ha^{-1} beyond the recommended thresholds of 2400 trees ha^{-1} and 2500 TE ha^{-1} respectively. Scattered bushland had a fair condition of 1950 trees ha^{-1} and 1198.1TE ha^{-1}. *Themeda triandra* as a key species was significantly higher (p<0.05) in grassland (31.1%) than scattered (15.6%) and dense bushland (6.1%). There was a declining trend in biomass production from grassland to dense bushland. The summer biomass production was significantly higher (p<0.05) in grassland than scattered and dense bushland but winter biomass was not significantly different (p>0.05) from all homogenous vegetation units of Peddie rangeland. However, the soil fertility increased with an increase in bush density except organic carbon (OC) which was 1.61% in grassland, 1.46% in scattered and 1.53% in dense bushland respectively. Soil N, K, P, Mg^{2+} Na^{+}, Ca^{2+}, Cu, Zn, Mn and pH were significantly higher (p<0.05) in dense bushland than grassland and scattered bushland. High soil fertility in dense bushland may be attributed to by abscission of woody plants and litter decomposition.

In the soil seed bank, the abundances of forbs were significantly higher than sedges (χ^2 = 12, df = 1, p = 0.001) and grasses (χ^2 = 8.333, df = 1, p = 0.004) in all homogenous vegetation units while sedges were not significantly different (χ^2 = 3, df = 1, p = 0.083) from grasses. The Sorensen's index indicated that soil seed bank and extant vegetation were significantly different (p<0.05). Annual and biennial forbs and sedges had high abundances while perennial grasses formed a bulk in above ground vegetation. This provided an insight that a reliance on soil seed bank for restoration of Peddie rangeland would not be advisable because it can result in retrogression. The communal rangeland assessment provided clear qualitative and quantitative data when the combination of indigenous knowledge and scientific assessments was done. The rationale is that conclusions and recommendations of range assessment are relient on the farmer's perceptions pertinent to their livestock production systems and their rangeland management objectives. This study has shown that inclusion of communal farmers in policy making can provide better insight because those are the people experiencing the consequences of range degradation.

Key words: Indigenous knowledge (IK), homogenous vegetation units, species composition, biomass production, soil chemical composition, soil seed bank composition and density.

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LIST OF ABBREVIATIONS

CFPs	Communal farmer's perceptions
CPO	Communal property ownership
HVU	Homogenous Vegetation Unit
ANOVA	Analysis of variance
SAS	Statistical Analysis System
SPSS	Statistical Package for Social Sciences
GLM	General Linear Model
S.E	Standard Error
LBM	Lowest Browsable material
TE	Tree Equivalents
BU	Browsing Units
DTPA	Diethylenetriamenepentaacetic
OC	Organic Carbon
N	Nitrogen
P	Phosphorous
K	Potassium
Mg	Magnesium
Ca	Calcium
Na	Sodium
Zn	Zinc
Cu	Copper
Mn	Manganese

CHAPTER 1 GENERAL INTRODUCTION

1.1 Background of the study

Communal rangelands in combination with their surrounding homesteads occupy 13% of the entire land surface in South Africa with 12.7 million people residing in these areas (Benett and Barrett, 2007, Benett *et al.*, 2012, Vetter *et al.*, 2006). Livestock production is a cornerstone for rural livelihood and is reliant on these rangelands for forage production. Livestock population in these extensive areas comprised of 52% of total cattle, 72% goats and 17% sheep (Palmer and Ainslie, 2006) which is currently expected to be significantly higher due to exponential growth of human population. The rangelands in this land tenure system have unrestricted access for all (Dreber *et al.*, 2011; Coronado-Quintana and McClaren, 2001; Benett and Barrett, 2007; Echavarria-Chairez *et al.*, 2010) due to communal property ownership (CPO) with poor management regulations. According to Vetter (2005), there is no proper management of the communal rangeland resources which consequently results in rangeland degradation.

Continuous grazing at higher stocking rates and the ascending human population are widely cited as serious threats to communal rangelands as rangeland resource is owned and utilised under the tragedy of commons (Vetter *et al.*, 2006; Mansour *et al.*, 2013; Moyo *et al.*, 2013). These threats correlate, with ascending human population calling for increase in livestock numbers (Vetter *et al.*, 2006) and other tragic anthropogenic uses of rangeland resources. Surplus stocking rate *per se* exacerbates the decline in general status quo of the rangeland (Kioko and Okello, 2010) and also sets up conditions for rangeland degradation (Bakoglu *et al.*, 2009; Smet and Ward, 2006; Nsinamva *et al.*, 2005; Muller *et al.*, 2007; Mortimore and Turner, 2005; Beyene, 2009). These surplus stocking rates are perpetuated by keeping more animals for various purposes such as to generate income, milk production, drought power, slaughter, bride price (Smet and Ward, 2005; Musemwa *et al.*, 2008), wealth and status (Vetter *et al.*, 2006).

Among all provinces of South Africa, the Eastern Cape Province is one of the most severely degraded provinces with rangelands under communal tenure system being dramatically degraded compared to commercial ones (Meadows and Hoffman, 2002). Severe degradation promotes detrimental shortages of forage causing death of livestock and diminution in performance of animal production and reproduction (Zerfu *et al.*, 2010). Despite its impact on livestock production, close to R2 billion in South Africa is spent annually in land rehabilitation which appreciates when expenses for vegetation degradation are included (Hoffman and Ashwell, undated). Nevertheless, Rezaei *et al.*, (2006) reported that the rangeland condition evaluation is crucial to facilitate adaptive management practices in effort to preclude rangeland degradation. Rangeland evaluation should constitute the herbaceous, tree and soil components (Abule *et al.*, 2007; Solomon *et al.*, 2007; Abate *et al.*, 2010).

There is an interlinkage between rangeland condition and soil quality (USDA-NRCS, 2001). The interdependency of soil chemical properties and vegetation that comprise similar climate and parent material may result in a diversification of plant species (Rezaei and Gilkes, 2006). The dynamics in vegetation characteristics may precede or follow the dynamics in soil properties and processes (USDA-NRCS, 2001) but there is an inferior understanding of the processes that lead to vegetation dynamics instigated by interaction of soil nutrients-vegetation under influences of grazing (Tessema *et al.*, 2011).

In rangeland evaluation, communal farmer's perceptions (CFPs) have been neglected by the rangeland management scientists and policy makers due to consideration of perception that they lack objectivity (Oba and Kaitira, 2006; Abate *et al.*, 2009). This criticism against CFPs has led the policy makers to label communal farmers as contributors to resource degradation with the rationale that they do not even contribute to national economy (Yayneshet and Kelemework, 2004). However, communal farmers are a part of the natural ecological systems (Kassahun *et al.*, 2008) hence they should not be overlooked. In addition, Homann and Rischkowsky (2005) stated that neglecting the communal farmer's perceptions (CFPs) have an enormous contribution to rangeland degradation with specific reference to soil erosion.

Farmer's perceptions can be used in tandem with the ecological methods of evaluating changes in rangelands (Angasa and Oba, 2008). CFPs can also aid in obtaining data of the local conditions in focus to rangeland degradation, thus adding value to scientific research (Angasa and Oba, 2008; Kgosigoma *et al.*, 2012). Researches involving the knowledge of communal farmers may also enhance in gaining information pertaining the sustainable use, development and protection of natural resources (Abate *et al.*, 2010). The CFPs should be incorporated with scientific knowledge when the plan and decision making is done.

When the rangelands are diagnosed as degraded, restoration through re-establishment of non-existing desirable species or proliferation of desirable species that have reduced in abundance is required (Snyman, 2004). Kinucan and Smeins (1992) reported that in post disturbance of the rangelands, the species establishment is highly dependent on soil seed bank, propagule immigration and persistence of vegetative structures. Moyo and Fatunbi (2010) reported that some plants have a reliance on the combination of both vegetative and sexual reproduction for propagation with soil seed bank being the paramount important storage system. In this context "soil seed bank is referred to as the populations of viable seeds on or in the soil that act as a potential seed source for natural revegetation and restoration" (Esmailzadeh *et al.*, 2011). The persistent soil seed bank plays a significant role in dictation of the successional trends that take place after a disturbance (Edwards and Crawley, 1999), recolonization of bare patches following a disturbance (Loydi *et al.*, 2012), conservation of genetic variability (Lemenih and Teketay, 2006) and restoration of the species richness in species poor grazing areas (Edwards and Crawley, 1999; Snyman, 2004).

1.2 Problem statement

Communal rangelands of South Africa are in poor condition where perennial species are replaced by annual species. Other communal rangelands of the Eastern Cape are highly encroached by *Acacia karoo* (Aucamp, 1976). All these changes result in reduction of biomass production. Therefore, the communal farmers are constrained by feed and forage scarcity more especially in winter (Bano *et al.*, 2009; Ahmad *et al.*, 2012; 2009). This constraint results in deleterious impacts on livelihood of communal livestock farmers since rangeland degradation results in decrement of forage production, and ultimately results in poor animal performance rendering livestock production in communal rangelands unsustained. In efforts to improve rangelands under communal tenure system, farmer's perceptions have been considered as of low value in policy making processes while at the same time management is bestowed to communal farmers.

1.3 Justification

There is limited scientific information on rangeland condition evaluation in semi-arid and arid areas of South Africa (Van Rooyen *et al.*, 1991). The results of this study provided knowledge on current rangeland and soil condition in Peddie communal rangeland and enabled recommendations to be made for appropriate rangeland management practices that can be applied to improve the quality and quantity of forage. The findings of this study also contributed towards recommending possible rangeland management and rehabilitation programmes of this communal rangeland to improve forage production for livestock. This in turn will support the success of the Nguni Cattle Development Project that is currently implemented in the Eastern Cape Province.

1.4 Objectives

1.4.1 General objective

To determine communal farmer's perceptions and interlink them with quantitative scientic rangeland condition data at Peddie communal rangeland in order to recommend appropriate rangeland management practices and rehabilitation programme for Peddie rangeland.

1.4.2 Specific Objectives

- ✓ To determine communal farmer's indigenous knowledge about rangeland condition and management practices applied in Peddie communal rangeland.
- ✓ To determine and compare botanical composition of existing vegetation and soil seed banks in Peddie communal rangeland.
- ✓ To determine biomass production and basal cover of the rangeland
- ✓ To determine the soil pH and nutrient status of the communal rangeland

1.4.3 Hypothesis

- ✓ It is hypothesised that Peddie communal rangeland is in poor condition such that it cannot support a sustainable livestock production.
- ✓ Soil seed bank and nutrient status of the rangeland are poor and they cannot support successful restoration of Peddie communal rangeland

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CHAPTER 2 LITERATURE REVIEW

2.1 Overview of the communal rangelands

Communal rangelands in South Africa are areas that were allocated to formerly confined groups of black people by the former South African government. These rangelands are multi-owned and are managed under norm free conditions where all citizens have equal access without any restrictions to the resource (Bennet and Barret, 2007). Communal areas are reported to be overpopulated with their rangelands being overstocked and continuously grazed hence they are in poor condition (Vetter *et al.*, 2005). This is intensified by the fact that exclusion of communal rangeland user is impossible (Bennet and Barret, 2007). The poor knowledge on rangeland management also contributes to poor condition of communal rangelands (Smet and Ward, 2005). Continuous grazing is brought about by the absence of fencing and poor rangeland management. Even the betterment planning implemented around 1960s failed with most of fences being vandalised hence the rangelands are in free access (Vetter *et al.,* 2005). Degradation seems to override in these areas due to the fact that limits on rangeland utilisation are restricted to individual, while the consequences of overutilization are shared by the whole community (Smet and Ward, 2006).

There is a need for assessment of rangeland condition to formulate their management practices (Rezaei *et al.*, 2006) and to estimate the extent of degradation in communal tenure system. The three tier system of rangeland assessment has been proposed as a good assessment system (Friedel, 1991; Solomon *et al.*, 2007). These include consideration of herbaceous vegetation, woody component and soil component if all exist in the rangeland (Solomon *et al.,* 2007). The different methods have been developed to assess rangeland condition. These methods include the use of bench mark, ecological index, key species method, weighted key species and degradation gradient method. The bench mark method is based on the comparison of the species composition of the sample site and bench mark (Friedel, 1991). It is assumed that different grazing regimes have different impacts on species composition. Therefore, grasses are categorised as Decreasers and Increaser species. Ecological index method was proposed by Voster (1982) where the weightings are given to each ecological group of grasses such as Decreasers and Increaser species. The index is not calculated based on the bench mark but at the end is compared to bench mark (Hurt and Bosch, 1991).

It is very clear that bench mark and ecological index methods provide bias estimates because their interpretation is reliant on ecological groupings of species while some species respond to other factors rather than grazing. Moreover, the climatic and fire regimes prevailed in the bench mark may be different from those of the sample site (Friedel, 1991). Key species method acknowledges that the distribution of other species is not grazing dependent. Here the rangeland condition is indicated by the relative abundances of the key species in the sample site and the index helps to estimate the grazing history of the rangeland. The degradation gradient and weighted key species methods allow measurements of the trend through site positioning along gradient of degradation. These methods are suitable where vegetation in a sample site is homogenous to minimise ecotypical differences in species. They are not reliant on ecological groupings instead weightings are species based (Hurt and Bosch, 1991).

The current studies have proposed the importance of communal farmer's to assess the rangelands in communal tenure system (Kgosigoma *et al.*, 2012). This assessment involves the use of structured and semi-structured questionnaires which are administered to individuals or focus groups in a community. The use of this approach has been proved that it can be analysed statistically and can be incorporated with scientific assessment of communal rangelands (Oba, 2012).

2.2 Farmer's perceptions on rangeland deterioration

Communal farmers are knowledgeable about the degree and time frames of deterioration of their rangelands. They cite different signs of rangeland deterioration including woody encroachment, shift in species composition, reduction in biomass production and occurrence of soil erosion (Angassa and Oba, 2008). In the study of Kgosigoma *et al*., (2012) farmers perceived that unpalatable species have a tendency to substitute the palatable grasses. This change has been perceived to be associated with improper grazing regime and variable rainfall in communal areas. Woody encroachment has been perceived by farmers to be a major problem that deteriorate the communal rangelands (Solomon *et al.*, 2007). This emanates from the fact that communal farmers in Southern Ethiopia perceived that reduction in biomass production and change in species composition was the consequences of woody encroachment (Angassa and Oba, 2008). Woody encroachment is known as an increase in unpalatable and poisonous woody plants. The communal farmers are also able to identify the invasive and non invasive woody species that threaten their rangeland conditions (Angassa and Oba, 2008). In some studies, the woody species that seem to threaten the communal rangelands are *Acacia species* (e.g Abebe *et al.*, 2010; Solomon *et al.*, 2007). However, the perception of woody encroachment varies between communities as farmers in KwaZulu Natal perceived that woody plant increase has positive impact to them as they use woods for fire, fencing and building (Wigley *et al.*, 2009). The occurrence of bare patches is also recognised by communal farmers as an indicator of deteriorated rangeland (Solomon *et al.*, 2007).

2.3 Farmer's perceptions on communal rangeland condition assessment

Communal farmers are reported to have knowledge about rangeland assessment (Ghorbani *et al.*, 2013). They apply a systematic way of assessing the rangeland condition. The three terms poor, fair and good are used for characterisation of rangeland condition (Admasu *et al.*, 2010). Communal farmers consider a variety of indicators such as vegetation, soils and livestock (Roba and Oba, 2008). The considerations for each parameter are diverse with species composition, biomass and bush component being of paramount importance for vegetation assessment (Oba and Kotile, 2001). Soil erosion identification and livestock products and performance are other factors of great consideration (Mapinduzi *et al.*, 2003). For example, perception on rangeland condition in study of Roba and Oba (2009) in Northern Kenya indicated that farmers acknowledge high milk production, high body gains and short calving interval as the indicators of rangeland in good condition. Others cited the decline in body condition as a resemblance of a diminishing rangeland condition. Even though poor animal health status can result to decline in body condition, there is a distinction made by communal farmers.

2.4 Herbaceous species composition in rangelands

Species composition is an important parameter to assess rangeland condition because of the variation in species palatability and acceptability to herbivory (Solomon, 2007). The rangeland in good condition should be characterised by more diverse perennial and palatable species composition. The trends in rangeland condition are usually measured in relation to previous rangeland condition with species composition being the major important determinant (Warburton, 2011). Species composition also provides the picture of the previous rangeland management (Walley and Hardy, 2000). Improper grazing regime results to complete replacement of palatable species by less palatable grazing-tolerant Increaser II species that characterise the poor condition (Tessema *et al.*, 2011). This indicates a form of retrogression which occurs as a consequence of prolonged overgrazing that favours reduction in competitive ability of perennials through reducing their growth rate and reproductive potential. This replacement is accompanied by the reduction of tuft size (Kioko *et al.*, 2012) and a consequent decline in forage quality and quantity of the grasses (Retzer, 2006). An intense successive grazing in the communal rangelands may also contribute enormously to reduced plant vigour because the more frequently the grazing the lower the carbohydrates stored for regrowth. This may allow the invasion of toxic unpalatable species to takeover thereby subtracting the rangeland potential to support livestock (Delcurto *et al.*, 2005). However, underutilisation may push plant succession to Increaser I dominated community (Smet and Ward, 2005). These species indicate a stable grass community and they may exhibit chemical deterrents and physical deterrents. Increaser II and Decreaser species also respond differently in different grazing regimes. Decreaser species tend to decrease with over and under utilisation while Increaser II species are favoured by overutilization (Kioko *et al.*, 2012). The adaptation strategies of these species to herbivory tend to differ depending on the extent of defoliation. They both exhibit tolerance and escape but the Decreaser species tolerate only during dormant season while Increaser II species tolerate year round (Danckwerts and Stuat-Hill, 1987).

However, according to Hoffman and Milton (1994), state and transition models emphasized that species composition transforms from one state to another due to unpredictable climatic changes and some disturbances. Additionally, high rainfall variability, competition among plant species and natural factors are major determinants of plant population fluctuations. In rangelands of high rainfall, perennial plants dominate while annuals dominate in rangelands with low rainfall (Fynn and O'Connor, 2000). Therefore, an investigation of rangeland degradation should not be restricted only to anthropogenic influences but the environmental impacts should be considered. Furthermore, a success of recolonisation of bare patched rangelands is largely determined by soil nutrients and moisture conditions (Solomon *et al.*, 2007).

2.5 Biomass production

Biomass production is defined as the total dry matter of living plant material which is actively and structural functional in a given area and is normally used for fuel and a source of energy for livestock (Bond-Lamberty *et al.*, 2002). The rangeland that produces biomass less than 1500 kg ha^{-1} $annum^{-1}$ is well recognised as in poor condition for livestock purposes. However, the rangeland with ≥800 kg ha^{-1} $annum^{-1}$ biomass has high protection potential against erosion (Teague *et al.*, 2009). The climatic conditions and grazing have marked influences on the forage production (Savadogo *et al.*, 2006; Van Rooyen *et al.*, 1991; Moyo *et al.*, 2010; Fynn and O`connor, 2000; Angassa and Oba, 2010). The climatic change impacts are manifested by increased atmospheric CO_2 which in turn plays a role in rangeland production through possessing impacts on plant growth. Enhanced CO_2 possesses considerable increase in plant photosynthesis thereby increasing plant growth. Despite high CO_2 concentration, climatic changes also enhance the increases in NH_4 and NO gases (Korner, 2006) which are the sources of nitrogen for plant growth. Angassa and Oba (2010) reported that forage production during dry season becomes less than during wet season. This provides an implication that seasonal variations are major driving forces of variation in forage production. The main cause of this variation may be the rainfall received per season (Angasa and Oba, 2010). In another study in Burkina Faso there was a positive correlation between the rainy days and forage production (Savadogo *et al.*, 2006). Therefore, due to aforementioned report it is necessary to set stocking rates according to forage seasonal fluctuations

After grazing, there is a need for remaining forage in the rangelands for a follow-up photosynthesis and manufacturing of energy for recovery of new vegetative parts, seed production and storage of carbohydrates in plant reserves for afterwards vegetation compensatory growth (Idaho Rangeland Resource Commision, 2011). A complete removal of leaf area may induce severe reduction in availability of energy to support the existing root biomass and future root production of vegetation (Briske *et al.*, 2008). Apart from severe impacts on leaf area, grazing strongly reduces the new shoot production through direct removal of the apical meristems of forage plants (Noy-Meir, 1993). Usually, the extent to which plants compensate from grazing stress is largely determined by the frequency and intensity of applied grazing regime (Noy-Meir, 1993). Therefore, a high grazing intensity which is common in communal rangelands reduces biomass production not only by repeated forage consumption but also through treading (Savadogo *et al.*, 2006).

High stocking rates may alter the plant distribution resulting in substitution of perennials by annuals (Tessema *et al.*, 2011; Savadogo *et al.*, 2006) and forbs, thereby causing reduction of forage production (Savadogo *et al.*, 2006). This results in the reduction of species diversity and increased exposure to bare ground, leading to increased runoff and soil erosion, which in turn leads to reduced water availability, nutrient retention and plant establishment (Mganga *et al.*, 2011). The ignorance of the rules and management systems that involve rangeland resting for forage production is a way to poor rangeland condition (Goqwana and Trollope, 2003). Due to shortage of resources and knowledge, it becomes not pragmatic in communal areas to consider resting systems and also the fact that there is a complexity in rangeland ownership which may cause one to ignore other livestock owner's views pertaining rangeland resource utilisation. Therefore, there is a need to provide trainings involving rangeland management in communal tenure system.

2.6 Vegetation cover and erosion potential

Basal cover is the estimate of the area covered by vegetation for erosion potential and is greatly determined by severity of grazing and other environmental factors. The severe grazing has dramatic influences on vegetation (Savadogo *et al.*, 2006) because it results in reduced vegetative cover and in alteration of dominance of perennials giving rise to annuals leading to land degradation (Todd and Hoffman, 1999; Savadogo *et al.*, 2006). The depletion in vegetation cover by overgrazing put soil at risk for runoff to takeover, thereby aggravating the extent of soil erosion (Oztas *et al.*, 2003). In South Africa the average soil loss through erosion is approximately 2.5 t ha^{-1} annually and at maximum it reaches 602.5 t ha^{-1} annually which is far greater than soil formation per annum (Malan and Niekerk., 2005).

Lutge *et al.*, (1998) reported 90% reduction in basal cover in Kokstad research station which was linked to patch grazing by livestock as the animals tend to focus on one portion thereby ruining the grass sward. The diminution in vegetation and litter cover brought about by herbivory permits rain drops to heat directly in the soil (du Toit *et al.*, 2009) and may also favour occurrence of hydrophobic substances that can limit infiltration (Savadogo, 2007; Snyman and Du Preez, 2005). Soil erosion on itself promotes reduction in water availability, nutrient retention and plant establishment (Mganga *et al.*, 2011). The loss in nutrient retention and water availability in eroded patches are the consequences of removal of litter and soil surface (O'connor, 2001). The amount and type of vegetative cover is the significant factor that influences water runoff (Malan and Niekerk, 2005). There is a correlation between changes in plant species composition and basal cover (Snyman, 2009). A healthy basal cover should be characterized by perennial grasses because annual grasses die after completion of lifespan living the bare soils in favour of soil erosion (Malan and Niekerk, 2005). According to (Sisay and Baars, 2002), basal cover increases with a decrease in rangeland condition due to the fact that the low creeping grasses tend to take over when the tall, erect grasses decline.

2.7 Bush composition and density in rangelands

A significant increase in bush density termed bush encroachment is a dramatic problem to livestock production (Angassa and Oba 2010). The underpinnings are that it reduces grazing carrying capacity of the rangelands and simultaneously causes forage inaccessibility and habitat loss for herbivores (Dube *et al.*, 2009). Bushes override at the expense of herbaceous vegetation due to shading and their vigorous competitive ability for available water and nutrients (Sawadogo *et al.*, 2005; Richter *et al.*, 2001; Smit, 2004; Abule *et al.*, 2007). It is globally documented that bush encroachment shapes the herbaceous composition and production but there is paucity of data elucidating the trend in species composition whether the direction of change moves from Decreaser to Increaser ecological group or the vice versa.

The prevalence of woody plants in rangelands is associated with disturbance regimes (grazing intensity, browsing and fire) and climatic factors (amount and seasonality of rainfall) (Hoffman, 1999; Smit, 2004; Tews and Jeltsch, 2004). For instance, Solomon *et al*., (2007) reported a high bush density in the bare patches as the result of heavy grazing. This is the outcome of the fact that a frequent grazing by herbivores favours water percolation from top soil which by-passes the herbaceous root zone to subsoil and indeed is accessed by bushes more significantly than grasses (Kraaij and Ward, 2006). Despite reduction of competitive ability of grasses, herbivores may promote the bush density through ingestion of seeds of already existing bushes loosening their seed coats thereby stimulating woody seedling and recruitment (Moleele and Perkins, 1998; Roques *et al.*, 2001). In addition, most tree seeds are tolerant to enzymes in the digestive tract of the ruminants (Abebe *et al.*, 2010).

Fire has been considered as a tool to control bush encroachment but it depends on tree species and fire intensity, as fire may break the seed dormancy of some bushes thereby stimulating the seedling of these species (Kraaij and Ward, 2006). However, some studies by Titshall *et al*., (2000) and, Western and Maitumo (2004) presented high density of woody plants in rangelands where herbivores were excluded for a prolonged period of time. The exclusion of herbivores and fire tend to allow the ingress of invasive woody plants like *Acacia mearnsii* (Titshall *et al.*, 2000). This may be attributed to by successional trends as underutilisation and exclusion of fire may drive the grassland to woodlands (Sawadogo *et al.,* 2005). In case of communal land tenure system underutilisation is substituted by intensive grazing due to large livestock numbers (Vetter *et al.*, 2006) which therefore reduces the standing biomass with negative consequences of reduced fire frequencies and intensity (Tobler *et al.*, 2003; Roques *et al.*, 2001). This implies that acute bush encroachment in communal rangelands is clearly attributed to by high grazing pressure and absence of fires (Kraaij and Ward, 2006). Suppression of fire favours sprouting of bushes with no obstacles on their growth. In some instances bush encroachment may be in a continuous state more especially if the encroaching species produce protective deterrents like chemicals (tannins, phenols and allelochemicals) and physical structures e.g. thorns (Moleele and Perkins, 1998; Kraaij and Ward, 2006). The prevalence of such tree species increases in rangelands because they are under browsed.

An increase in atmospheric CO_2 from fossil fuel producing industries and nitrogen deposition are other factors that are likely to increase bush encroachment in rangelands (Wheeler *et al.*, 2007). For example, some trees and bushes play a considerable role in increasing bush density more especially the leguminous trees and bushes. This follows that the leguminous trees are able to fix Nitrogen in the soil which therefore plays an important role for recruitment of under canopy tree seedlings (Kraaij and Ward, 2006). Older shrubs/trees also create a microhabitat for their seedlings but at some point they impede the growth of seedlings through shading (Simons and Allsopp, 2007). Acacia species are known to give rise to increased density of bush clumps in South African savannas (Hester *et al.*, 2006). Climate as another causative factor plays a fundamental role in proliferation of bushes with high post seedling rainfalls favouring an enormous increase in bush density (Kraaij and Ward, 2006).

Although increase in bush density is criticised and cited as another indicator of rangeland degradation, there is a growing literature that acknowledges its significance (Wheeler *et al.*, 2007). Increase in bush density is a source of high quality browse for browsers and it plays a significant role in CO_2 sequestration and soil fertility enrichment in rangelands (Wheeler *et al.*, 2007). The Acacia species are widely considered as being more significant for household use because they are a source of firewood, charcoal, resins and gums (Loth *et al.*, 2005).

2.8 Soil chemical properties in rangelands

The rangeland condition is largely determined by soil quality and vegetation composition. The shift in vegetation composition is a function of shift in soil nutrient status which is a function of accerlerated soil erosion (USDA-NRCS, 2001). The soil quality is defined as a functional capacity of the soil and how well the services are provided by soil to the ecosystem in relation to specific use (Snyman and Du Preez, 2005). The poor soil nutrients resemble a rangeland in poor condition.

2.8.1 Soil nutrient composition in rangelands

Organic matter is the reservoir that holds the nutrients which can be released to the soil (Mganga *et al.*, 2011). Soil carbon constitutes 60% of the soil organic matter (Teague *et al.*, 2011). It is found in two forms in soil namely; soil organic carbon (SOC) which is formed originally from carbon received by plants from the atmosphere which then cycles from plants to soil and soil carbon is in soil inorganic carbon (SIC) form which results from weathering (Fynn *et al.*, 2009).

Soil organic carbon affects and is affected by vegetation and it plays a pivotal role in soil fertility. The carbon input in the soil is highly determined by the vegetation production and composition such as below and above ground plant allocation (Jobbagy and Jackson, 2000). The extent to which vegetation contributes to soil organic carbon inputs in the soil is also dependent on the plant parts death and decomposition. This process is driven by microbial organisms through decomposition of plant residues, dead roots and animal carcasses which therefore makes more nutrients to be available to vegetation for growth. Except leaves and stems, roots contribute in two ways such as through dearth and decomposition and also by the rhizo-deposition which give rise to exudation, mucilage production and sloughing (Jones and Donnely, 2004). Soil organic carbon abundance is directly proportional to the increase in bush density than herbaceous component (Wheeler *et al.*, 2007). This is supported by Mganga *et al.*, (2011) who speculated that the increased soil organic matter in upper soil horizons were the results of higher litter fall from *Acacia senegal* species. Any shifts in vegetation causes shift in soil organic carbon equilibrium (Bird *et al.*, 2001).

Improved organic matter favours the increase in species richness in rangelands (Yayneshet, 2011). The sound rangeland management practices that improve and maintain the soil properties induce less CO_2 emissions and sequester more carbon due to improved primary productivity (Whalen *et al.*, 2003). The change in land use results in low organic carbon and organic matter content. This was evidenced by the study conducted by Mojiri *et al*., (2012) in Western Iran, where undisturbed rangeland yielded an organic matter of 2.678 % and a transformed rangeland into cultivated land yielded 0.912 %.

Livestock has positive and negative contribution in soil fertility in rangelands; notable the defecation adds more nutrients in the soil (Mganga *et al.*, 2011). This is supported by Smet and Ward (2006) who stated that animals through grazing, trampling, defecation and urination tend to impact the soil fertility due to impacting the phosphorous, nitrogen and organic carbon concentrations. The imbalances between animal's forage intake and excretion of feaces and urine favour nutrient loss in rangelands (Hiernaux *et al.*, 1999). The nutrient uptake kinetics of individual plant is largely dependent on plant's root foraging ability (Arredondo and Johnson, 2009). The plant growth rate and amount of biomass production are enhanced by individual plant's nitrogen uptake and its use efficiency (Fransen *et al.*, 1999).

The availability of some nutrients can be inhibited by other soil nutrients in the soil. For example the compounds like calcium carbonate, iron oxides and magnesium tend to bind with phosphorous thereby masking its potential and availability to plants (Belnap *et al.*, 2003; Drenovsky and Richards, 2004). In elaboration Belnap *et al*., (2003), these nutrients may induce increase in soil acidity – nutralizing ability which therefore diminishes the availability of manganese and copper to plants. Different soils of rangelands have different mineral concentrations which display different mineral concentrations in plants. Some nutrients in the rangelands e.g. copper may increase toxicity and reduce palatability in forage plants (Brotherson and Osayande, 1980). Soil pH as another vital chemical indicator is considered to have effects on the soil geochemistry and vegetation distribution in the rangelands (Ahmad *et al.*, 2012).

At high stocking rate, reduction in herbage due to defoliation may be another cause of reduction in soil nutrients. Lutge *et al*., (1998) indicated that patch selective grazing reduces soil nutrients notable P and K, as the nutrient cycling becomes less as a result of reduction in plant material. The parent material and inherent diversity is considered as the major causes of high abundance of macro (N, P, K, Mg and Ca) and micro (Fe, Cu and Zn) nutrients in hardveld than in sandveld. High amounts of potassium in the cultivated and grazing areas can be attributed to higher clay mineral content in the soil. The nutrient availability is positively correlated with soil clay content (Mills and Fey, 2005). The mafic rocks that are originally from basalts are the sources of Mg and Zn and they easily weather to form soils that are rich in clay minerals (Grant *et al.*, 2000).

Modification of thickets to open Savannas through browsing causes the reduction in carbon and nitrogen in the soil. This is underpinned by the fact that nitrification and production of ammonium and nitrate is higher in woody vegetated rangelands than open savannas and grasslands. This variation is the product of the variation in heat occurrence with woody dominated rangelands consisting of lower temperatures than open grasslands that possess positive support to NH4-oxidizing bacteria under tree canopies (Herman *et al.*, 2003). Hiernaux *et al*., (1999) also speculated that the reduction in soil nutrients may be due to more active mineralization, higher nutrient uptake by stressed plants and greater leaching with increased infiltration.

2.8.2 Soil pH in rangelands

An increase in leaching and a reduction in soluble alkali cations tend to intensify the activity of H^+ resulting in acidic soils (Rezaei *et al.*, 2006). Production of rangelands is highly affected by the soil salinity and alkalinity (Rezaei *et al.*, 2006). The alkalinity in rangeland soils is caused by the presence of salts in high amounts, contributing salts being magnesium, sodium and Ca carbonates (Moyo *et al.*, 2010). Fire breaks in rangelands are proved to cause soil acidity and a reduction of nitrogen and carbon (O'Connor *et al.*, 2004). When the bare soils are protected from grazing the soil pH tends to be higher while in intensely grazed and burned rangelands soil acidity increases. The alterations in soil pH under canopy may affect the growth of herbaceous vegetation in rangelands (Ooescher *et al.*, 1986). Availability of some nutrients including P and other micro minerals depreciate with an increase in pH above 7 (Lechmere-oertel *et al*., 2005).

2.9 Soil seed banks in rangelands

In any pragmatic efforts of restoration and management of rangelands the knowledge of soil seed bank regeneration potential is of great significance. Soil seed bank is a storage system not only for seeds but also for other plant propagules (Asadi *et al.,* 2012). Soil seed bank composition is largely dependent on the recent and previous above ground vegetation and seed dispersal from plants of adjacent regions and is largely influenced by the management of the rangeland (Chaideftou *et al.*, 2009; Asadi *et al.*, 2012). Soil seed bank plays a significant role in restoration of degraded rangelands through seedling recruitment. Rangeland degradation is in a continuous state because the efforts on preclusion are still not pragmatic instead are theoretical based (Rothauge, 2000). A plenty of studies during rangeland condition assessment usually focus on the aboveground vegetation overlooking the importance of soil seed bank in resistance and resilience of the rangelands (Dreber *et al.*, 2011). Therefore, soil seed bank evaluation may be used as a valuable tool to assess rangeland condition and potential (Snyman, 2004; Solomon *et al.*, 2006; Dreber *et al.*, 2011).

The knowledge about seed bank ecology is necessary to understand the development and dynamics of the ecosystem and may be useful for pragmatic aspects of management and conservation (Shaukat and Siddiqui, 2004). This knowledge may involve understanding of soil seed bank potentials and regeneration (Kassahun *et al.*, 2009). Soil seed banks may compose of viable seeds which may be persistent (Shaukat and Siddiqui, 2004) and those that are transient. However, the efficacy of recruitment from seed bank is largely dependent on moisture and nutrient status of the soil (Snyman, 2004).

2.9.1 Factors affecting germination and seedling density

Herbivores display an enormous influence on germination through their hooves during movement in wet soils. This normally occurs when the hooves immersed into the soil resulting to damage of roots of some grasses which will later on result in vegetation regeneration (Smith *et al.*, 2002). Too frequent and intense defoliation particularly grazing prior to seed production stage is the cause of reduction in seed production in rangelands (Smith *et al.*, 2002; Solomon, 2011). This grazing regime normally causes imbalances in botanical composition, with perennial plants being replaced by annuals which therefore possess an increase in seed numbers of annuals giving rise to reversed succession (Bakoglu *et al.*, 2009). The short-lived plants that rely on seed rain for their regeneration are largely affected by herbivores than the long-lived perennials or annuals with long leave-soil seed bank. Even at high grazing pressure, the species with long lifecycle as adults or dormant seeds have ability to compensate over a long time (Maron and Crone, 2006). In most cases the grazing positively affects germination through soil compaction which enhances the percentage germination of some grasses (Saravi *et al.*, 2005). Espinar *et al.*, (2005) considered the removal of seeds and propagules by wind and water into the soil cracks of the neighbouring site increases the distribution of seeds and propagules in an area.

Rodents and birds also tend to exert a larger prey press to large seeds that are in top soil surface. It seems that the prey press of seeds is normally determined by the seed size as the small sized seeds are largely consumed by small ants (Shun-li *et al.*, 2003). It is estimated that germinable seeds in seed bank may exceed 20 000 m^2 with larger proportion being in the litter just above the soil surface which therefore exposes them to predation (George *et al.*, 1992).

According to Fayos and Verdu (1998), weather conditions have a paramount effect on the germination with prolonged heavy rains resulting in higher seedling emergence. It is also reported that time to detect seedling emergence in winter becomes prolonged than autumn due to differences in temperatures. Any alterations in hydrologic regime of the soil give rise to major influences on the soil seed bank (Lu *et al.*, 2010). Elsafori *et al.*, (2011) recognised some internal and external seed related factors that impact the germination. The internal factors such as the presence of seed coat, biochemical inhibitor within the seed and the maturity of seed embryo are the vital ones that can impact the germination. The recognised external factors are soil moisture content and temperatures (Elsafori *et al.*, 2011). The age of a seed is a major determinant of seed viability because as the seed ages it becomes buried at deeper soil depths while the young seeds are available at soil surface. Therefore the seed density is proved to be negatively related to soil depth (Espinar *et al.*, 2005).

2.9.2 Soil seed bank composition in relation to above-ground vegetation in rangelands

The composition of seed bank is classified into temporary and persistent in relation to the regeneration of the vegetation in different times, with temporary seed bank reflecting the seeds that are non-dormant with short lifecycle and the persistent one referred to as the perennial seed bank (Elsafori *et al.*, 2011). The significance of studying this relationship is to have understanding of the previous management of the rangeland and to study the life history of existing vegetation (Lopez-Marino *et al.*, 2000). The perennial palatable species that have no persistence in seed bank are removed in the existing above ground vegetation as well as in the soil seed bank as consequences of heavy grazing (Bertiler, 1996). Apart from changing the above and below ground species composition, herbivores can exert a grazing pressure directly on new growing seedlings through selective grazing (Esmailzadeh *et al.*, 2011). The species that are promoted by continuous grazing are unpalatable species with'r-selected' life history traits including shorter-lived tufts and a high output of small, long- lived and well-dispersed seeds (O'Connor and Picket, 1992). Some grasses may have a small or absent abundance in soil seed bank while they are more abundant in above-existing vegetation due to their reliance on vegetative recovery (Bakoglu *et al.*, 2009) or produce seeds of short persistence (Shaukat *et al.*, 2004). Tessema *et al*., (2012) reported that the differences in soil texture and other soil quality parameters may play a considerable role to cause variation in species composition, number of species and success in seed germination vertically the soil profile. However, it is of great importance to have an idea of species that are present and those that are absent in soil seed bank to have a knowledge on how succession will occur if the climax is disturbed (Esmailzadeh *et al.*, 2011). Contrary, if there is a correlation in above-ground vegetation and soil seed bank composition the reasons may be the lack of seed dispersal away from the parent plant and or the long seed persistence (Henderson *et al.*, 1988).

2.10 Rationale for the study

There are few studies that have investigated vegetation dynamics and their impacts to the surrounding incorporating the empirical and social findings. Therefore, this study aims at evaluating the vegetation dynamics through comparison of different homogenous vegetation units, examination of soil seed banks and underpinning with the farmer's indigenous knowledge about the history of the rangeland in question. Studying soil seed bank composition will provide a clear picture of the trends in successional stages of the rangeland. The recommendations on management of the rangeland at Peddie will be formulated using the indigenous and scientific understandings of communal rangeland utilisation to meet the standard of communal farmers.

The important questions that the study intends to address are:

- Does the indigenous knowledge underpin the scientific findings of Peddie communal rangeland?

- Is the condition of the rangeland in question good enough to support a sustainable livestock production?
- Does the species composition of the soil seed bank exhibit a resemblance of the existing aboveground species composition?
- Does the bush distribution play a significant role in shaping inter-canopy herbaceous composition and production?

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CHAPTER 3 COMMUNAL FARMER’S PERCEPTIONS IN PEDDIE COMMUNAL AREA

Abstract

Communal farmer’s perceptions were investigated at Peddie in Eastern Cape of South Africa to interlink them with scientific rangeland condition assessment. The two questionnaires were used to interview 120 respondents in 60 households. The mean household size was 8 people, 5 adults and 3 children. The respondents comprised of 63% females and 37% males. The majority (45%) of respondents were at 21 – 31 years of age. Cattle production (42%) was a high significant production system than goats (38%) and sheep (20%). The livestock production was perceived to have declined over two decades by 83% respondents (n = 120). Vegetation change was also perceived by 93% respondents with bush encroachment being the major attribute of this change. The results have shown that 85% of respondents conducted rangeland assessment usually through site visits. Woody plants, grass species and soil components were ranked as paramount important indicators of rangeland condition. Forty percent (40%) of respondents perceived that Peddie rangeland was in poor condition, while 39% perceived that it was in good condition. Bush encroachment, overgrazing and exclusion of fire were perceived as major causes of rangeland deterioration. *Acacia karoo* was perceived as the most encroaching woody species in Peddie rangeland. All (100%) respondents indicated that their rangeland is mainly used for browsing and grazing, fire wood, building, medicinal purposes and dry dung collection. This study indicated that farmers were knowledgeable about rangeland condition and this could assist to make recommendations based on production sytem and objectives of the communal farmers. This knowledge also provided qualitative data on the history of the rangeland which could be used as a basis to underpin scientific assessment.

Key words: Indegenous knowledge (IK), vegetation dynamics, livestock changes, rangeland uses

3.1 Introduction

Communal famers have a reliable and qualitative knowledge pertinent to long term dynamics of their rangelands (Kgosikoma *et al.*, 2012). This knowledge is obtained and maintained through continuous farming (Angasa and Oba, 2008; Mapinduzi, 2003) and rangeland visits (Abate *et al.*, 2010). Indigenous knowledge and experience is vertically spread from generation to generation through story telling. This knowledge varies from place to place and may also vary from individual to individual within the same location. This knowledge does not involve only the understanding of rangelands dynamics but also their causes (Kgosikoma *et al.*, 2012). In ecological studies, indigenous knowledge was overlooked and criticised (Abate *et al.*, 2010). Some rationalised that this knowledge is significant for local resources and some criticise communal farmers for being the resource degraders (Thebaud and Batterbury, 2001). In South Africa, the communal farmers are labelled by extension officers as being ignorant with application of non-realistic grazing systems (Allsorp *et al.*, 2007). However, Kgosikoma *et al*., (2012) viewed as an advantage to acquire the indigenous knowledge related to rangeland degradation and conditions. This forms a base of research because ignorance of farmer's perceptions can result to bias conclusions (Kassahun *et al.*, 2008) and also the communal farmers are managers of their communal land.

Currently, the indigenous knowledge has been viewed as a panacea to communal rangeland disturbances (Thomas and Twyman, 2004) and the recognition of those experiencing the consequences of range degradation is significant (Abule *et al.*, 2007). This emanates from the fact that communal farmers are knowledgeable about species composition and palatability of these species to their livestock (Kgosikoma *et al.*, 2012). Some communal farmers even apply some mitigation strategies to counteract forage scarcity (Moyo *et al.*, 2013). These include foggage conservation, browse cutting and supplementary feeding and livestock selling as a last option (Kassahun *et al.*, 2008).

In other regions (e.g. Kalahari region), the resource users have been included in national policy making (Thomas and Twyman, 2004). Oba (2010) assumed that communal farmers apply indigenous rangeland management through their experience and knowledge. Secondly, the knowledge of communal farmers can be measured and compared and this knowledge can play part in policy making. Therefore, a research was conducted to explore the communal farmer's perceptions to interlink them with scientific evaluation of Peddie rangeland. This in turn was done to formulate management practices based on the production system and objectives of Peddie communal farmers.

3.2 Site selection and overview of the Nguni Cattle Project

The study was conducted in Machibi communal area at Peddie and the selection of the area was based on the fact that it is one of the beneficiaries of Nguni cattle development project. In 2004, University of Fort Hare in collaboration with rural development agencies initiated Nguni cattle development project (Musemwa *et al.*, 2008). The project is re-introducing the Nguni cattle in communal areas of the Eastern Cape in South Africa (Mapiye *et al.*, 2007). The Nguni cattle development project operates in a ‘pay it forward system’ in which the project selects communal areas and supply them with two bulls and ten heifers which are then passed to second community after five years (Musemwa *et al.*, 2008). Therefore, selection of area to conduct a research is based on the fact that it is currently the recipient of the Nguni cattle from Nguni cattle development project since there had been no evaluation of rangeland condition conducted in this community prior to introduction of Nguni cattle. The map showing the study area is presented in Figure 3.2.

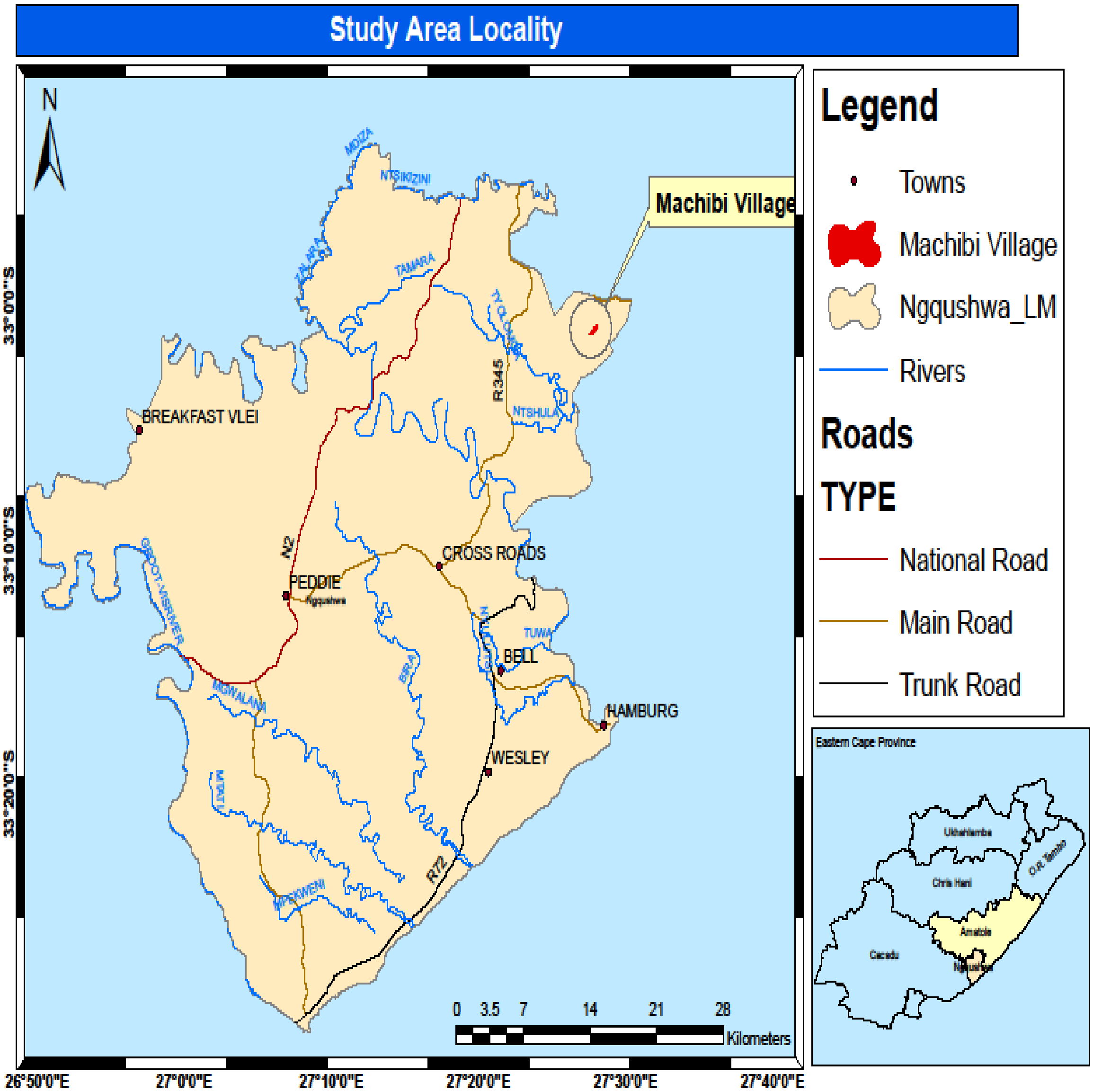

Figure 3.2: Map of Machibi communal area and surrounding communities at Peddie

3.3 Materials and Methods

Two structured questionnaires consisting of various open and close-ended questions were used to interview the communal farmers about their household and herd sizes, rangeland condition, indigenous rangeland management practices and history about their rangelands and livestock. The sample size of 60 households that are herd owners including the Nguni Cattle Project members were randomly selected and interviewed. In each household two respondents were selected according to their age groups such as the elder or key informant of at least greater than 40 years and other respondent of any age greater than 20 years. The questions were administered in a local language (Xhosa) which is best understood by the respondents. Each household was allocated two enumerators to conduct the interview. The data was coded with the use of numbers, ranges and alphabets for ease and precise analysis. Data ranking for attributes and causes of rangeland condition and uses of rangeland resource was done with the use of ordinal scale depending on the significance of each parameter as perceived by farmers (Nyakiri *et al.*, 2005).

3.4 Statistical analysis

The data pertaining the farmer's perceptions and demographics was analysed through the use of SPSS (Version 20). Descriptive statistics such as means, standard errors and percentages were also put in place to present differences on farmer's demographics and livestock numbers. In case of a ranked data a Friedman's test (χ^2) was employed to find significant differences on the mean rankings of causes and attributes of rangeland, livestock dynamics and uses of Peddie communal rangeland. To find significant differences ($p<0.05$) between causes and attributes of rangeland dynamics and uses, a Sign test was also employed.

3.5 Results

3.5.1 Household demographics in Peddie communal area

The mean household size of Peddie communal area was 8 people, 5 adults and 3 children. Sixty-three percent (63%) of respondents (n = 120) were females and 37% were males. Sixty-seven percent (67%) of the respondents were never married with 37.7% of them being married and 1.7% being widowed. The majority (51.7%) of respondents have reached the secondary educational level with 33.3% of the respondents ceased studying in primary level and 8.3% studied up to a tertiary level with a low proportion of 6.7% of residents that did not attend school. The research was dominated by unemployed respondents (65%) with only 6.7 % of them being employed and 13.3% of pensioners. Out of all respondents, 11.7% were still learning, 87.7% were reliant on farming and another 1.7% are household wives. It was 22% only of respondents that were involved in community farmer's organisations. These farmer's organisations are government funded initiatives such as Crop Production Corporation and Nguni Cattle Empowerment Project. The Age groups of respondents are presented in Figure 3.5.1.

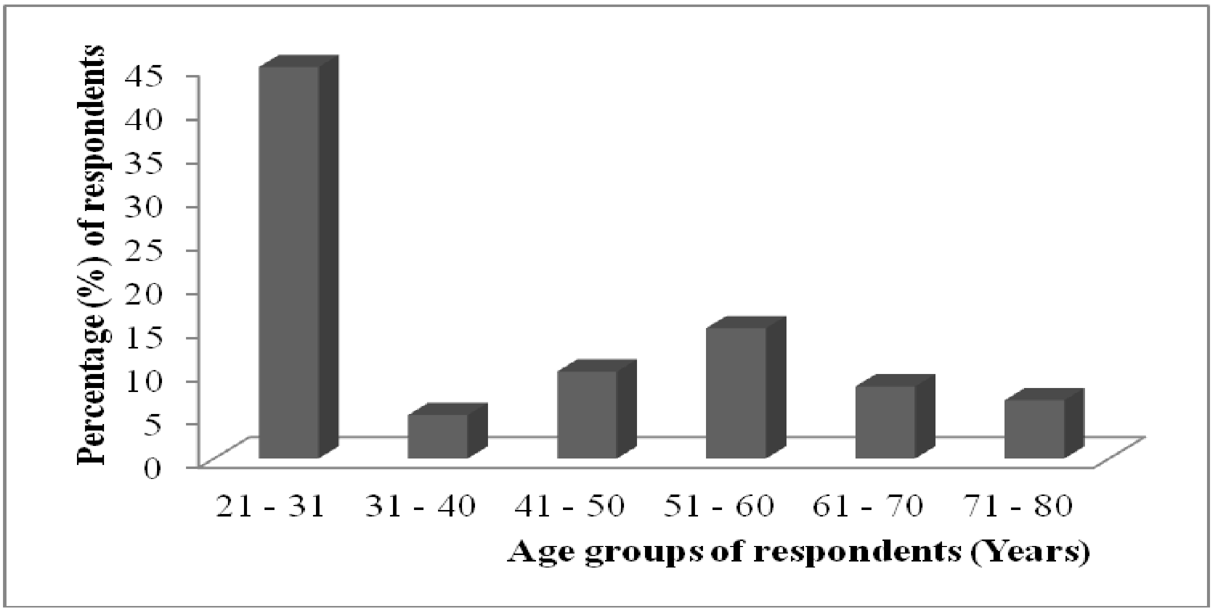

Figure 3.5.1: Age groups of respondents at Peddie area.

3.5.2 Livestock population and composition in Peddie communal area.

Livestock in Peddie communal area was dominated by cattle (42%) followed by goat (38%) production and sheep (20%) (Figure 3.6.2). Livestock composition (cattle, goats and sheep) in Peddie communal area was dominated by large proportion of dams over the sires. The respondents indicated that they kept livestock for multi-purposes (meat production during ceremonies, lobola, generating income, drought power and milk production in Peddie communal area.

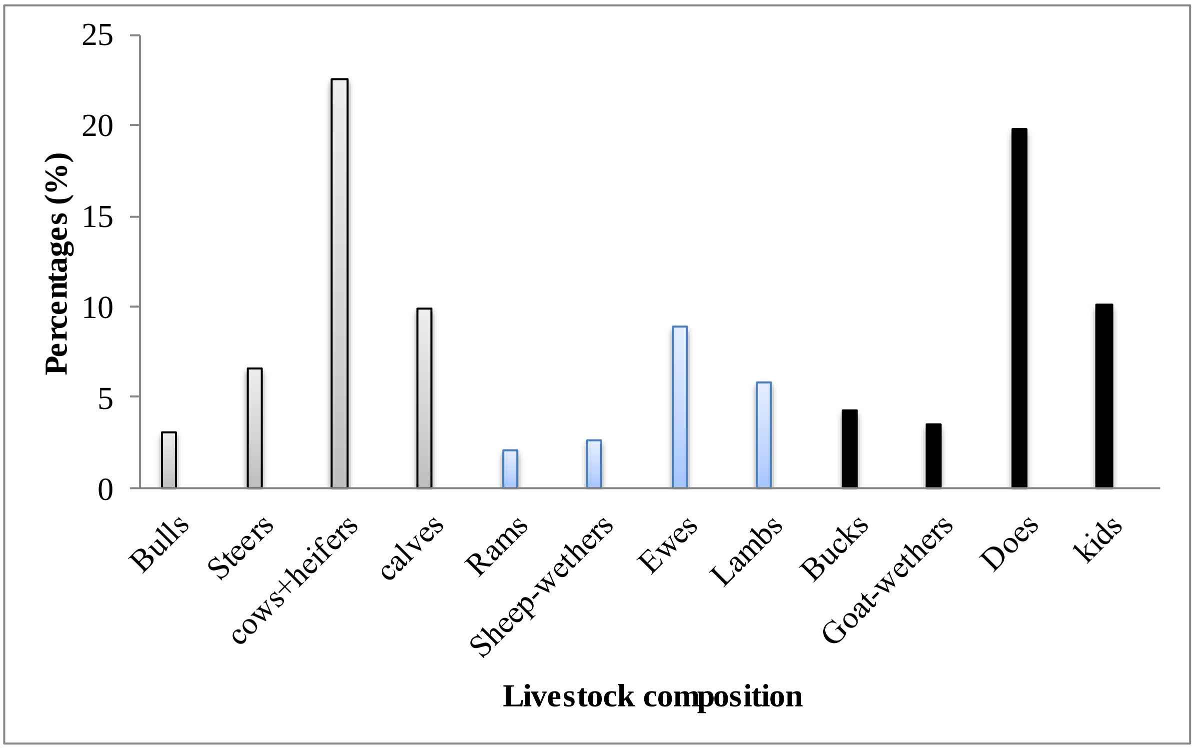

Figure 3.5.2: Livestock population and composition of respondents in Peddie communal area.

3.5.3 Livestock changes and their driving forces over two decades in Peddie communal area

Eighty-three percent (83%) of the respondents (n = 120) perceived that livestock numbers declined over two decades while 17% of respondents having a perception that livestock had increased in Peddie communal area. Seventy-eight percent (78%) of respondents also perceived that livestock declined over one decade and 22% of them perceived that livestock had increased. The respondents elucidated that a low forage quantity (2.1) was the major cause of a decline in livestock numbers (Table 3.5.3). It was also perceived that an enormous increase in bush density (2.4) was the second most contributing cause through its reduction effects on production of under and inter-canopy herbaceous vegetation and its accessibility to livestock.

Respondents also ranked grass quality (2.7) and recurrent drought (2.9) as the second most important causes that induced this decline (Table 3.5.3). Respondents justified that a diminution in forage quantity and quality was mostly observed during times of dryness when grasses were dried-up with a resultant suppressed leaf production with ceased growth and delayed recovery, and opportunistic growth of forbs. All respondents (100%) related the forage quality to most preferred or acceptable plant species to livestock present in the rangeland e.g. *Themeda triandra* (Iqunde) was considered as of high quality by respondents. It was also reported that large livestock mortality was related to poor forage quality such as diseases and poisoning caused by toxic plants e.g. *Moraea polystachya*. Crop farming (5.9) and soil degradation (4.9) were rated as the least significant causes of decline in livestock numbers over two decades. Crop farming was considered by 98% respondents as the significant way to derive fodder (crop residues) to supplement the rangeland during the dormant season (winter) when the grass quality and quantity decline.

Table 3.5.3: Mean ranks of perceived causes of livestock trends in Peddie communal area in previous two decades (n = 120).

Causes	**Mean (±S.E)**	**Rank**
Low forage quantity	2.1(0.1)[a]	1
High bush density	2.4(0.2)[abc]	2
Low forage quality	2.7(0.1)[c]	3
Recurrent drought	2.9(0.2)[bc]	4
Soil degradation	4.9(0.1)[d]	5
Crop farming	5.9(0.1)[e]	6

Causes with different superscripts are significant different ($p<0.05$).

3.5.4 Indigenous rangeland ownership, management and constraints in Peddie communal area

All respondents (n = 120) indicated that all community members have equal rights to manage and utilise the rangeland in Peddie communal area. This right was obtained by being the resident of the community. Although there is community chairman in the area, there was no specific personnel to set the rules and regulations towards the sustainable use of rangeland resources. The respondents also mentioned that there were no access restrictions to the rangeland because there is a complexity in ownership of the rangeland as everyone in the community is entitled to utilise resources to maximum with no binding rules. All respondents were consistent that there were no protected rangelands and cultivated pastures and also there was no division of camps of the existing rangeland in the community. This was indicated as a driving force for communal farmers to be reliant on and continuously graze one rangeland which is recently been subdivided for Nguni Cattle Project.

Management of livestock movements was permanently (year around) conducted by 81.7% of respondents while 8.3% applied free ranging referred to by Oba (2005) as "grazing management by cattle" and 10% introduce livestock to rangelands without any follow up management of livestock movements. Sixty-seven percent (67%) of respondents mentioned that livestock movements are managed by elders such as fathers and grandfathers while 33% mentioned that livestock movements are managed by children. About (90%) of respondents agreed that management of livestock movements in Peddie communal area is based on changing herds from one habitat to another to seek for high quality and quantity of forage, drinking water, avoidance of stock theft and illegal grazing of maize fields. All respondents reported that vandalised fencing which allows migration to neighbouring communities and influx of neighbouring livestock is their major constraint. Ninety eight percent (98%) respondents reported that shortage of water sources makes it difficult to manage livestock in a manner that reduces rangeland degradation around water point in Peddie communal rangeland.

3.5.5 Perceived rangeland degradation in Peddie communal rangeland

Eighty-five percent (85%) of respondents said they conduct indigenous rangeland evaluation through observing and site visits while 15% said they do not evaluate the rangelands. Communal farmers in Peddie employ three main rangeland condition indicators when evaluating rangelands namely; bush, grass and soil components. The grass component involves the consideration of forage quality and quantity while bush component involves the consideration of species cover, distribution and tree density. Soil component mainly focuses on erosion, compaction, colour and texture. The grass (1.6) and bush (1.5) components were ranked as the most important indicators over soil component (2.9). Respondents also added the animal body condition and availability of water sources in the rangeland as the additional indicators though they were not considered as main indicators in this study. Respondents further mentioned that a decline in animal's body size is a true image of diminishing rangeland condition.

Peddie communal rangeland was perceived to be in poor condition by 40% of respondents (n = 120) while 38.3% considered it to be good (Figure 3.5.5). The difference on the judgement of rangeland condition by respondents was explained by the type of livestock the farmer kept and the additional uses of the rangeland on which one is benefiting. For example some respondents considered the rangeland with high bush density to be in good condition because they are farming with goats and they harvest large abundances of woods for household use. However, in some perception, bush encroached rangelands symbolise degradation.

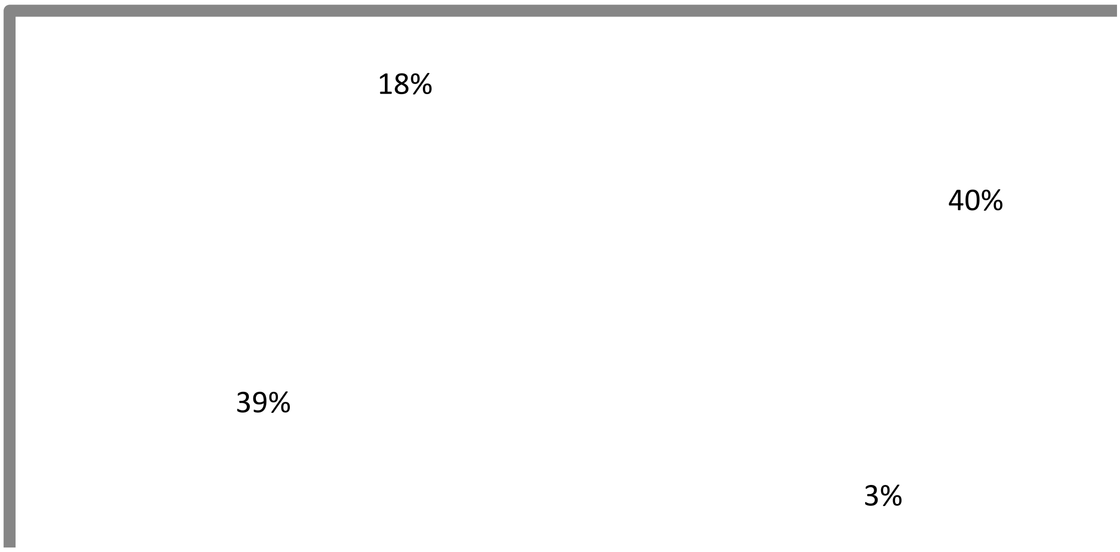

Figure 3.5.5: Frequencies (%) of perceived current condition of the Peddie communal rangeland.

Bush encroachment (2.0) was perceived as the major cause of rangeland deterioration in Peddie communal area with *Acacia karoo* being the main encroaching species (said the respondents) (Table 3.5.6). The encroachment of the rangeland by *A. karoo* was considered a threat to livestock grazing in Peddie communal rangeland. The respondents also mentioned that the spines of *A. karoo* cause injuries to livestock bodies. They also elucidated that these spines also restrict livestock from grazing and browsing.

Overgrazing (2.5) and burning (2.7) were acknowledged as the second most causes of rangeland deterioration. Respondents were aware of the effects of overgrazing on grasses as 67% of them perceived that prior the rangeland was dominated by highly nutritious herbaceous species but recently it is dominated by plant species with low nutritive value with some farmers pointed out *Eragrostis plana* as an indicator of overgrazed rangeland. According to (86%) respondents, burning occurs at low frequencies with the last fire outbreak occurred in previous 4th year (2008) in Peddie rangeland. Those aforementioned fires are perceived to be human induced and they occurred at night during the dormant season.

High rainfall variability (4.0) was considered as the third most important cause of current rangeland deterioration and also the changes in grass species composition was regarded as the consequence of the interaction between variable rainfall and overgrazing. The development of kraals, dip tanks and water points (5.7), and human population (5.7) were the fifth most important causes of vegetation change. Soil depth (6.9) and topography (6.4) were pointed out as the least significant causes of poor rangeland condition. Although 78% of key informants noted the signs of erosion, they highlighted that disturbance of soil structure prior to 1960s may be the major cause because the bush encroached part of the rangeland was used as a residential area before human relocation occurred.

Table 3.5.6: Mean ranks of perceived causes of current rangeland condition of Peddie communal rangeland (n = 120).

Causes	**Mean rank (±S.E)**	**Rank**
Bush encroachment	2.0(0.3)[a]	1
Overgrazing	2.5(0.1)[abc]	2
Burning	2.7(0.2)[c]	3
Rainfall	4.0(0.2)[d]	4
Human population	5.7(0.4)[e]	5
Kraals, dip tanks and water points	5.7(0.3)[efg]	5
Topography	6.4(0.2)[gh]	6
Soil depth	6.9(0.3)[h]	7

Different superscripts denote significant differences ($p<0.05$) between causes.

3.5.6 Perceived vegetation trends and their attributes in previous two decades in Peddie communal area

Ninety-three (93%) of farmers perceived that there was an observed change in vegetation of Peddie rangeland while 6.7% of farmers (n = 120) perceived no change over one decade. All farmers (100%) perceived that there was pronounced change in their rangeland over two decades. Bush encroachment (1.3) was perceived as the most important cause of vegetation change in the previous two decades (Table 3.5.7). All respondents (100%) perceived that in past decades around 1960s after human relocation the whole rangeland was the open grassland afterwards there was an abrupt encroachment of *Acacia karoo*, *Coddia rudis* and some thicket species such as *Scutia myrtina*. The respondents stated that grass species like *Themeda triandra*, *Digitaria eriantha* and *Cynodon dactylon* were dominating in the rangeland but as bush density increased over time there was also a concomitant decline in the abundance of these palatable species.

Human settlement (2.3) and overgrazing (2.9) played the second most roles on shaping the vegetation change in previous two decades. In this regard, respondents considered human settlement prior to relocation as the factor that has contributed to this change through anthropogenic pressure that was applied by communal residents. Overgrazing was perceived to cause a reduction in herbaceous vegetation cover in favour of recruitment of bush species. Respondents also ranked drought (3.9) as the third cause of vegetation change in previous two decades. The respondents underpinned that during the times of dryness grasses could not adapt to severe conditions of drought. It was also mentioned that most bush species were tolerant to these adverse conditions because they were able to absorb water from deeper depths of the soil profile. Development of water points, dip tanks and kraals (5.9) and change in land use (5.4) were ranked as the fifth most causative factors of vegetation change. Crop farming and land alienation were least causes of vegetation change over two decades.

Table 3.5.7 Mean rankings of causes of vegetation dynamics over two decades in Peddie communal rangeland (n = 120).

Causes	**Mean rank(±S.E)**	**Rank**
Bush encroachment	$1.6(0.1)^{a}$	1
Human settlements	$2.3(0.2)^{b}$	2
Overgrazing	$2.9(0.1)^{c}$	3
Drought	$3.9(0.2)^{d}$	4
Change in land use	$5.4(0.3)^{ef}$	5
Water points, Dip tanks and kraals	$5.9\ (0.2)^{f}$	6
Land alienation	$6.7(0.2)^{h}$	7
Crop farming	$7.2(0.2)^{gh}$	8

Different superscripts denote significant mean differences ($p<0.05$).

3.5.7 Rangeland uses in Peddie communal area

The rangeland in Peddie communal area is a multi-purpose resource used for grazing and browsing, wood collection for making fire, wood and grass collection for building, medicinal plant collection and dry dung collection. Respondents perceived that rangeland in Peddie communal area was used mainly for grazing and browsing (1.0) throughout the year with the exception of winter when grass biomass and quality decline (Table 4.3.8). This was an implication only to grazers as some browse material remained green even in winter in the rangeland (said the respondents). Wood collection (2.5) for making fire is the second most important use with *Acacia karoo* being the species of paramount importance for making fire. The respondents reported that wood collection took place throughout the year but the preferred times were winter and summer when most of ceremonies were conducted with the famous one being the boys traditional circumcision. Farmers also mentioned that the use of woods for making fire was just a supplemental measure to save electricity because woods are free and electricity is costly.

Wood and grass collection (3.0) for building and fencing were rated the third important uses of Peddie communal rangeland. Respondents perceived that the bush species of high preference for fencing or making kraals is *Coddia rudis* due to ease of harvesting over other species. It was also mentioned that the thorny and spiny species like *Acacia Karoo* and *Scutia* *myrtina* are dangerous to harvesters and livestock. Medicinal plant collection (3.6) for manufacturing of traditional remedies was ranked the fourth important use. According to respondents, most traditional remedies were used as ethno-veterinary medicines to cure animal diseases. In addition, respondents said other remedies are those that are used to treat human diseases and to repel evil spirits. This collection involves plant tissue harvesting such as barks, tubers, roots and leaves. Dry dung collection (4.9) was ranked as the least important use as most of the fire was prepared with woods in the area.

Table 3.5.8: Mean ranks of rangeland uses in Peddie communal area (n = 120).

Uses	**Mean rank(±S.E)**	**Rank**
Grazing and browsing	1.0(0.0)^{a}	1
Firewood collection	2.5(0.1)^{b}	2
Wood and grass collection	3.0(0.1)^{c}	3
Medicines collection	3.6(0.1)^{d}	4
Dry dung collection	4.9(0.1)^{e}	5

Different superscripts denote significant differences ($p<0.05$).

3.6 Discussion

In this study, most of respondents were females which emanated from the fact that males were at work. Unlike the study conducted by Admasu *et al*., (2010) in Southern Ethiopia, the respondents in Peddie communal area were educated with 51.7% of respondents having reached secondary school and 8.3% even furthered their education up to tertiary level with an implication that technology transfer can be effective in Peddie communal area. The results of this study also revealed a mean household size of 8 people with a mean livestock of 10 cattle, 4 sheep and 7 goats. The household size of this study was significantly higher than that reported by Mwale and Masika (2009) in Centane village of the Eastern Cape. The livestock was perceived to decline over two decades in Peddie rangeland with low forage quality and quantity being cited as major drivers of this decline. Kassahun *et al*., (2008) reported a relationship between the household size and livestock kept per household with household from 7 – 10 people keeping large livestock numbers. The mean adults of Peddie communal area was 5 people which underpinned a postulation that the higher the number of elders the greater the care for livestock. This postulation was supported by the perception that livestock movements are managed by 67% of elders in Peddie communal area. However, this postulation contrasts the findings of Ayantunde *et al*., (2000) at Niger who found out that herding during the day was the responsibility of children.

Farming comprised of multi-species in Peddie communal area which is a way to satisfy farmer's livelihood with different livestock functions as stated by (Abate *et al.*, 2010). Even though livestock production is diverse, cattle production in Peddie communal area is a major production system followed by goat production which is also followed by sheep production respectively with few if any equine species. The significance of each species is mainly determined by its uses. Respondents were consistent that high cattle production is favoured by high demand for draught power and also cattle worth higher returns through sales while goats are used mainly for slaughter during boy's traditional circumcision. This animal diversification is one of strategic actions to reduce inter and intra-specific competition among livestock so as to reduce resource degradation (El Hadary and Samat, 2012; Abate *et al.*, 2010). The motive behind is that animal diversity allows ecological separation (El Hadary and Samat, 2012). For example grazers such as cattle and sheep prefer grasses while goats prefer browse material (Nyakiri *et al.*, 2005).

The results of this study pertinent to rangelands revealed that Peddie communal farmers were familiar with rangeland and livestock dynamics, their causes and time frames of these dynamics. Despite that knowledge, farmers suggested the correct measures to address the adverse effects of these dynamics but due to the fact that these control measures are capital intensive they fail to apply them. These measures include provision of infrastructure (fences) for rangeland subdivision into camps, agricultural engineering services (building of water points) and trainings on modern rangeland management strategies. For example respondents at Peddie and other studies (e.g Kgosikoma *et al.*, 2012, Angassa and Beyene, 2003) have pointed out bush encroachment as the major driving force of vegetation and livestock dynamics (Table 3.5.3 and 3.5.7). This also supports other scientific findings that bush encroachment results in reduction in grazing carrying capacities (Smit, 2004; Hudak, 1999) as reported by respondents that there was a reduction in the abundance of highly palatable and productive grass species and there were negative trends in livestock numbers.

There was a divergence in the views and justifications of respondents on the perception of current rangeland condition of Peddie communal area. This stemmed from the fact that 39% of respondents (mostly goat farmers) perceived a rangeland with bushes as in good condition because they are farming with goats and they harvest large abundances of woods for household use (Figure 3.5.5). This perception was in disagreement with 40% respondents who perceived that their rangeland is in poor condition because bush encroachment reduces biomass production for their cattle. The perception of 39% respondents was in line with Kadjiua and Ward (2007) who found out that rangeland with bushes may be considered good with underpinning that browse material forms large amount of cattle diet more especially during dry-season and drought periods. The research output of Reed and Dougil (2002) is another resemblance of this perception with similar rationale that when farming with small stock browsers, woody plants are a source of forage.

The judgement of rangeland condition by rangeland scientists in previous studies seems like it was focussing on the grasslands under commercial tenure system where mutton and beef production systems are an economic mainstay. The scientists did not consider that a change from grasslands to bushlands can result in addition of chevon production as a third production system. Despite this postulation, it seems like the previous studies ignored the importance of bushes and acknowledged one facet that increase in bush density exerts competitive effects on herbaceous vegetation. However, it depends on the extent of bush density, type of encroaching species and other bonus benefits of range resources to communal farmer in order to draw a conclusion on whether or not the communal rangeland is in poor condition when bush ingress is an attribute of such condition.

Communal farmers also pointed out overgrazing as another great cause of vegetation change (Table 3.5.3). The similar findings were reported by Wasonga *et al*., (2011) and, Baars and Aptidon (2002) which means that overgrazing is a threat to most rangelands. Although overgrazing was perceived to yield adverse effects, currently the farmers apply permanent herd movements in effort to preclude rangeland degradation in Peddie communal rangeland. This is a way of grazing where livestock owners select key resource areas where they place their livestock during forage scarcity (Ghorbani *et al.*, 2013; Homann *et al.*, 2008). Practicing livestock movements helps to abate overgrazing except around human settlements where plant overexploitation by cattle and human beings is beyond control (Roba and Oba, 2009). Although management of livestock movements from the study of Selemani *et al*., (2012) were seasonal, the objectives are similar to those of Peddie communal farmers. Even though the livestock movements are managed in the Peddie rangeland, it is an individual's choice as there are no rules binding the herd owners towards sustainable grazing management of the rangeland. The findings of this study concerning resource management are consistent with Ward *et al*., (2000) and contrast with Admasu *et al*., (2010) in Southern Ethiopia where rangeland resource management is bestowed to tribal leaders. Similarly, due to indigent or even absence of rules for sustainable grazing management in Peddie communal area, there were no rules formulated for vegetation harvesting for household use. Mishra *et al*., (2003) have provided an insight of how community rules work to ensure avoidance of resource overexploitation. An example of Mishra *et al*., (2003) was considered effective where a time of resource harvesting was set for farmers and a collection over that time led to imposition of fines which was equivalent to loads of resources harvested by farmers.

Although Moyo *et al*., (2008) reported an approximate 50% increase in household numbers in areas around Peddie town, it was not the case in this study because 100% farmers elucidated that land division for communal residents is done on arable land at which crop production is no longer practiced. It seems like a pre-relocation settlement have also contributed to large extent to many of changes that occurred in Peddie rangeland. This follows that, farmers had a belief that anthropogenic activities that they practiced prior may be the foundation of change in bush encroached part of the rangeland. One of these activities is the disturbance of soil structure through tillering which was perceived to weaken the soil thereby causing soil erosion leading to dongas. The absence of areas conserved for foggage production in the area to supplement the rangeland during times of diminishing forage as the rangeland undergone division for Nguni cattle project with no adjustments in the stocking rate of the communal livestock is speculated to contribute in future degradation of Peddie rangeland. It is well known that land is inelastic but interlinkage of traditional and scientific strategies to increase forage production is recommended even in a small available land of Peddie rangeland.

3.7 Conclusions

The results of this study have shown that the judgement of rangeland condition by communal farmers is based on the livestock species the farmer has and on other uses of the rangeland resources. This stemmed from the fact that 39% respondents (mainly goat farmers) considered that rangeland with bushes is in good condition while 40% (mainly cattle farmers) were consistent that it is poor. This perception indicated that in order to draw conclusion on whether the rangeland is in good or poor condition, there is a need to know the farming systems of the communal area in question. Respondents also indicated that there are constraints they are facing pertinent to rangeland resource management. These include poor knowledge on rangeland management, shortage of water points and uncontrolled livestock movements due to vandalised fences in their rangeland. Furthermore, progressive bush encroachment and overgrazing were perceived to be the major causes of livestock decline over two decades. This study has shown that indigenous knowledge is a valuable tool for rangeland assessment and investigation of problems affecting the livelihood of communal farmers. Additionally, the use of communal farmer's perception can supplement scientific approaches of rangeland evaluation when assessment is conducted under communal tenure system. Therefore, it is recommended that famer's perceptions can be used as a first priority before any empirical field assessment in communal rangelands.

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CHAPTER 4 HERBACEOUS AND WOODY VEGETATION COMPOSITION AND PRODUCTION

Abstract

Rangeland condition assessment with the use of three tier system was conducted in Peddie rangeland, Eastern Cape to explore its potential inorder to answer the following question "Is the rangeland of Peddie in good condition to sustain the communal livestock and Nguni Cattle Project?" Species composition, biomass production, ecological stability, woody density, phytomass and browsing potential were determined in 2012/2013 respectively. Peddie rangeland was demarcated into four replicates of 3 HVUs namely; open grassland, scattered and dense bushland respectively. The step point method was applied to estimate species composition and basal cover. The grass biomass was harvested in ten 0.25 m^{-2} quadrants in each replicate and oven dried to find dry matter production. Woody plant density, tree equivalents and browsing units were estimated from number of trees and their total heights and lowest browse material. Twenty seven herbaceous species were recorded in Peddie rangeland. These comprised 24 grasses, some forbs, sedges and karoo species. The rangeland was dominted by Increaser II (44.4%) species. *Themeda triandra* was significantly (p<0.05) higher in grassland (31.1%) than scattered (15.6%) and dense bushland (6.1%). *Cynodon dactylon* and *Eragrostis plana* were significantly (p<0.05) higher in dense bushland than grassland and scattered bushland. The grassland biomass production in summer (2944.8 kg ha^{-1}) was significantly higher (p< 0.05) than in scattered and dense bushland in both seasons. The trend in biomass production declined from grassland to dense bushland. The ecological stability in all homogenous vegetation units was very high as shown by low point-tuft distance (< 3cm). Dense bushland showed a significantly high (p<0.05) encroached condition with 6650 trees ha^{-1} and 4909.5 TE ha^{-1} beyond recommended thresholds of 2400 trees ha^{-1} and 2500 TE ha^{-1} respectively. Scattered bushland had a fair condition of 1950 trees ha^{-1} and 1198.1TE ha^{-1}. *Acacia karoo* was the most encroaching woody species comprising of abundances beyond 70% in both HVUs. The condition of Peddie rangeland is in a declining trend as bush density increases. Therefore, this calls for strict control measures to halt bush encroachment in Peddie rangeland.

Key words: Homogenous vegetation units, season, species composition, biomass production

4.1 Introduction

Rangeland condition monitoring is a pivotal way to evaluate whether or not the rangeland management objectives are met and it indicates the trends that may threaten the rangeland ecosystem (Fernandez-Gimenez *et al.*, 2005). The key information for monitoring the rangeland condition involves the understanding of the livestock preferences for specific forage species (Maselli and Maselli, 2004). This follows the notion that all plant species differ in phenology and palatability to grazers (Abule *et al.*, 2007; Solomon *et al.*, 2010). This information is fundamental for planning the elimination of undesirable or even harmful plants, and the maintenance of highly palatable and nutritious plants in the rangelands (Maselli and Maselli, 2004). The tandem use of plant species composition and biomass production provide proper estimates of stocking rate for sustainable grazing management (Kunst *et al.*, 2006). Moreover, the amount of soil loss through surface runoff in communal rangelands is largely dependent on the ecological stability such as basal cover (Rowntree *et al.*, 2004).

In any approaches aimed at monitoring the rangelands that comprise different vegetation components, three tiers of assessment are recommended (Friedel, 1991). This includes the assessment of herbaceous vegetation, woody component and soil parameters. The assessment of woody component is fundamental for reckoning the browsing carrying capacities of the rangelands because some woody species are palatable to livestock (Moleele *et al.*, 2001). Some indegenous goats and Boer goats are considerd as the potential browsers in the Eastern Cape (Aucamp, 1976). However, many studies assessed woody vegetation to investigate the extent of bush encroachment and its effects on the surrounding, particularly on the understory vegetation and soil properties (Solomon *et al.*, 2010a). The parameters of concern are woody density, phytomass and species composition (Solomon *et al.*, 2010b). The objective of this study was to explore the rangeland condition of Peddie communal rangeland since there was no assessment conducted before the introduction of the Nguni Cattle.

4.2 Materials and Methods

4.2.1 Description of the study site

The study involved seasonal data collection in dry and wet seasons in Machibi communal area in Peddie, Eastern Cape. The area is situated North East of Peddie town under

Ngqushwa Municipality (33^0 0′ 12″S and 27^0 26′ 16″E). The rangeland of the area is a common pool property and is grazed continuously throughout the growing season by different livestock species (cattle, sheep, and goats) with the exception of the camp comprising of pure grassland where Nguni cattle of the project are kept. The entire rangeland is peripheral fenced and there is fence at the centre separating the rangeland used for Nguni Cattle Project from that used for communal livestock. The communal livestock and Nguni Project share the same water point which is located at the centre of the rangeland.

The mean annual rainfall of the Peddie area is 412mm $annum^{-1}$, most rainfall normally falls in summer. The area experiences average temperatures of 19.3^0C in July and 25.8^0C in February. The rangeland comprises of various vegetation distributions with a portion on the North being open grassland and the rest is invaded by *Acacia karoo* but even the bush density differs within the rangeland. Woody vegetation comprises of *Acacia karoo* and some thicket species including *Scutia* and *Rhus species*. The grass layer is dominated by *Themeda triandra, Cynodon dactylon, Eragrostis plana, some forbs and karoo species.* The veld type of the study area is referred to as Eastern Thorn bush veld.

4.3 Experimental layout and Sampling

A preliminary survey was conducted to identify and divide the rangeland at Machibi into three homogenous vegetation units (HVUs). The three homogenous vegetation units were identified as open grassland, scattered bush and dense bush taking consideration of homogenous plant physiognomy, soil type, aspect and topography (all were on top of undulant). In each HVU, four sample sites of 100m X 50m were permanently demarcated. In each sample site, two parallel 100m transects were laid with 30m equidistant apart and 10m left in each side to eliminate the edge effect. The three tier system of rangeland assessment (Abule *et al.*, 2007, Abate *et al.*, 2009) was employed in the assessment of Peddie communal rangeland. The three homogenous vegetation units of Peddie communal rangeland are presented in Plate 3.3 below.

Plate 4.3: Three homogenous vegetation units (HVUs) of Peddie communal rangeland

4.4 Data Collection

4.4.1 Determination of herbaceous species composition

The step point method was employed to determine the herbaceous composition of the rangeland. The nearest species and basal strikes were estimated in 200 points collected along two 100m parallel transects per sample site In every 1m intervals, the metal rod was dropped and any herbaceous species on which the rod stroke (basal strikes) was identified following plant nomenclature by Van Wyk and Van Outshoorn (2004). In case where a rod stroke on a bare ground, the nearest herbaceous species to the strike was identified. Grasses were identified to species level, while other herbaceous plants belonging to other families were categorised as forbs, sedges, rushes and Karoo species. Grasses were then classified into ecological status such as Decreasers (the desirable species that increase in rangeland with proper management), Increaser I (the less desirable species that increase with underutilisation) and Increaser II (those increase with over utilisation). The plant life form was also included as another classification criterion such as annual and perennial. The grazing value groupings (H = high grazing value, M = moderate grazing value and L = low grazing value) of each species was considered as another species distinguishing criterion. When the step point method was applied for botanical composition, the point-tuft distance was also determined to estimate basal cover. The estimation of point-tuft distance was achieved by equating 1 thumb to 2 cm. If the rod strikes on a bare area exceeding 40 cm, the area was recorded as bare. The mean point-tuft distance was determined in 200 points collected per sample site.

4.4.2 Determination of biomass production

Each sample site was subdivided into five 20m X 50m plots. In each plot, two 0.25m^2 quadrants were laid randomly in 10m intervals and any herbaceous material within these quadrants was clipped at a stubble height of 30mm with hand shears and placed in a well labelled brown paper bags. Old dead grass material (Moribund) was separated from fresh herbaceous plant material. All herbaceous plant samples collected were oven-dried at constant temperatures at 60^{0}C for 48 hours and weighed at a constant mass to determine the dry matter production (kg ha^{-1}).

4.4.3 Determination of woody species composition in Peddie communal rangeland

The same sample sites used for grass survey in bushland homogenous vegetation units (scattered bush and dense bush) were used for identification, measurement of LBM (Lowest Browseable Material) and height of bush species. A 100m straight transect was laid down 2 times a sample site and a 2m aluminium rod was laid down across every 10m of each transect. All bush species within the two $200m^2$ belt transects were identified and recorded on a data sheet. After species identification, the height of LBM and a total height of bush species were measured according using a well calibrated aluminium rod. The tree density and structure were estimated by counting all trees within $200m^2$ belt transects and the density was expressed as woody plants ha^{-1}. The tree phytomass was estimated from tree equivalents (TE ha^{-1}), a tree which is 1.5m high (Teague *et al.*, 1981).

4.5 Statistical analysis

For quantitative field data, a completely randomized design (CRD) was employed. Each of the three homogenous vegetation units was replicated 4 times.

Outline of the model employed: $Y_{\iota j\ (k)} = \mu + \alpha_{\iota\ (K)} + \varepsilon_{\iota j\ (K)}$

Where $Y_{\iota j}$= Response variables (species composition, biomass production, basal cover).

μ= overall mean

$\alpha_{\iota\ (k)}$ = effect of the ι^{th}HVU's (open grassland, scattered bush and dense bush)

$\varepsilon_{\iota j(K)}$ = effect of a Random error.

A Fischer least test and Analysis of Variance (ANOVA) was conducted and analysed using General Linear Model (Glm) procedure of SAS (1999) to conduct post hoc pairwise mean comparison at ($p \leq 0.05$) on herbaceous species composition, biomass production, basal cover, woody composition, density, tree equivalents and browsing units among different HVU's of the rangeland. The data was also log transformed for mean point to tuft distance. The interactions between homogenous vegetation units and season on species composition, basal cover and biomass production were also tested using General Linear Model (Glm) procedure of SAS (1999).

4.6 Results

4.6.1 Species composition in Peddie communal rangeland

There were 27 herbaceous species found in Peddie rangeland with 24 grasses with some forbs, sedges and karoo species. The species composition comprised of 44.4% Increaser II species, 26% Increaser I species, 7% invaders and 22% Decreaser species. Out of 27 species, 48% had a low grazing value, 37% had high grazing value and 15% had moderate grazing value. There was only one annual species (*Microchloa caffra*) while the rest were perennials.

Table 4.6.1: Overall mean abundances (%) of herbaceous species composition in Peddie communal rangeland.

Plant Species	Ecological status	Grazing value	Plant lifeforms	% Abundance
Eragrostis capensis	Increaser II	Moderate	Perennial	7.4
Eragrostis curvula	Increaser II	Moderate	Perennial	4.2
Karoochloa curva	Increaser I	Low	Annual	1.5
Cynodon dactylon	Increaser II	High	Perennial	9.8
Eragrostis plana	Increaser II	Low	Perennial	8.3
Cymbopogon excavates	Increaser I	Low	Perennial	9.7
Sporobolus africanus	Increser II	Low	Perennial	4.1
Sporobolus fimbriatus	Increaser II	High	Perennial	3.3
Digitaria eriantha	Decreaser	High	Perennial	4.3
Digitaria argyrograpta	Decreaser	High	Perennial	2.7
Themeda trianda	Decreaser	High	Perennial	19.3
Brachiaria serata	Decreaser	High	Perennial	3.8
Hyperrhenia hirta	Increaser I	Moderate	Perennial	12.7
Paspalum dilatatum	Invader	High	Perennial	3.7
Panicum maximum	Decreaser	High	Perennial	8.2
Chloris gayana	Invader	High	Perennial	1
Forbs	Increaserc II	Low	Unknown	12
Aristida congesta	Increaser II	Low	Perennial	2.8
Microchloa cafra	Increaser II	Moderate	Perennial	4.6
Heteropogon contortus	Decreaser	High	Perennial	8.7
Karoo	Increasder II	Low	Perennial	6.1
Eragrostis chloromelas	Increaser II	Low	Perennial	1.7
Eulalia vilosa	Increaser I	Low	Perennial	8.8
Tristichya leucothrix	Increaser I	Low	Perennial	2
Sedge	Increaser II	Low	Unknown	2
Elionurus muticus	Increaser I	Low	Perennial	2.4
Festuca costata	Increaser I	Low	Perennial	2.5

4.6.2 Seasonal differences on the abundances of herbaceous vegetation

In total of 27 species there were 8 common species in grassland, scattered and dense bushlands of Peddie rangeland. These comprised of *Themeda triandra, Cynodon dactylon, Eragrostis plana, Hyperrhenia hirta, Sporobolus africanus, Cymbopogon excavatus, Microchloa caffra* and forbs. Seasonality did not have impacts (p>0.05) on the abundances of *C. dactylon, E. plana, H. hirta, S. africanus, C. excavatus* and *M. caffra* (Table 4.6.2). There were seasonal significant differences in the abundance of *T. triandra* and forbs in grassland where summer and winter abundances were 20.4% and 44.1% respectively while forbs had 6.4% and 19.5% respectively.

Table 4.6.2: Mean (±S.E) % abundances of 8 common species in homogenous vegetation units/season.

Species	Season	Grassland	Scattered bushland	Dense bushland
C. dactylon	Winter	$3.3(8.0)^{a}$	$7.5(5.7)^{a}$	$17.1(5.7)^{a}$
	Summer	$0.5(8.0)^{a}$	$5. 9(5.7)^{a}$	$16.8(5.7)^{a}$
E. plana	Winter	$4.7(2.5)^{bc}$	$5.1(2.2)^{bc}$	$13.1(2.2)^{a}$
	Summer	$1.3(2.5)^{c}$	$8.8(2.2)^{ab}$	$14.1(2.2)^{a}$
C. excavatus	Winter	$1.5(6.9)^{a}$	$11.1(3.5)^{a}$	$10. 9(3.5)^{a}$
	Summer	$0.5(6.9)^{a}$	$7.6(3.5)^{a}$	$13.6(3.5)^{a}$
S. africanus	Winter	$1.1(2.3)^{a}$	$4. 9(2.0)^{ab}$	$2.3(2.0)^{ab}$
	Summer	$1.0(2.8)^{ab}$	$8.1(2.0)^{b}$	$6.4(2.0)^{ab}$
T. triandra	Winter	$44.1(6.6)^{a}$	$18.5(8.0)^{b}$	$6.0(8.0)^{b}$
	Summer	$20.4(5.7)^{b}$	$15.0(5.7)^{b}$	$7.7(6.7)^{b}$
H. hirta	Winter	$12.0(5.8)^{a}$	$11.5(4.1)^{a}$	$7.5(5.8)^{a}$
	Summer	$18.5(4.1)^{a}$	$13.8(4.1)^{a}$	$7.3(5.8)^{a}$
Forbs	Winter	$6.4(2.8)^{b}$	$10.1(2.8)^{b}$	$10.0(2.8)^{b}$
	Summer	$19.5(2.8)^{a}$	$13.5(2.8)^{ab}$	$12.6(2.8)^{ab}$
M. cafra	Winter	$6.6(2.0)^{a}$	$5.6(2.0)^{a}$	$3.7(2.3)^{a}$
	Summer	$1.9(2.0)^{a}$	$5.7(2.3)^{a}$	$4.2(2.3)^{a}$

Different superscripts for each species in a column denote significant differences at p< 0.05 between seasons.

4.6.3 Effects of homogenous vegetation units on species composition at Peddie communal rangeland

When considering the homogeneity of vegetation units, the abundance of *Themeda triandra* in the grassland (32.6%) was significantly higher (p<0.05) than both the scattered bushland (16.8%) and dense bushland (6.8%) of Peddie rangeland.The abundances of forbs, *Hyperrhenia hirta* and *Microchloa Caffra* did not differ among all HVUs with *Sporobolus africanus* only that was significantly different (p<0.05) in scattered bushland and grassland with no significant difference (p>0.05) in dense bushland of Peddie rangeland. The abundance of *Cynodon dactylon* differed significantly (p<0.05) between grassland and dense bushland while scattered bushland was not significantly different (p>0.05) from both grassland and dense bushland. The abundance of *Eragrostis plana* in dense bushland was significantly higher (p<0.05) than both grassaland and scattered bushland. An increasing trend in abundances of *C. dactylon*, *E. plana* and *C.excavatus* from grassland to dense bushland were noted while *T. triandra*, *H. hirta*, and forbs declined from grassland to dense bushland of Peddie (Figure 4.6.3).

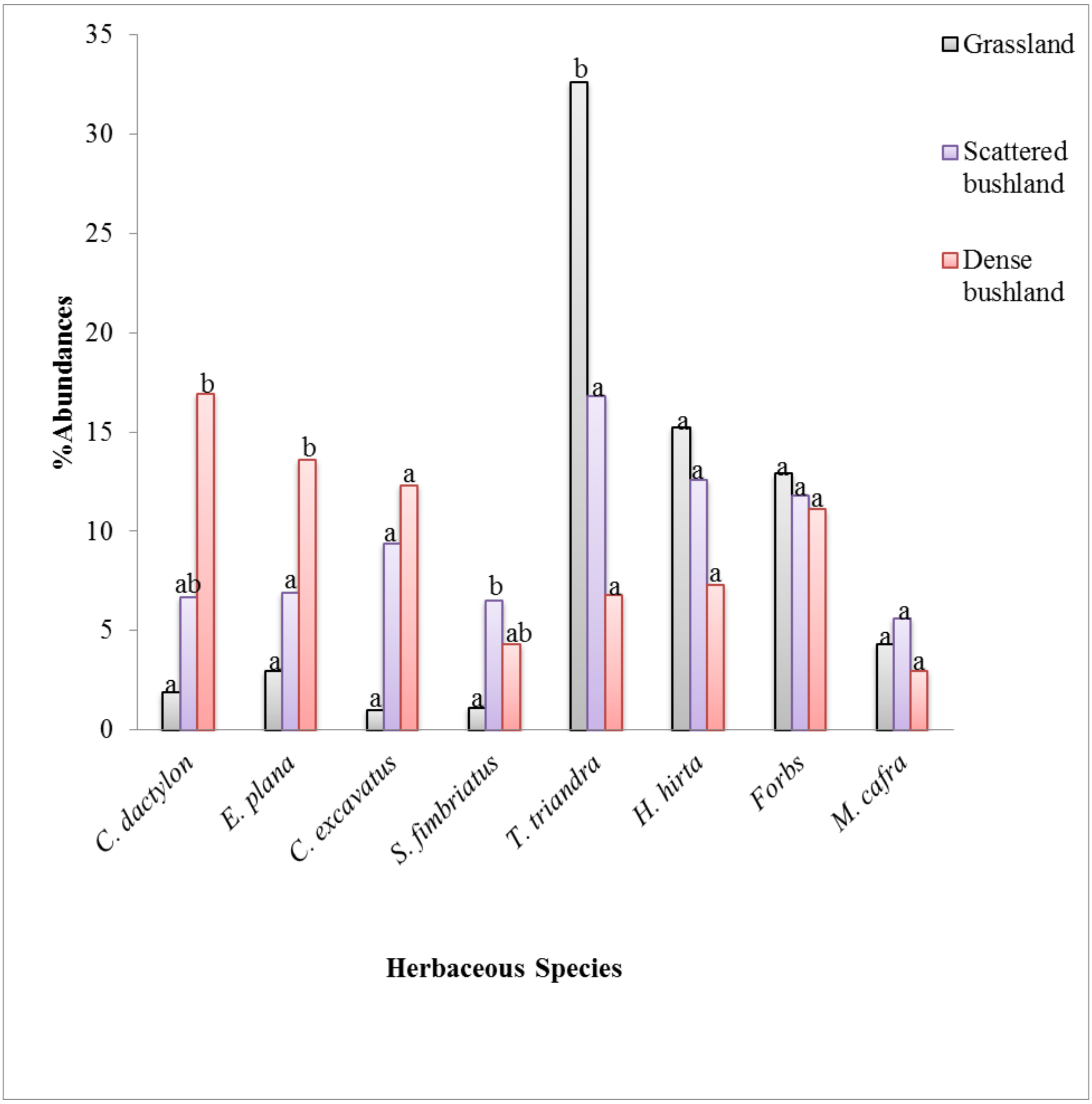

Figure 4.6.3: Effects of homogenous vegetation units (Grassland, scattered and dense bushlands) on abundances of 8 common herbaceous species in Peddie rangeland.

Different superscripts on the different histograms per species indicate significant differences ($p<0.05$) on the abundances of that species between two compared HVUs of Peddie rangeland.

4.6.4 Biomass production at Peddie communal rangeland

All homogenous vegetation units (p = 0.0006) and seasons (p = 0.002) displayed significant differences on the biomass production, and showed a strong interaction (p = 0.008). Summer biomass production (kg ha^{-1}) in grassland was significantly higher ($p<0.05$) than in scattered and dense bushland. Winter biomass production in all homogenous vegetation units showed no significant differences ($p>0.05$) but both seasons were characterized by a declining trend from grassland and dense bushland (Figure 4.6.4).

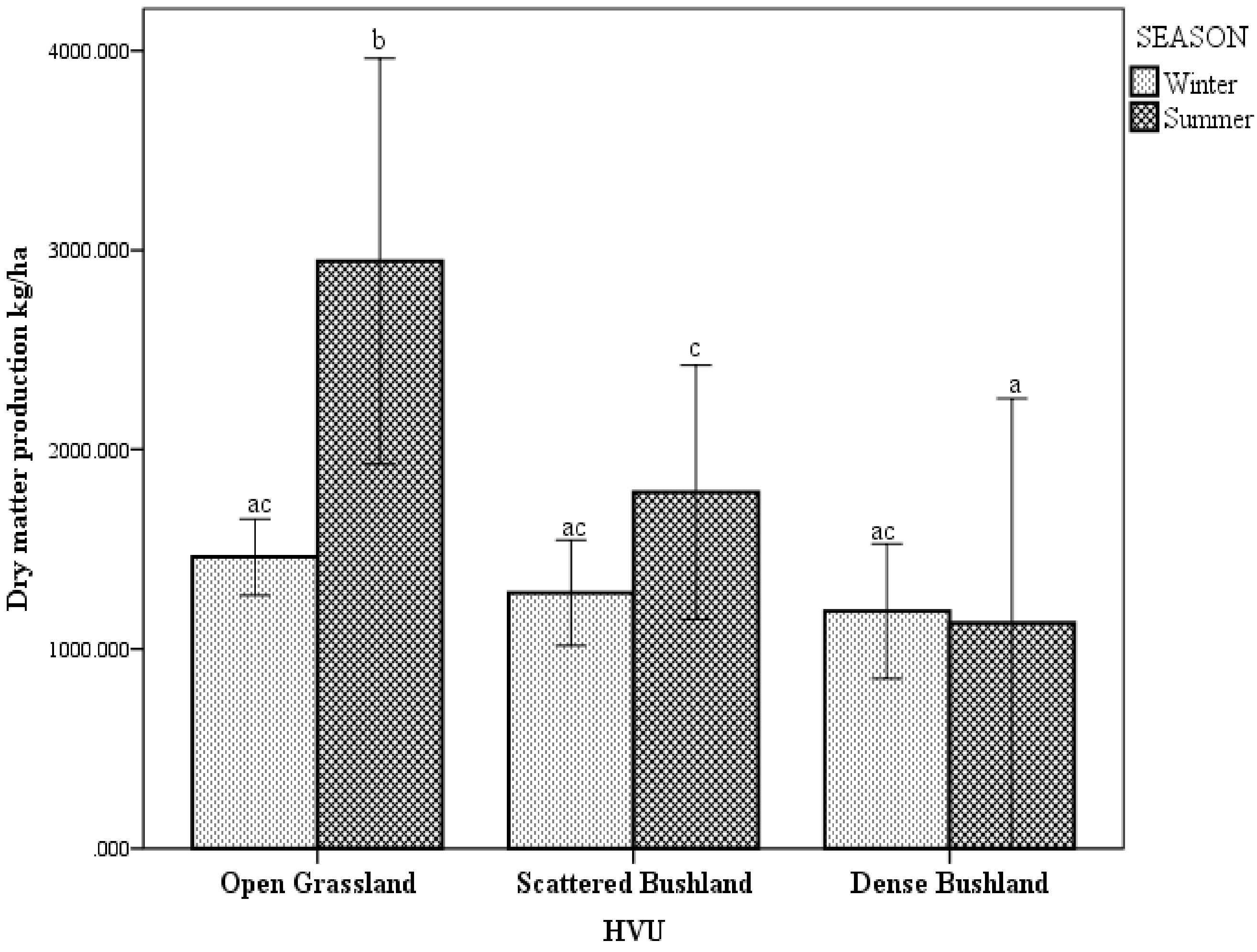

Figure 4.6.4: Seasonal dry matter production (kg ha^{-1}) in three homogenous vegetation units (HVUs) of Peddie communal rangeland.

Different superscrips indicate significant differences ($p<0.05$) on the dry matter production between and within Seasons/HVU.

4.6.5 Basal cover in three homogenous vegetation units of Peddie rangeland

There were no significant effects (p>0.05) of the interaction of season and HVUs on the basal cover. There were no significant differences (p>0.05) on the mean basal cover of grassland and scattered bush but dense bushland tended to have significantly higher (p<0.05) mean basal cover (cm) than both grassland and scattered bushland. There was an increasing trend in basal cover from grassland to bushlands.

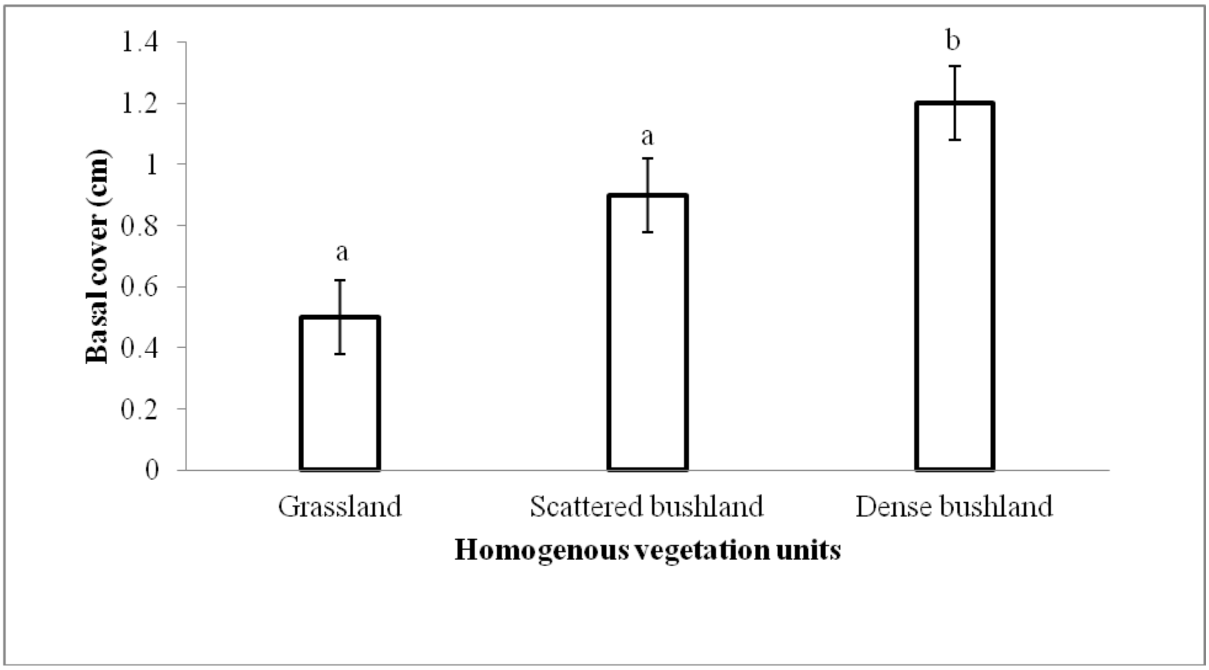

Figure 4.6.5: Mean basal cover (cm) in grassland, scattered and dense bushland of Peddie rangeland

Different superscripts denote significant differences (p<0.05) on the mean basal cover of the three homogenous vegetation units.

4.6.6 Woody species composition in Peddie communal rangeland

Peddie rangeland comprised of 15 woody species with 73% species being acceptable for browsing and 40% were thorny species. These species were *Acacia karoo, Coddia rudis, Lipia javanica, Dyospyros scabrida, Grewia occidentalis, Maytenus heterophylla, Rhus refracta, Dovyalis Caffra, Canthium inerme, Phyllanthus verracosus, Plumbago auriculata, Ptaeroxylon obliquum, Euphobia Coerulescens, Dovyalis zeyheri* and *Scutia myrtina.* There were 4 species that were common in both scattered and dense bushland namely *Acacia karoo, Lipia javanica, Coddia rudis* and *Diospyros scabrida*. The *Acacia karoo* was the dominant species (73.4%) while *Maytenus heterophyla, Plumbago auriculata* and *Ptaeroxylon oblicum* were the least abundant species.

Table 4.6.6: Percentage (%) abundances of the woody species found in scattered and dense bushlands of Peddie rangeland.

Species	Acceptability	Thorns/spines	% Abundance
Acacia karoo	+	+	73.4
Coddia rudis	+	–	6.3
Lippia Javanica	+	–	10.9
Diospyros Scabrida	–	–	10.2
Grewia occidentalis	+	–	1.4
Maytenus heterophylla	+	+	3.2
Rhus refracta	+	–	0.6
Dovyalis Caffra	–	+	1.2
Canthium inerme	+	+	3.1
Phyllanthus verracosus	+	–	1.6
Plumbago auriculata	+	–	0.6
Ptaeroxylon obliquum	+	–	0.6
Euphorbia coerulescens	–	–	3.6
Dovyalis zeyheri	–	+	2.4
Scutia myrtina	+	+	1.8

4.6.7 Woody species composition in scattered and dense bushlands of Peddie communal rangeland

There were no significant effects ($p>0.05$) of the interaction of the season and HVU on the abundances of woody species. Significant differences ($p<0.05$) were found on the abundances of *Lippia javanica* with dense bushland comprised of higher abundance compared to scattered bushland. *Codia rudis* also differed significantly ($p<0.05$) between scattered and dense bushlands of Peddie rangeland. A thorny leguminous *Acacia karoo* outweighed other species in both scattered and dense bushlands but its abundance did not differ significantly ($p>0.05$) in both bushlands of Peddie rangeland.

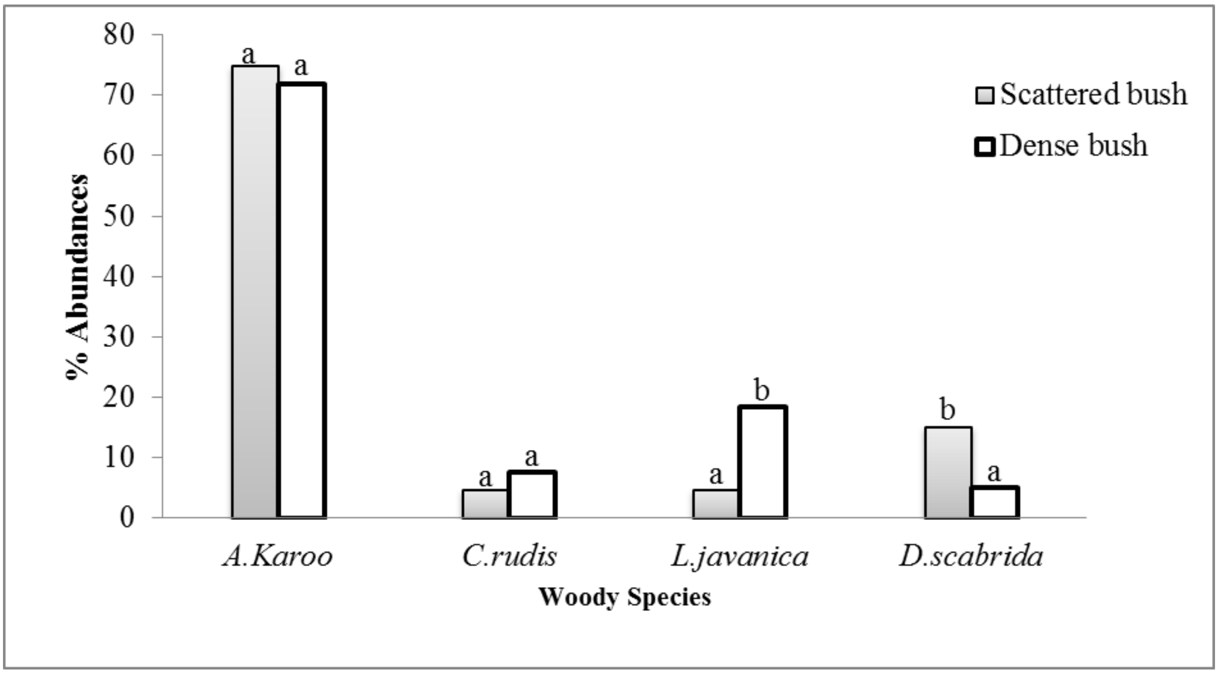

Figure 4.6.7: Mean abundances of 4 common species in dense and scattered bush areas of Peddie rangeland.

Different superscripts denote significant differences per species ($p<0.05$).

4.6.8 Woody Plant density, tree equivalents and browsing units in Peddie rangeland

The seasonality and the interaction did not have significant effects (p<0.05) on the woody density, tree equivalents and browsing units. Dense bushland (6650 trees ha^{-1}) had a significantly higher density than the scattered bushland (1950 trees ha^{-1}). The tree equivalents of scattered bushland (1198.1TE ha^{-1}) were significantly lower than dense bushland (4909.5 TE ha^{-1}). The browsing units of scattered bushland (1212.5BU ha^{-1}) were also significantly lower than dense bushland (4737.5BU ha^{-1}).

Table 4.6.8: Woody density, tree equivalents and browsing units in scattered and dense bushland of Peddie rangeland

	Scattered bushland	Dense bushland	±S.E	*p*-value
Density (trees ha^{-1})	1950^{a}	6650^{b}	878.7	0.009
Tree equivalents (TE ha^{-1})	1198.1^{a}	4909.5^{b}	894.9	0.026
Browsing units (BU ha^{-1})	1212.5^{a}	4737.5^{b}	719.6	0.013

Different superscrips across the row denote significant differences (p<0.05) between HVUs

4.7 Discussion

4.7.1 Herbaceous species composition in Peddie communal rangeland.

The results of this study revealed that a grazing tolerant *Cynodon dactylon* increases with increase in bush density (Figure 5.3.3). These results were consistent with Angassa (2012), who recorded more *C. dactylon* on bush encroached than non-encroached rangeland. The relationship of co-existence of bushes and grasses should be explained by individualistic resistance of each herbaceous species (Scholes and Archer, 1997). Therefore, the prevalence of *C. dactylon* in dense bushlands of Peddie rangeland may be induced by combination of high stocking rate and continuous grazing during pre-encroachment and its resistance at post-encroachment.

Although Abdallah *et al*., (2012) studied the influences of individual *Acacia tortilis* rather than density on understory vegetation; they found high prevalence of *C. dactylon* under tree canopies which underpins that *C. dactylon* is well adapted under tree canopies. Despite its adaptation, bushes may provide facilitation rather than competition to some species (Scholes and Archer, 1997). This has led to conclusion that since Peddie rangeland is encroached by leguminous *Acacia karoo* which is known by its nitrogen fixation ability that it should have benefited *C. dactylon* through soil nutrient amelioration mechanism (Stuart-Hill and Tainton, 1989). However, there is a paucity or even absence of the studies conducted to quantify the tolerance strategies of *C. dactylon* on the negative effects of high bush density. Therefore, it is speculated that the creeping habit of *C. dactylon* makes it easy to access the light in inter-tree canopy spaces while its root production on the nodes of the creeping stems provides great ability to absorb more water and soil nutrients.

Another overgrazing tolerant species (*E. plana*) showed high abundances in dense bushaland than grassland and scattered bushland (Figure 5.3.3). The strong root production and dissemination ability, and drought tolerance of this species (Scheffer-Baso *et al.*, 2012) gave it advantage to strongly compete with bushes for resources. Despite these postulations, grasses with their numerous roots have ability to extract water and nutrients from top soil horizons within 0 – 15cm preceding the woody plants (Dube *et al.*, 2010; Belsky, 1994). On the other hand, herbaceous vegetation may benefit from hydraulic uplift of deeply rooted trees (Simmons *et al.*, 2008).

The high abundance of *T. triandra* in grassland was observed in winter than summer which can be associated to selective continuous grazing by animals to compensate for depleted body nutrient reserves in winter (Table 5.3.2). The selective continuous grazing in summer facilitated a considerable decline of *T. triandra* and favoured proliferation and uninterrupted growth of forbs in grassland of Peddie rangeland as the large abundance of forbs 19.5% were observed in summer than in winter 6.4%. Although Solomon and Mlambo (2010) discovered that *T. triandra* is adapted to micro habitats under *Acacia brevispica*, an increase in tree density in Peddie rangeland more especially of *Acacia karoo* reduced the abundance of *T. triandra* and the same case was reported by (Riginos and Grace, 2008; Mugasi *et al.*, 2000). Friedel (1987) concluded that *Acacia karoo* improves rangeland condition due to close linkage of high palatable species including *T. triandra* to its base. The aforementioned reports did not provide a clear association of the increase in bush density instead they emphasised the impacts of individual *A. karoo* tree. A downward trend of *T. triadra* from grassland to dense bushland of Peddie rangeland is the manifestation of fragility of the competition against bushes (Figure 5.3.3).

Ecological changes in a form of shift in species composition in Peddie rangeland from grassland to bushland resemble the findings of Oba and Kotile (2001) who discovered that bush encroachment drives the herbaceous composition to unpalatable species composition. However, there is no clear elucidation of the effects of bush encroachment on herbaceous species composition (Eldrigde *et al.*, 2011) whether the trend moves from Decreaser to Increaser state or vice-versa and these effects are known to be variable. Generally, high abundance of increaser II species in bushlands of Peddie rangeland provided no clear association of ecological changes in herbaceous composition and bush encroachment. The reason behind is that both the dominance of increaser II species and progressive bush encroachment are a product of heavy grazing.

4.7.2 Biomass production in Peddie communal rangeland.

The results of this study revealed that grassland produced high biomass in summer (Figure 5.3.4) which could be attributed to by high summer rainfall and temperatures (Sherry *et al.*, 2008). The spatial heterogeneity of rainfall distribution has been reported by Moustakas *et al.*, (2009) and Ward *et al*., (2004). High summer rainfall is speculated to promote increased leaf production and leaf area of herbaceous species thereby promoting high production per plant. The openness of grassland promoted the exposure of herbaceous vegetation thereby increasing the light accessibility for photosynthesis. Although continuous grazing which is selective is suspected to cause reduction in highly productive *T. triandra*, underutilised species e.g. *H. hirta* and avoided forb species contributed large amounts in biomass production of grassland in Peddie rangeland. Biomass production of scattered 1533.3 (kg ha^{-1}) and dense bushlands 1159.3 (kg ha^{-1}) of Peddie rangeland regardless of the season did not differ significantly ($p>0.05$) but a downward trend in biomass production among HVUs (grassland>scattered bushland>dense bushland) was observed. These results are in contrast with Le-Houerou (1980) who discovered that open grasslands produce less forage than bushlands with the underpinning that the photosynthetic efficiency in bushlands is greater than in open grasslands.

The unrestricted access of grazers in scattered bushland should have intensified the competitive ability of the woody plants against herbaceous species though the density was not too high. However, Oba (2010) argued that poor rangeland condition does not emanate from grazing alone but can be instigated by successional trends of woody encroachment which also emanates from improper grazing. This reflects that as grass is heavily grazed, woody plants become the champions through uninterrupted access to growth resources as grasses lose the ability to sequester these resources (Scholes and Archer, 1997; Tessema *et al.*, 2011). A high bush density in dense bushland has exacerbated the decline in biomass production further low than scattered bushland. These results concur with Angasa (2005) who obtain slightly lower herbage in encroached than non-encroached rangeland. These results are also in accordance with the model of Aucamp *et al*., (1983) which stressed that an increase in woody density in *Acacia karoo* encroached rangelands favours a decline in grass productivity.

A concomitant decline in biomass production in dense bushland implies that efforts for abatement of real threat of bush encroachment are required in Peddie rangeland. The rationale is the preclusion/reduction of competitive ability of woody plants over grasses. As a well-known notion, bushes compete strongly for light accessibility, soil nutrients and moisture resulting to reduced leaf production or even termination of some herbaceous species (Abate *et al.*, 2012; Higgins *et al.*, 2010). Biomass production below margin (< 1500kg ha^{-1}) (Teague *et al*., 2009) in dense bushland is a reflection of rangeland in non-good condition which cannot ensure future sustainable livestock production in Peddie communal area not unless control measures are put in place. Nevertheless, biomass production in all HVUs (Figure

5.3.4) of Peddie rangeland exceeded the recommended threshold (800 kg ha^{-1}) acquired for preclusion of rangeland degradation (Teague *et al.*, 2009).

4.7.3 Ecological stability in Peddie communal rangeland

All homogenous vegetation units displayed a high ecological stability (<3 cm) with dense bushland showing a diminution in ecological stability than grassland and scattered bushland. This implies that increase in tree density negatively affected basal cover although it was not reduced below the base line. Oba (2000) and Angassa *et al.*, (2006) also noticed a negative relationship between woody plant density and basal cover. Even though dense bushlands leave little room for grass existence, the dominance of a creeping *C. dactylon* and a disseminating *E. plana* provided a great protection against negative impacts of direct rain drops that may cause soil erosion under and inter tree canopies in dense bushland of Peddie rangeland. The dominant *Acacia karoo* in dense bushland should have provided facilitation mechanism (Moustakas *et al.*, 2013) by slowing down the speed and intensity of raindrops thereby ensuring high infiltration rate in micro habitats under canopies. This in turn provided a refuge from water stress thereby benefiting the understory vegetation to grow expanding above large area on the surface.

4.7.4 Woody plant species composition in Peddie rangeland

The woody species composition of Peddie rangeland comprised of high abundance of highly accepted species (Table 5.3.5). These involved some shrub species *L. javanica* and *C. rudis* and some thicket species e.g. *S. myrtina* which should be closely related to high abundance of *A. karoo* which could be acted as nuclei to these species (Hester *et al*., 2006). *Acacia karoo* seems to increase drastically at an alarming rate with its deleterious effects on rangeland productivity (Dube *et al.*, 2009). This was mostly observed in dense bushlands where its abundance was higher beyond 70% (Figure 5.3.6). A continuous increase of this woody species in rangelands is mostly exacerbated by anti-nutritional factors and thorns (Moleele *et al.*, 2002). The encroachment by *A. karoo* is a provincial problem in the Eastern Cape which is reported to override over vast areas (Aucamp, 1976).

In Peddie rangeland, encroachment by thorny *A. karoo* was also pointed out as being responsible for jeopardizing accessibility of herbaceous vegetation to grazers (Farmer's perception).This perception was in agreement with the perception of pastoralists in southern Oromia in Ethiopia (Gemedo *et al.*, 2006). Nevertheless, *A. karoo* is a highly acceptable species for browsing ungulates and it is perceived to be an excellent species for making fire (farmer's perception). Therefore, a focus is required to halt its problematic encroachment which will be accompanied by economic improvements through stocking with browser ungulates plus cattle (Stuart-Hill, 1987). The grazer to browser stocking ratio under bush dominated rangelands should be planned according to tree density levels (Stuart-Hill, 1987).

4.7.5 Tree density, browsing units and tree equivalents in Peddie communal rangeland

According to the results of this study, dense bushland (6650 trees ha^{-1}) of Peddie rangeland can be labelled as bush encroached than scattered bushland (Table 4.6.8). This assumption is supported by Abate *et al*., (2010) and Gemedo *et al*., (2006) who considered 2400 trees ha^{-1} as a barrier between bush encroached and non-encroached rangeland. However, woody density alone cannot be considered as a single factor affecting competitive behaviour against herbaceous vegetation (Abule *et al.*, 2007). Therefore, tree equivalents of dense bushland (4909.5 TE ha^{-1}) beyond the threshold (2500 TE ha^{-1}) is a true mirror of highly encroached condition in Peddie rangeland (Richter *et al.*, 2001). Moreover, a curve developed by Aucamp *et al*., (1983) which relates tree density and biomass production have elucidated that biomass production increases proportionally with tree density up to a certain point thereafter it declines.

A progressive bush encroachment has been associated with a variety of factors (Glasscock *et al.*, 2005) but overgrazing and suppression of fire in Peddie rangeland could be the primary ones. This was underpinned by the perception of farmers that overgrazing occurred previously and fires are rare in Peddie rangeland with last fire outbreak occurred in 2008. Therefore, this suggested that trees coppice without impediment in Peddie rangeland because efficacy of browsing as a control is fire dependent (Hester *et al.*, 2006). However, Teague *et al*., (1981) suggested that one mature goat can result to a complete consumption of 2000 browsing units. This implied that paying attention on goat production in Peddie communal area can ensure an effective control if browsing is applied concurrently with fire or bush thinning or as a follow up treatment (Nyamukanza and Scogings, 2008; Hudak, 1999). The Angora and Boer goats are excellent *Capra hircus* breeds known to have massive play even when used as a primary or secondary farming enterprise (Aucamp, 1976).

4.8 Conclusions

The study indicated that dense bushland of Peddie rangeland is in a highly encroached condition than grassland and scattered bushland. The most encroaching species is *Acacia karoo*. This encroachment in dense bushland caused considerable decline in abundances of highly palatable species and in overall biomass production. Generally, *Themeda triandra* was the dominant herbaceous species in Peddie rangeland but it was less abundant in dense bushland. Biomass production and basal cover also showed a declining trend from grassland to dense bushland. These consequences are likely to impact livestock production negatively through reduction in forage quantity and quality. Moreover, a progression of bush encroachment to the area used for Nguni Cattle Project will have negative impacts on the performance of Nguni cattle. This arises from the fact that acute encroachment also restricts forage accessibility to grazers. Therefore, a control of a continuous encroachment is required to prevent severe events of degradation.

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CHAPTER 5 SOIL CHEMICAL COMPOSITION IN PEDDIE RANGELAND

Abstract

Soil nutrients play diverse roles in vegetation in rangelands. The deficiencies of these minerals in soil imply deficiencies in vegetation which in turn imply deficiencies in livestock. These mineral deficiencies can cause the disorders in livestock bodies. The study was conducted at Peddie rangeland to determine micro and macro nutrients and soil pH. The soil samples were collected at 200mm depth in December 2012. The soil nutrients comprised of pH, OC, P, N, K, Mg, Ca and Na, Zn, Cu, and Mn. The soil solutions were prepared following the methods of soil chemical analysis and the concentrations were observed under photospectrometer. The results indicated significantly higher (p<0.05) organic carbon (OC) in grassland (1.61%) than scattered (1.46%) and dense bushland (1.53%). Nitrogen (N) was significantly higher (p<0.05) in dense bushland (1.11%) than grassland (0.1%) and scattered bushland (0.1%). Phosphorous (P) was also significantly higher (p<0.05) in dense bushland (19.0 mg kg^{-1}) than grassland (6.3 mg kg^{-1}) and scattered bushland (6.95 mg kg^{-1}). Both P and N were not significantly different (p<0.05) between scattered bushland and grassland. Potasium (K) was significantly higher (p<0.05) in dense bushland (142.9 mg kg^{-1}) than grassland 67.55 mg kg^{-1}) but did not differ significantly (p<0.05) from scattered bushland (89.10 mg kg^{-1}). Sodium (Na^{+}), calcium (Ca^{2+}) and magnesium (Mg^{2+}) were also significantly higher in dense bushland than grassland and scattered bushland. The concentrations of these minerals except N, P and K fluctuated from grassland to dense bushland. All micro minerals (Cu, Zn and Mn) were significantly higher (p<0.05) in dense bushland than grassland and scattered bushland. Soil pH was significantly different (p<0.05) between grassland (4.46 KCl), scattered (4.64 KCl) and dense bushland (5.09 KCl). The results indicated that there was an increase in soil fertility as woody density increases. This implied that if tree thinning can be applied, there can be a quick recovery of herbaceous vegetation in dense bushland.

Key words: Soil micro nutrients, macro nutrients, soil pH, homogenous vegetation units

5.1 Introduction

Soil is a paramount bio-physical rangeland resource (Rezaei *et al.*, 2006). It is composed of three quality indicators such as physical, chemical and biological properties that require attention to evaluate the functional capacity of the soil resource in rangelands. These are referred to as soil quality indicators since they can be modified in a short time by land use dynamics (Mojiri *et al.*, 2012). Their use in rangeland evaluation is mostly vital to add value and to obtain a high precision of evaluation and trend analysis (USDA-NRCS, 2001). Overgrazing, transformation of rangelands and forests and deforestation are considered as the driving forces of the diminution in soil quality indicators (Nael *et al.*, 2004).

In rangeland science the soil chemical properties that are of interest are soil acidity and salinity as they indirectly or directly impact the vegetation growth through elimination of vital nutrients in the soil and they mask the access of these nutrients to vegetation (Herrick, undated). Specifically, the spatial heterogeneity of soil chemical composition is attributed to physical and biotic factors such as topography, grazing, microclimate of the soil and vegetation (Chaneton and Lavado, 1996). Among chemical properties, soil nutrient availability largely affects vegetation growth and competition in the rangelands (Blank *et al.*, 2007). The considerable effects of poor soil mineral concentration are not displayed only on quantity of biomass but also on palatability and nutritive value of individual plant (Brotherson and Osayande, 1980). There is a strong interaction between rangeland soils, plants and animal performance (Khan *et al.*, 2006). The nutrient deficiencies in soils induce deficiencies in vegetation which in turn induce the deficiencies in animals (Brotherson and Osayande, 1980). The study was conducted to investigate the soil chemical composition to estimate the functional capacity of the soil of Peddie rangeland.

5.2 Materials and Methods

5.2.1 Soil sampling and analysis

A total of 10 soil samples were collected in each HVU replicate within a 0.25 m^2 quadrant at a depth of 200mm with the use of auger and they were placed in well labelled brown paper bags. Immediately after collection, two soil samples per plot per HVU replicate were oven dried at constant mass at 60^0C for 48 hours, pulverized through a 2mm sieve, blended, weighed and analysed for soil pH, OC, P, N, K, Mg, Ca and Na, Zn, Cu, and Mn contents. Organic carbon was analysed with a Waltley-Black method (Nelson and Somers, 1982) while nitrogen was analysed in digestion prepared with concentrated sulphuric acid, selenium powder and hydrogen peroxide as described by Okalebo *et al*., (2002). Other nutrients including Mg, Na and Ca were analysed with ammonium acetate method (Marx *et al*., 1999). The soil pH was determined with an electrode pH-meter in a soil: water slurry. The analysis of Zn, Cu and Mn was achieved by the DTPA (Diethylenetriamenepentaacetic) extraction method (Linday and Norvell, 1978) and their concentrations were observed under photo spectrometer.

5.3 Statistical analysis

Soil samples were collected in completely randomised design. A Fisher least test and analysis of variance were analysed with the use of SAS (1999) to find significant differences on the mean concentrations of each nutrient between homogenous vegetation units. The significant differences between means were recognised at a confidence level of 95% (p<0.05).

5.4 Results

5.4.1 Soil macro nutrients in Peddie communal rangeland

The homogenous vegetation units significantly ($p<0.05$) affected the soil chemical composition of Peddie rangeland. Organic carbon (OC) differed significantly ($p<0.05$) between the grassland (1.61%) and both scattered (1.46%) and dense bushlands (1.53%) (Table 5.4.1). Nitrogen (1.11%), magnesium (1.65 cmol kg^{-1}) and phosphorous (19.0 mg kg^{-1}) were significantly higher ($p<0.05$) in dense bushland compared to grassland and scattered bushland of Peddie rangeland whilst the concentration of potasium (142.9 mg kg^{-1}) in grassland were significantly lower than scattered (89.1 mg kg^{-1}) and dense bushland (142.9 mg kg^{-1}). Sodium was significant lower in grassland (49.85 mg kg^{-1}) than scattered (53.3 mg kg^{-1}) and dense bushland (53.15 mg kg^{-1}). It was calcium (Ca^{2+}) only that displayed significant differences ($p<0.05$) among all HVUs of Peddie rangeland with dense bushland (3.34 cmol kg^{-1}) produced considerable higher amounts than grassland (1.79 cmol kg^{-1}) and scattered bushland (1.69 cmol kg^{-1}). The concentration of all nutrients despite OC and Mg increased from grassland to dense bushland. Organic carbon declined from grassland to bushlands of Peddie rangeland (Table 5.4.1).

Table 5.4.1: Effects of homogenous vegetation units on soil macro minerals in Peddie communal rangeland.

Soil Mineral	Grassland	Scattered bushland	Dense bushland	±S.E
OC (%)	1.61^{a}	1.46^{b}	1.53^{ab}	0.03
N (%)	0.10^{a}	0.10^{a}	1.11^{b}	0.00
P (mg kg^{-1})	6.30^{a}	$6. 95^{a}$	19.00^{b}	0.40
K (mg kg^{-1})	67.55^{a}	89.10^{b}	142.90^{b}	3.10
Na (mg kg^{-1})	49.85^{a}	53.30^{b}	53.15^{b}	0.70
Ca (cmol kg^{-1})	1.79^{a}	1.69^{b}	3.34^{c}	0.03
Mg (cmol kg^{-1})	1.54^{a}	1.47^{a}	1.65^{b}	0.03

Different superscripts across the row indicate significant differences ($p<0.05$) on each soil nutrient.

5.4.2 Soil micro nutrients in Peddie communal rangeland

All micro minerals were significantly affected ($p<0.05$) by homogenous vegetation units of Peddie rangeland. There were significant differences ($p<0.05$) in concentrations of copper (Cu) in grassland (0.63 mg kg^{-1}), scattered (0.53 mg kg^{-1}) and dense bushland (1.06 mg kg^{-1}). The concentrations of Zinc (Zn) also fluctuated, with grassland (0.77 mg kg^{-1}) had large amounts followed by decline in scattered bushlands (0.71 mg kg^{-1}) while dense bushland (2.28 mg kg^{-1}) yielded significantly higher ($p<0.05$) amounts than both grassland and scattered bushland. Manganese (Mn) was significantly different ($p<0.05$) between grassland (32.57 mg kg^{-1}), scattered (53.27 mg kg^{-1}) and dense bushland (147.34 mg kg^{-1}). There was an increasing trend in Mn from grassland to dense bushland. Soil pH displayed significant differences ($p<0.05$) in an increasing pattern from grassland (4.46 KCl), scattered bushland (4.64 KCl) to dense bushland (5.09 KCl).

Table 5.4.2: Effects of homogenous vegetation units on soil pH and micro minerals in Peddie communal rangeland.

Soil Minerals	Grassland	Scattered Bushland	Dense bushland	±S.E
Cu (mg kg^{-1})	0.63^{a}	0.53^{b}	1.06^{c}	0.01
Zn (mg kg^{-1})	0.77^{a}	0.71^{a}	2.28^{b}	0.03
Mn (mg kg^{-1})	32.57^{a}	53.27^{b}	147.34^{c}	2.60
pH (KCl)	4.46^{a}	4.64^{b}	5.09^{c}	0.01

Different superscripts across the row represent significant differences ($p< 0.05$). S.E stands for standard error.

5.5 Discussion

5.5.1: Effects of homogeneous vegetation units on soil macro minerals of Peddie rangeland.

In rangelands, soil minerals are a source of nutrition for vegetation with macro minerals being acquired in large amounts for plant growth. The results in Table 6.1 showed a high organic carbon (OC) production in grassland than both scattered and dense bushlands of Peddie rangeland. These results concur with Retallack (2001) who found high organic carbon in grasslands compared to woody dominated rangelands. The study conducted by Mpairwe *et al*., (2011) in Uganda revealed high organic carbon in an herbaceous only rangeland over woodlands. Soil carbon pool had been associated with leaf inputs from abscission, herbaceous plant production and microbial activity (Gemedo *et al.*, 2006). Therefore, high OC in grassland can be closely linked with high organic matter which may be the product of high moribund decomposition in grassland of Peddie rangeland. Despite moribund decomposition, grass roots have high contribution than woody plant and forb roots in organic matter (USDA-NRCS, 2001).

According to Hudak *et al*., (2003), bushlands were expected to yield high OC content; unfortunately the opposite occurred in Peddie rangeland. This may be explained by lower microbial activity caused by presence of tannins, lignins and other secondary compounds in woody plant tissues which are low in graminoids (Liao and Boutton, 2008). Woody plants also sequester large carbon content in their bodies thereby reducing carbon increment in the soil. In addition, indirect impacts of tree canopy such as radiation obstruction and reduced soil temperatures diminish litter decomposition in wooded rangelands (Throop and Archer, 2007). Nevertheless, other plant desirable minerals such as N, P and K increased with a switch in plant physiognomy from grassland to bushland resembling Schlesinger and Pilmanis (1998). However, exchangeable bases such as Ca^{2+}, Mg^{2+} and Na^{+} fluctuated from grassland to dense bushland. This fluctuation was characterized by increase of nutrient content from grassland followed by a decline in scattered bushlands which was also followed by an abrupt increase in dense bushland further higher than grassland. Ignoring the fact that Abdallah *et al*., (2008) took account of individual tree, they found high abundances of N, P, K, Ca^{2+}, Mg^{2+} and Na^{+} under *Acacia spp* compared to open grassland. Even though Schlesinger (2000) reported nitrogen losses through nitrogen oxide emission in bush encroached rangelands it was not the case in Peddie rangeland. Therefore we speculated that the nitrogen availability depends on dead leaf input and on amount added as an input by a prevalent bush species if it is leguminous. This pushed to the point that prevalence of a leguminous *Acacia karoo* in dense bushlands should have acted as soil ameliorator through N-fixing rhizobium bacteria (Angassa *et al.*, 2012). In general, soil fertility increases with bush encroachment in rangelands (Archer *et al.,* 2000).

5.5.2 Effects of physiognomic structure on soil pH and micro minerals in Peddie communal rangeland.

The plant growth is dependent on the variety of nutrients for many processes responsible for photosynthes. Therefore the evaluation of these nutrients is essential for knowing the functional capacity of the soil. These may include micro minerals such Zn, Cu, Mn and Fe (Tiedemann and Lopez, 2004). Dense bushland comprised of higher production of all micro nutrients which elucidated that tree leaf litter inputs provided soil enrichment (Smit, 2004) where change in plant physiognomy from grassland to bushlands occurred. Moreover, Tyrer *et al*., (2007) considered the Zn content between 0.15 and 6.56 mg kg^{-1} as being in an acceptable state which cannot cause retardation of plant growth. Therefore, this indicated that all homogenous vegetation units of Peddie can favour non-retarded plant growth. Nevertheless, low herbaceous biomass production in dense bushland should be reflected to other factors rather than soil fertility not unless trees enrich soil for their benefits. If not so, soil nutrient requirements of herbaceous vegetation may be higher than soil nutrient produced in each homogenous vegetation unit thereby giving rise to lower biomass production.

The soils in all homogenous vegetation units reflected an acidic state because all HVUs comprised of pH (KCl) ranging from 4.46 to 5.09. The soil pH in dense bushland of Peddie was significantly higher than both grassland and scattered bushland. Soil pH increased with tree density in Peddie rangeland which underpins that soil nutrient enrichment by tree leaf litter stabilised soil pH although it was below neutral state. Gemedo (2004) reported the similar trend of soil pH stating that there was a positive relationship between tree density and soil pH. Acidic pH in the rangelands may be the consequence of high leaching of bases in favour of acidic compounds (Angasa *et al.*, 2012).

5.6 Conclusions

The results of the study indicated that dense bushland is a nutrient reach homogenous vegetation unit. Almost all nutrients and pH except organic carbon were higher in dense bushland. This elucidated that woody increase has positive effect in soil fertility although there were unexpected low organic carbon. Unfortunately soil fertility alone cannot determine the resilience and survival of plants in the rangelands. Therefore, if tree thining can be practiced to reduce the competition for soil nutrients, light and water between trees and herbaceous plants in dense bushland a quick recovery of herbaceous vegetation can be instigated.

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CHAPTER 6 SOIL SEED BANK COMPOSITION IN PEDDIE COMMUNAL RANGELAND

Abstract

A soil seed bank experiment was conducted to investigate the potential of soil seed bank for restoration of Peddie rangeland. Five soil samples per HVU replicate were collected at a depth of 80 mm in June 2012 at Peddie rangeland. The soil samples per HVU replicate were mixed and five soil samples per replicate were scooped for germination in Fort Hare forestry nursary. Germination commenced on day 5 after inception and it was monitored on daily basis. There were 26 germinated herbaceous species including 14 forbs, 9 grasses, two sedges, one karoo species and one woody species (*Phyllanthus verracosus*) respectively. The results showed that the soil seed bank is dominated by large abundances of annual and biennial forbs and sedges. The abundances of forbs were significantly higher than sedges ($\chi^2 = 12$, df = 1, $p = 0.001$) and grasses ($\chi^2 = 8.333$, df = 1, $p = 0.004$) in all homogenous vegetation units. Sedges were higher than grasses but not significantly different ($\chi^2 = 3$, df = 1, $p = 0.083$) in grassland, scattered and dense bushland of Peddie. There was no evidence that bush encroachment favours proliferation of forbs as there were no significant differences ($p<0.05$) in the abundances of each plant catergory in all homogenous vegetation units. The dominant forb *Conyza albida* was significantly higher in grassland (42%) than scattered (27.9%) and dense bushland (23%). The second most dominant species, *Cyperus adoratus* was also significantly higher in grassland (32.9%) than scattered (27.5%) and dense bushland (15%) of Peddie rangeland. There was a slight relationship (Sorensen's = 26%) between extant vegetation and soil seed bank composition. Above vegetation composed of high abundance of perennial grasses including *Themeda triandra*, *Cynodon dactylon* and *Eragrostis plana*. Plant density in scattered bushland was significantly higher ($p<0.05$) than both grasland and dense bushland but it was not significantly different ($p> 0.05$) from grassland

A poor relationship between above vegetation and soil seed bank composition revealed that reliance on soil seed bank would not be advisable and it can not be able to push the transition from Increaser dominated state to highly productive Decreaser state.

Key words: Soil seed bank composition, plant density, homogenous vegetation units, Sorensen's index

6.1 Introduction

The efficacy of restoration in rangelands is largely determined by the soil seed bank (Solomon *et al.*, 2011). The soil seed bank composition *per se* is primarily determined by historical or present vegetation and is the estimate of the future populations (Chaideftou *et al.*, 2009). The accumulation of seeds as part of seed bank composition depends on the fecundity of parent plant and on the seed spread from neighbouring plants (Solomon *et al.*, 2011). Furthermore, anthropogenic and natural events play a significant role on shaping the future seed bank of a particular community. The soil seed bank can also be static or dynamic depending on the management of the rangeland (Chaideftou *et al.*, 2009). Many studies have reported negative shifts in seed bank composition in relation to application of non-realistic grazing regime (Tessema *et al.*, 2012; Snyman, 2013). The ability of an ecosystem to recruit from seed bank is also restricted to seed, edaphic and soil related factors. These include rainfall and light, soil pH and nutrients, seed viability and persistence (Solomon *et al.*, 2007).
Therefore, studying the soil seed bank is essential for understanding the directional changes of plant succession. Additionally, seeds in soil reserves act as buffers for disturbed patches through re-colonisation (Loydi *et al.*, 2012) and may also act as proxy for species poor rangelands (Snyman, 2004). In ecology, there has been a growing interest on investigating relationships between above ground vegetation and soil seed bank composition and density in relation to grazing regime (Tessema *et al.*, 2012). However, there is paucity if any studies conducted to explore the state of soil seed bank in relation to different levels of woody component. Therefore, a study was conducted in Peddie communal rangeland to answer the following questions “Can the reliance on soil seed bank be fruitful to push the transition of present state to more productive state? Does the progress in bush encroachment demonstrate negative/positive shifts in soil seed bank composition and plant density of Peddie rangeland?

6.2 Methods and Materials

6.2.1 Determination of soil seed bank composition and plant density

A total of 120 soil samples (10 per HVU replicate) for seedling emergence were collected in grassland, scattered and dense bushland of Peddie rangeland in June 2012. These samples were collected at a depth of 80mm with the use of auger. Sampling points were indicated by randomly throwing ten 0.25 m^{-2} quadrants along 100m transects in each homogenous vegetation unit. The seedling method was employed to determine composition of the seed banks where 3000 g sterile composite was evenly placed in 72 plastic pots at a depth of 10 cm. The twelve pots were considered as control pots on which there was no soil sample added to evaluate whether or not the composite is contaminated (Solomon, 2011). The visible litter, roots, stolons, rhizomes and tubers were carefully removed in soil samples (Loydi *et al.*, 2012).The soil samples collected were mixed and 300 g of soil was scooped and evenly spread above the composite in 60 pots to make a thin layer of 3 cm. Then, all plastic pots were labelled and placed in the agro-forestry nursery of the University of Fort Hare and were automatically irrigated three times a day (at 9:15 o'clock, 12:15 o'clock and 3:15 o'clock respectively) in an overhead computerised sprinkler irrigation system. The first germination took place on day 5 after experimental inception.

All emerged seedlings were counted (Scott *et al.*, 2010) and marked with great care with sharp tooth picks (Jones and Esler, 2004) to avoid double counting of the seedlings. In case where germination occurred in excess of the area of a pot, transplanting was done to avoid overcrowding which may result in retarded horizontal root growth. A Hoagland's solution (Coffin and Lauenroth, 1987) was prepared and applied twice a week to stimulate germination and to speed up growth rate of seedlings. The specimens were pressed and submitted to Selmar Schonland herbarium in Grahamstown for plant identification and verification. The plants were then categorised according to life forms as annual or perennial graminoids, forbs, sedge, Karoo and woody species. The plant density was calculated as the number of plants relative to the area of a pot. The Soresen's index ($\beta = 2c \div A + B \times 100\%$) was used to evaluate similarities and differences between above ground and below herbaceous composition.

6.3 Statistical analysis

The Analysis of Variance (ANOVA) and a Fisher least test were used to get mean abundances of herbaceous species and plant density of the soil seed bank through the use of SAS (1999). The significant differences of means were tested at 95% confidence level ($p<0.05$). The Box and Whisker plots for plant classes or categories such as forbs, sedges and grasses were analysed with SPSS (version 20). The Box and Whisker plots were used to present variation of each plant category within homogenous vegetation unit while the significant differences were investigated with the use of Chi-Square test at $p<0.05$.

6.4 Results

6.4.1 Soil seed bank composition in Peddie rangeland

Soil seed bank composition of Peddie rangeland comprised of 14 forbs, 9 grasses, 2 sedges and 1 palatable karoo species. Among forbs, 50% were annuals, 36% were perennials and 14% were biennials with 7% being highly palatable. Graminoids comprised of one annual and perennial sedges respectively while 89% of grasses were perennials and 11% were annuals. All sedge species were not palatable while 33% grasses were highly palatable, 11% moderate palatable and 56% were low palatable. *Conyza albida* was the most abundant species (31.1%) followed by *C. adoratus* (25.1%) while *C. vulgare* and *P. dilatatum* (1.2%), *S. inaequidens* (1.4%), *D. eriantha*, *C. excavatus* (1.6%) and *R. scabra* (1.7%) were the least abundant species. The names, description and % abundances of these species are presented in Table 6.4.1.

Table 6.4.1: Overall mean abundances of soil seed bank composition in Peddie communal rangeland

Species	Plant Class	Palatability Status	Life form	% Abundances
Cyperus adoratus	Sedge	Unpalatable	Annual	25.1
Centella asiatica	Forb	Unpalatable	Annual	12
Plantago lanceolata	Forb	High Palatable	Annual	3.1
Lobelia flaccid	Forb	Unpalatable	Annual	2.7
Eragrostis curvula	Grass	Low Palatable	Perennial	2.1
Paspalum dilatatum	Grass	High Palatable	Perennial	1.2
Conyza albida	Forb	Unpalatable	Annual	31.1
Ficinia nigrescens	Sedge	Unpalatable	Perennial	6.3
Conyza bonariensis	Forb	Unpalatable	Annual	5.5
Crassula tetragona	Forb	Unpalatable	Annual	1.7
Sporobolus africanus	Grass	Moderate Palatable	Perennial	8.5
Eragrostis plana	Grass	Low Palatable	Perennial	5.6
Digitaria eriantha	Grass	High Palatable	Perennial	1.6
Cymbopogon excavatus	Grass	Low Palatable	Perennial	1.6
Eragrostis spp	Grass	Low Palatable	Perennial	2.6
Cirsium vulgare	Forb	Unpalatable	Biennial	1.2
Richardia scabra	Forb	Unpalatable	Annual	1.7
Panicum maximum	Grass	High Palatable	Perennial	4.2
Teraxicum officionale	Forb	Unpalatable	Perennial	3
Senecio inaequidens	Forb	Unpalatable	Perennial	1.4
Helichrysum arenarium	Forb	Unpalatable	Perennial	1.6
Chenopodium murale	Forb	Unpalatable	Perennial	0.8
Gnaphalium purpureum	Forb	Unpalatable	Biennial	4.2
Microchloa caffra	Grass	Low Palatable	Annual	2.2
Cotula heterocarpa	Forb	Unpalatable	Perennial	4.1
Walafrida geniculata	karoo	High Palatable	Perennial	3.8

6.4.2 Effects of homogenous units on the abundances of 7 dominant species in soil seed bank

In total, 27 species were identified and comprised of 7 species (3 forbs, 2 grasses and 2 sedges) were common species in three homogenous vegetation units of Peddie. These were *Centella asiatica, Plantago lanceolata, Conyza albida, Cyperus adoratus, Ficinia ningrescens, Sporobolus africanus* and *Eragrostis plana*. The abundance of *C. asiata* was significantly higher (p<0.05) in dense bushland (16.6%) than grassland (4.5%) and scattered bushland (15%). *C. asiata* increased with a change in grassland to bushland. *Plantago major* showed significantly lower abundances in all homogenous vegetation (3.3%, 3.1 and 3.0 respectively. *Conyza albida* was the dominant species in grassland (42.5%), scattered bushland (27.9%) and (23.0%) respectively and its abundances were significantly different (p>0.05) in grassland and dense bushland. *Conyza albida* demonstrated an increasing pattern from grassland to dense bushland. *Cyperus adoratus* followed the similar trend with the abundance in grassland (32.9%) being significantly higher (p<0.05) than scattered (27.5%) and dense bushland (15.0%). There were no significant differences on the abundances of *F. ningrescens*, *S. africanus* and *E. plana* between the grassland, scattered and dense bushlands of Peddie.

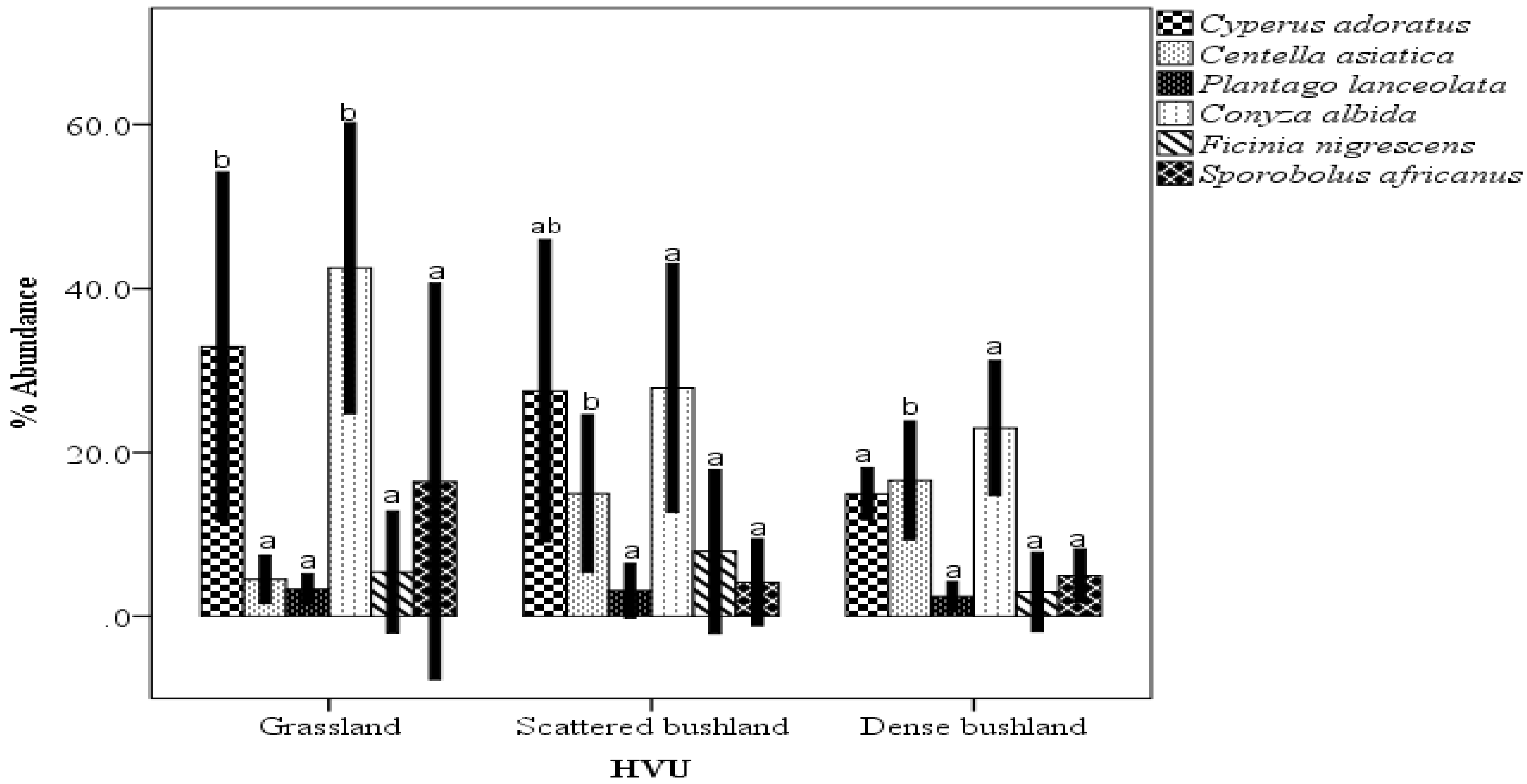

Figure 6.4.2: Percentage (%) abundances of dominant herbaceous species on the soil seed bank of grassland, scattered and dense bushland of Peddie.

Different superscripts denote significant differences on each species in grassland, scattered and dense bushland (p<0.05).

6.4.3 Effects of homogenous vegetation units on the abundances of forbs, grasses and sedge species

In figure 6.4.3 below there was a variation in the abundances of forbs, sedges and grasses in grassland, scattered and dense bushlands. Forbs ranged between 52.6 – 63.6% in grasslands, 42.7 – 59.5% in scattered bushland and 49.8 – 55.6% in dense bushland while sedges ranged between 15.8 – 40% in grassland, 13.5 – 46% in scattered and 22.8 – 41.3% in dense bushland. Grasses (graminoids) had a less contribution on the soil seed bank with a range of 2 – 31.6% in grassland, 11.3 – 27% in scattered bushland and 8.9 – 22.9 % in dense bushland. The abundances of forbs were significantly higher than sedges ($\chi^2 = 12$, df = 1, $p = 0.001$) and grasses ($\chi^2 = 8.333$, df = 1, $p = 0.004$) in all homogenous vegetation units while sedges were not significantly different ($\chi^2 = 3$, df = 1, $p = 0.083$) from grasses. In the comparison of each plant category, there were no significant differences on the abundances ($p > 0.05$) of forbs, sedges and grasses in grassland, scattered and dense bushlands.

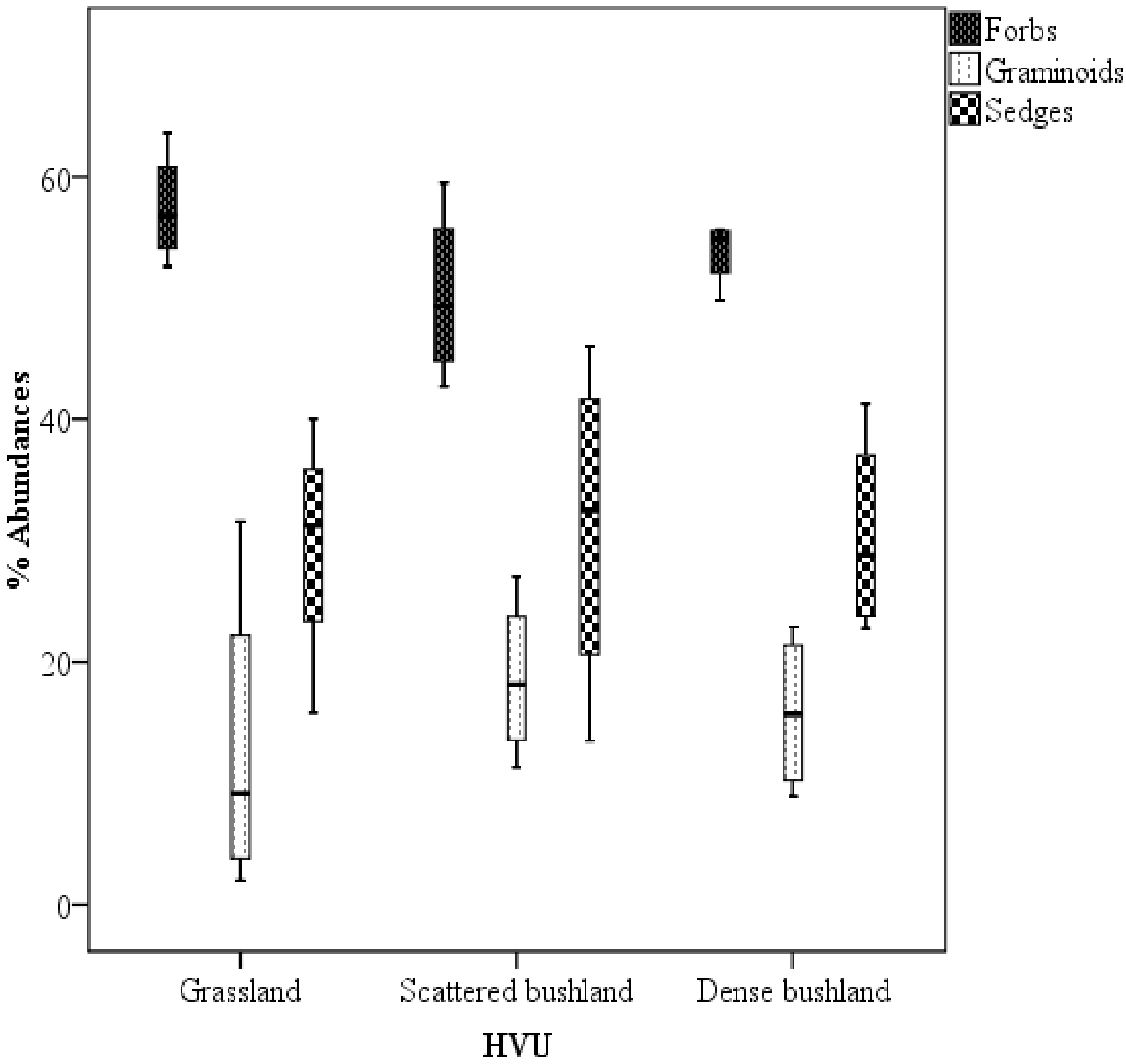

Figure 6.4.3: Percentage (%) abundances of the herbaceous plants in the soil seed bank of three homogenous vegetation units of Peddie rangeland.

Different superscripts in different and within herbaceous plant class denote significant differences (p<0.05).

6.4.4 Soil seed bank density in Peddie communal rangeland

There were significant differences ($p<0.05$) on plant density (plants m^{-2}) between dense bushland and scattered bushland, while grassland did not differ ($p>0.05$) between both scattered and dense bushlands. Scattered bushland had a significantly higher plant density than dense bushland but not different from grassland.

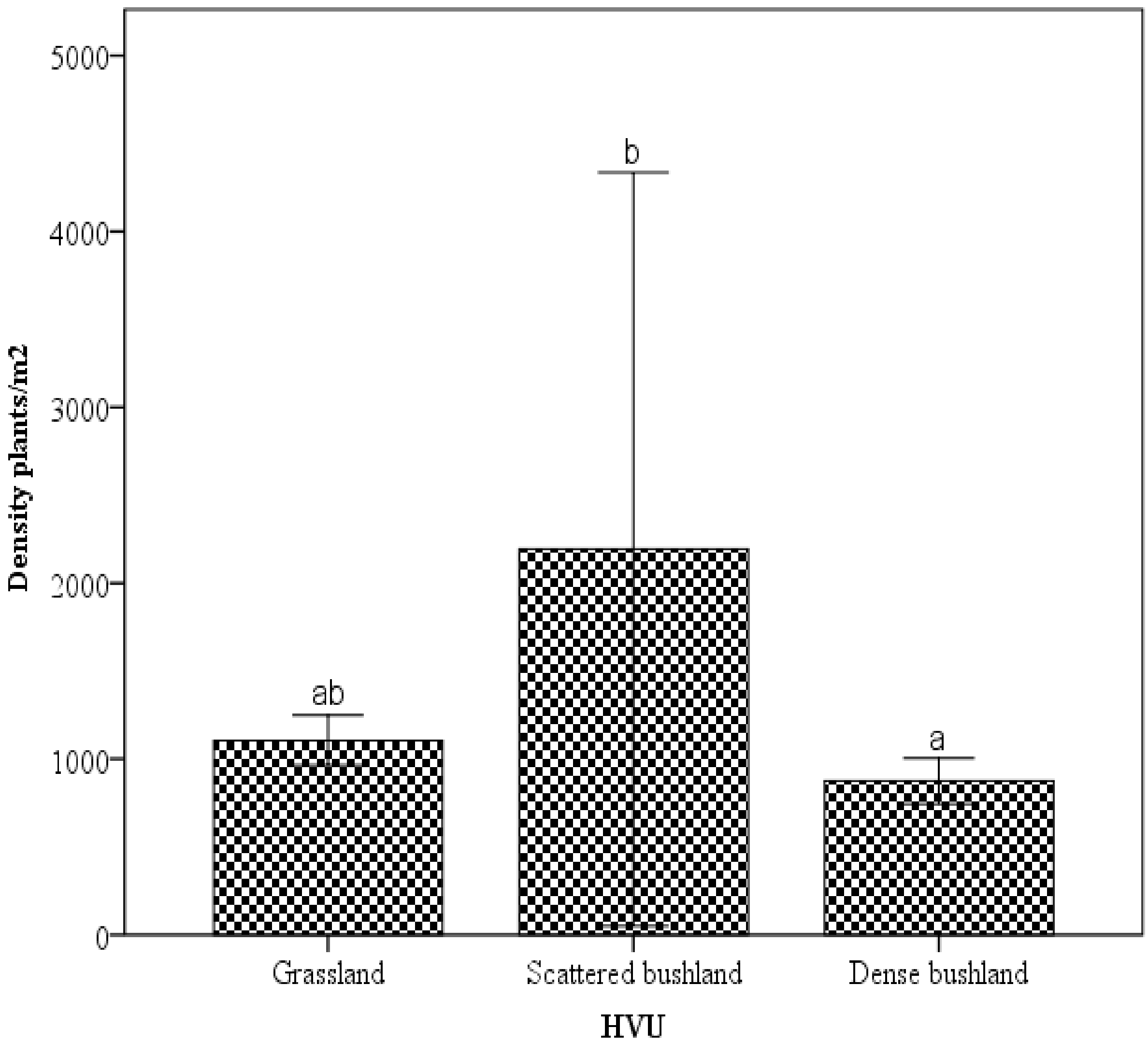

Figure 6.4.4: Effects of homogenous vegetation units on plant density in Peddie rangeland. Different superscripts denote significant differences ($p<0.05$) on plant density between grassland.

6.5 Discussion

6.5.1 Soil seed bank composition in three homogenous vegetation units of Peddie rangeland.

The soil seed bank composition in this study comprised of several graminoids such as sedges and grasses, some non graminoids (forbs) and karoo *species* in different abundances (Table 6.4.1). In the case of Peddie rangeland two factors, namely grazing and bush density levels were primary factors of consideration that were speculated to impact below and above ground composition. This emanated from the fact that every parameter was evaluated in association with homogenous vegetation units (Grassland and bushlands).

All homogenous vegetation units of Peddie rangeland in soil seed bank composition displayed high abundances of forb species followed by sedges and grasses (Figure 6.4.3). *Conyza albida* and *Cyperus adoratus* were species which were more abundant in all homogenous vegetation units of Peddie rangeland. This provided a clear picture that in years ago the rangeland of Peddie experienced the traumatic impacts of high grazing pressure as highlighted by (Bakoglu *et al.*, 2009; Solomon *et al.*, 2006). These results were in accordance with those reported by Kinucan and Smeins (1992) and Tessema *et al*., (2012) who reported that substitution of perennial grasses by annual forbs in soil seed bank is associated with heavy grazing. This stemmed from the fact that when grasses are heavily grazed, forbs are ignored thereby their seed production state is undisturbed (Koc *et al.*, 2013). However, some studies have confirmed that forbs form a bulk (30% - 60%) of sheep diet (O'cconor *et al.*, 2011) but in case of Peddie rangeland, *Plantago lanceolata* (3.1%) was the only palatable forb species recorded.

A plenty of studies have emphasised that soil seed bank act as a buffer during post-disturbance and it restores species poor rangelands (Snyman, 2004). Solomon *et al*., (2011) reported that soil seed bank must be considered for restoration when grasses form a bulk in soil seed bank. In contrast to other studies, there was no evidence that bush encroachment favours high prevalence of forbs as there was no statistical difference of forbs abundances between grassland and bushlands of Peddie. This was evident in both above vegetation (Figure 6.1) and soil seed bank composition (Figure 6.4.3). According to Bakker and Van Diggelen (2006), bush encroachment reduces seed production due to reduced light which in turn reduces flowering of herbaceous plants.

6.5.2 Comparison of vegetation and soil seed bank composition of Peddie rangeland.

The results of this study have revealed a variation between above and soil seed bank composition with Sorensen's index of 33% while grassland comprised 11%, scattered and dense bushlands comprised 26% respectively. The poor resemblance between above vegetation and soil seed bank was also reported by (Lemenih and Teketay, 2006; Solomon *et al.*, 2006). This emanated from the notion that perennial grasses were more prevalent in above ground composition compared to below ground where annual and biennial forbs plus sedges dominated (Figure 7.5). This variation was not only species-based but also the abundances varied. For example, the observed grass species in the soil seed bank were of low abundances while *Themeda triandra, Cynodon dactylon* and *Hyperrhenia hirta* were completely absent from the soil seed bank. Continuous grazing prior to or even at reproductive stage should have resulted in low seed input of these species in the soil seed bank as stated by Snyman (2013) and Koc *et al*., (2013).

The seed size is another pivotal trait of consideration because the seeds of perennials are very small, transient and are poor contributors in soil seed bank (Graham and Hutchings, 1988). The annual plants are well-known as great seed producers with their seeds being long persistent in soil reserves than perennials (Koc *et al.*, 2013). On perspective of seed longevity, *T. Triandra* yields the seeds of annual lifespan (O'Conor, 1997). This elucidated that if unfavourable conditions prevail resulting in failed germination of seeds of a particular year followed by high grazing stress; *T. triandra* cannot contribute to future seed banks and restoration. Except direct seed consumption, perennial grasses use vegetative propagation more than sexual reproduction (Snyman, 2013; Bakoglu *et al.*, 2009; Tessema *et al*, 2012; Chapano *et al.*, 2012). Annual plants are discovered to be dominant over perennials. However, Tessema *et al*., (2012) discovered similarities in soil seed bank and extant vegetation of a lightly grazed rangeland.

6.5.3 Plant density in soil seed banks of three homogenous vegetation units (Grassland, scattered and dense bushlands) of Peddie rangeland.

Soil seed bank density of scattered bushlands of Peddie rangeland was significantly higher than grassland and dense bushlands. There are scant informative studies to justify the large germination occurrence in scattered bushlands versus pure grasslands and dense bushlands. The seedling densities of Peddie bushlands (Figure 7.2) were far less than those cited by

Solomon *et al*., (2006) e.g. scattered bushland of Peddie (2193 plants m^{-2}) versus Australian open woodland (13350 seedlings m^{-2}). Dense bushland of Peddie had lower density (874 plants m^{-2}) compared to 13207 seedlings m^{-2} of Australian woodland. However, grassland of Peddie rangeland tended to have higher seedling density (1102 seedlings m^{-2}) compared to some South African grasslands (e.g. Adams, 1996).There are rare if any studies that provided soil seed bank standards that can be used as reference to conclude that a particular plant density is realistic for restoration purposes. There is a close relationship between the soil seed bank composition and density (Bakoglu *et al.*, 2009). The higher the percentage of forbs, the higher is their contribution to plant density. Seed bank density is largely affected by physiographic factors of the study area and grazing (Bakoglu *et al.*, 2009). There is a concurrent diminish of dispersed seeds as grazing intensity increases (Drebber *et al.*, 2011).

6.6 Conclusions

The study has indicated that plant density tended to be higher in scattered bushland than grassland and dense bushland. The soil seed bank was characterised by poor seed bank with forbs and sedges being the dominant plants in the soil seed bank of the grassland, scattered and dense bushlands. The results also showed that standing vegetation was dominated by perennial grasses while they were absent in soil seed bank. This implied that the reliance on soil seed bank for restoration and livestock production purposes would not be advisable in Peddie rangeland. We speculated that the dominance of forbs and sedges can result in poor restoration of Peddie rangeland. Therefore, it is recommended that restoration of Peddie rangeland should focus on relaxation of grazing or reseeding.

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CHAPTER 7 GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

7.1 General discussion

The rangeland of Peddie displayed signs of degradation that were revealed by the transition from grassland to bushlands. These signs include pronounced bush encroachment beyond a critical level in bushland, reduction in biomass production and shift in herbaceous composition. These shifts followed the shift in vegetation physiognomy with highly palatable *T. triandra* declining from grassland to dense bushland of Peddie. The shifts in vegetation were reported by farmers as the events that took place over two decades ago (farmer's perception). However, some grazing tolerant species e.g. *C. dactylon* and *E. plana* withstood the progression of bush encroachment in Peddie rangeland.

The most encroaching species at Peddie was *Acacia karoo* beyond 70% which is also reported by Friedel (1987) and Aucamp (1976) as a catastrophe in Transvaal and Eastern Cape region at large. An acute increase of *A. Karoo* was also noticed by respondents in this study and that of Moyo *et al.,* (2013). The increase of *A. karoo* species has consequencies of reduction in biomass production (Dube *et al.,* 2009) and accessibility of herbaceous vegetation whilst their browse material is also less accessible to browsers (Moleele *et al.,* 2002). The browse material of these species becomes less accessible due to chemical and physical deterrents (Moleele *et al.*, 2002). The defence mechanisms of young *A. karoo* are very high compared to older ones (Teague, 1989). Although bush encroachment was revealed to be a major problem in Peddie rangeland, some communal farmers considered it as no problem (farmer's perception). This was underpinned by their farming system as farming with small stock browsers (goats) led them to reject negative impacts brought about by bush encroachment on herbaceous vegetation. The similar findings were reported by Kadjua and Ward (2008) in Namibia.

Although the effects of high bush density were observed in dense bushland, its impact on biomass production was still at an acceptable state for protection against degradation because biomass production was greater than 800kg ha^{-1} which was recommended by Teague *et al*., (2009). However, for livestock production perspective, biomass production was far less than the recommended threshold (1500 kg ha^{-1}) by Teague *et al*., (2009). This indicated that

further steps pertinent to woody encroachment control are strictly required in Peddie rangeland.
The historical grazing system and practices which involve heavy grazing and fire suppression, and episodic rainfall events are highly recognised as the driving forces of the rangeland dynamics (Angasa, 2005; Ward, 2005). Moreover, the repeated removal of grasses through heavy grazing in Peddie rangeland should have diminished the competitive ability of grasses against woody plants hence the fire frequencies are prolonged and intensities become not effective to halt bush encroachment. Furthermore, the replacement of perennial and palatable plants by ephemeral and unpalatable plants negatively affect grazing carrying capacity.

This in turn possesses negative implications on the livestock production in communal tenure system. Despite the anthropogenic forces, the high variable rainfalls and drought events were perceived as other contributors to rangeland deterioration in Peddie rangeland. This was supported by Angasa (2005) who stated that episodic rainfall events may interplay with anthropogenic factors such as severe grazing and fire to increase bush density. The key informants were consistent that during the outbreaks of drought, bushes were resistant to severe effects of drought while herbaceous vegetation suffered. These findings suggest that there is an agreement between farmer's perceptions and scientific findings, the differences were only on the perception of rangeland condition which composed of two different perceptions.
As stated by Solomon (2011) and Snyman (2004), heavy grazing in communal areas exerts negative impacts through repeated consumption of plant seeds thereby reducing the seed number of grazed plants. The soil seed bank of Peddie rangeland was dominated by annual forbs that recieve less effect of grazing. This therefore, provided the limitations on reliance on seed bank recruitment for range restoration in Peddie rangeland. The assumption was that, consideration of forb plus sedge dominated seed bank can result to retrogression in Peddie rangeland. The reliance on soil seed bank for restoration is more significant where grasses predominate (Solomon, 2011). Generally, the soil seed bank density of grassland of Peddie was fairly good compared to other grasslands of South Africa (Adams, 1996).

Although bush encroachment was revealed as a great problem, some positive impacts on soil chemical composition were noticed. Many soil nutrients and pH despite organic carbon were significantly higher in dense bushland owing to the contribution of leaf litter from abcision.

This was an indication that tree leaf fall is a significant factor contributing to soil nutrient enrichment. However, in grasslands the nutrient cycle is dependent on decomposition of dead herbaceous vegetation.

7. 2 Conclusion

There were negative shifts in species composition, biomass production and pronounced bush encroachment. There was a decline of *Themeda triandra* with an increase of *Cynodon dactylon* and *Eragrostis plana* from grassland to dense bushland. The communal farmers at Peddie had an idea of vegetation and livestock dynamics. They indicated that in previous decades, the Peddie rangeland was the grassland and bush encroachment increased overtime. Famers perceived that the most encroaching species was *Acacia karoo*. However, soil pH and nutrients except organic carbon were higher in dense bushland which indicated that trees contribute higher amounts in soil fertility than grasses. The soil seed bank of Peddie rangeland was characterised by dominance of forbs and sedges which also underpinned that restoration through recruitment from seed bank cannot be effective in Peddie rangeland. The perceptions in rangeland condition were different, 39% of farmers (mostly goat farmers) elucidated that the rangeland with high bush density is in good condition while 40% (mostly cattle farmers) indicated that it is in poor condition. Goat farmers were consistent that high bush density is the source of their goats while cattle farmers said high bush density reduces biomass production and accessibility. This therefore, indicated that when rangeland monitoring is conducted in communal tenure system, it is essential to know the production system of the area in question. This can be achieved by incorporating the social and scientific approach of rangeland monitoring.

7. 3 Recommendations

Due to common pool resource ownership of Peddie communal rangeland, it is recommended that communal farmers formulate the rules and regulations to manage resource use such as vegetation utilisation and harvesting. In this regard, it is recommended that a chairman with the community committee should be in authority to govern the vegetation harvesters and herd owners. These rules and regulations should be based on management of livestock movements, seasons of collection and amount of vegetation to be collected for household use. For abatement of bush encroachment which seems to be a farmer's threat in Peddie communal rangeland, it is recommended that wood harvesting should be conducted seasonally (winter and summer only) when most of residents require great loads of woods. This harvesting should target the most encroaching species and monitoring of harvesters by man in authority is vital to abate overexploitation of vegetation resource. In case of amount to be collected, an empirical field data will be needed to count the percentages and types of trees that can be harvested for household use and that can be left as a remainder for browsing. All goats of the community must be directed to the rangeland to ensure efficient consumption of woody species inorder to maintain the dominance of herbaceous stratum above woody stratum.

In grazing management point of view, in understanding that communal farmers are resource poor it will depend on governmental assistance such as service delivery of equipment for rangeland demarcation into camps and building of water points which will allow ease application of rotational grazing, a uniform animal distribution and camp resting systems. For now, it is recommended that farmers rely on their indigenous movement of their herds as to counteract overgrazing of same habitats. Lastly, it is recommended that introduction of herds to water point must be sequential such as allocation of herds into a number of groups and introduction must be in a drink and go system to eliminate degradation around water point.

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APPENDICES

Appendix A: Questionnaires

Evaluation of range condition, soil seed bank and farmer's perceptions in Pedi communal rangeland, Eastern Cape

The objective is to evaluate the communal people on their indigenous knowledge and perceptions about the range condition and management practices applied in the Pedi communal rangeland
Enumerator's name…………………………Date…………………………Village…………..
Name of respondent…………………………………..Questionnaire reference number………

A.HOUSEHOLD DEMOGRAPHY

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

Codes:
Relation to head: **1** Head, **2** Spouse /husband, **3** Child, **4** Grandchild, **5** Father or mother,
Marital status**:** (**S**) single (**M**) married (**D**) divorced or separate **(W) w**idow
Education: **1** Preschool **2** Up to std 5, **3** Std 6-9 **4** Std 10 **5** Tertiary

6 None
Status: (**F**) farming (**H**) household wife, (**E**) employee (**P**) pensioner (**B**) business
(**N**) No occupation (**S**) student
A.2. Household size…………… Adults …………… Children (less than 13 years)……..
A.3. Sex of head of household…………………………………………………………..
A.4.1. Do you belong to any farmers' organisation? Yes or no
A.4.2.If yes, which one...

A.4.3. If no, what are your reasons...

B. Livestock population

Livestock type	Livestock population Age				
Cow					Total
	Age				
Sheep					
	Age				
Goat					
	Age				

Other (specify)					

E.13. has the livestock population in the area

E.13.1.Declined, increased or not changed in the past 20 years…………………………

E.13.2. Declined, increased or unchanged in the past 10 years ………………………….

E.13.3.Declined, increased or unchanged compared in the past 5 years……………………………

E.13.4.What is the reasons (rank 1 as most important reasons for declining)

Reasons	**Rank**
Low forage quality	
Low forage yield	
Recurrent drought	
High bushes	
Soil degradation	
Crop farming	

B.3.Crop farming

B.3.1. what do you farm (from most important to least important?)

Crop type	Area
1)	
2)	
3)	
4)	

B.3.2. Choose (A-C), size of crop area (decreased, increased, not changed) after

a) 25 years ago
b) 15 years ago
c) 5 years ago

B.3.3.If there is change in size, what are the reasons (in order of importance)

Reasons
1)
2)
3)

B.4.Do you feed crop residues to livestock?

Crop	Livestock(cattle=1,goat=2,sheep=3)	When (months)
1)		
2)		
3)		
4)		

B.5.1Do you have cultivated pasture?

B.5.2.If yes, name the species……………………………………………………………...

B.6.1.Do you have protected natural grazing land? Yes or no

B.6.2. what is the size of the area

B.6.3. is it for common to the villagers? Or private?

B.6.4.The protected area is used all over the year or when there is drought or in winter, spring, summer, autumn and for grazing

…………………………………………………………………………………………………

C. Rangelands / Grazing

C.1. Do you have access to rangeland? Yes ☐

No ☐

C.2. how did you obtain access?

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

C.3.At what time of the year would you experience a shortage in grazing? (Winter, summer, autumn, spring)-specify the month

…………………………………………………………………………………………………..

C.4.What could be the cause of such a shortage?

....

C.5. Who monitors that users of the grazing land adhere to rules and regulations?

....

C.6. Rangeland is access for? (In order of importance: 1-most important 6-least important)

Uses	Yes/No	Season of access(summer, winter, year round)
Grazing/browsing of animals		
Collecting fire wood		
Collecting wood and grass for building and Fencing		
Collecting plants for medicinal purposes		
Collecting dry dung for cooking		
Other (specify) ………………………………………………		

C.7.1. Are there times of restricted access to rangelands? Yes ☐

No ☐

C.7.2.If Yes, Which month/s………………………………………..

C.8.1. Does your community have grazing camps? Yes ☐

No ☐

C.8.2. If yes, what is the purpose of camps? (Give answer in order of importance)

…………………………………………………………………………………………………

C.9. Do you manage livestock movement during grazing?

a) Permanently (daily) YES / NO if yes, who?...
b) Monthly YES / NO if yes, who?..
c) In Summer YES / NO if yes, who?..
d) In Winter YES / NO if yes, who?.......................................
e) When rain comes? YES / NO if yes, who?......................................
f) Free ranging? YES / NO if yes, who?......................................

Key informants (12 Elders) should answer the following

C.10. Do you classify land scape for grazing/browsing (yes or no)?
C.11.1. How many landscape do you have in your village rangelands
C.11.2. what are the criteria for classification? (Soil, topography, etc)
C.12. Do you assess the range condition?
C.13. what criteria do you take into account (in order of importance)

Criteria	Tick
Grass (what aspect of grass-yield, quality? Etc)	
Soil (erosion, Compaction, colour, texture etc)	
Bush (density, cover, species distribution etc)	

C.14. how would you describe the condition of the rangeland?

	Description
Deteriorating- Very Poor	
Deteriorating -Poor Condition,	
Fair	
Good	
Very Good	
I don't know	

C.15.1. what has led to the current state of rangelands?

	Tick	Rank
Grazing(overgrazing or under-grazing or optimum grazing)		
Burning (presence or absence)		
Soil Depth		
Rainfall (constant, variable or recurrent drought)		
Woody plants (bush encroachment)		
Human population (increase, decrease or unchanged)		
Topography (slopy, plain or mountainous)		
Development of water points, kraals/dip-tanks		

C.15.2. what are the reasons for your answer above?
....

C.16.1.Doyou consider your soil? Good ☐
Fair ☐
Poor ☐
Very poor ☐

C.16.2. What is the reason for your answer above?..

C. 17.What control measures need to be put in place to ensure a sustainable utilization of grazing resources?

....

C.18. what problems or constraints do you face in management of grazing areas?

……………………………………………………………………………………………………

……………………………………………………………………………………….

C.19.1.Do you use arable land for grazing purpose? Yes or No

C.19.2. If yes, when and why?

when……………………………..why………………………………………………………..................

....

E.11. Do you perceive vegetation change in the grazing area?

E.11.1.Compared to 25 years ago………………………………………………………………

E.11.2.Compared to 10 years ago………………………………………………………………

E.11.3.Compared to 5 years ago……………………………………………………………..

E.12.What is the factors that induce vegetation change? (Rank 1 as the most important cause of the change)

Factors	Rank
Grazing	
Human settlement	
Drought	
Bush encroachment	
Crop farming	
Land alienation	
Water, diptank, kraals development	
Change in land use	
Other (specify)	

Any other comments

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University of Fort Hare
Together in Excellence

Questionnaire to evaluate farmer's demographics and perceptions on Pedi communal rangelands of the Eastern Cape, South Africa.

Objective: To interview farmers on their indigenous knowledge and perceptions about the range condition and management practices applied in the Pedi communal rangelands.

Enumerator's name …………………………………………………
Date……………………………
Respondent's name ……………………………………………… Designation: Household/Elder (Tick)

A.HOUSEHOLD DEMOGRAPHY

	Relation to head	Age	Gender	Marital status	Education	Occupation
A1						
A2						
A3						
A4						
A5						

A1.Relation to head: **1** Head ; **2** Spouse, **3** Child, **4** Grandchild, **5** Parent, **6**. Other
Education: **1** Primary **2** Secondary **3** Tertiary **4** None
Occupation: (**F**) farming (**H**) household wife, **(E**) employee (**P**) pensioner (**B**) business (**N**) Unemployed (**S**) student
A2. Household size: …………… Adults …………… Children (0-21 years)…………
A3. Do you belong to any farmers' organisation? **Yes** or **No**
A.4 If yes, which one...
A.5 If no, what are your reasons...

B. LIVESTOCK POPULATION

Livestock type	Livestock Size (numbers)				
	Bulls	**Adult males**	**Adult females**	**Calves**	**Total**
Cattle					
Sheep					
Goats					
Other s (specify)					

B.2. Has the livestock population in the area:
B.2.1.Declined, increased or not changed compared to 20 years ago……………………………..
B.2.3.Declined, increased or unchanged compared to 10 years ago……………………………
B.2.4.If declined, What are the reasons (rank 1 as most important reasons for declining)

Reasons	**Rank**
Low forage quality	
Low forage yield	
Recurrent drought	
High bushes	
Soil degradation	
Crop farming	

B.3.Do you feed crop residues to livestock during times of forage scarcity?

Yes
No

If **yes**, which type
…………………………………….........................
B.41.Do you have protected natural grazing land? **Yes or No**
B.5 If yes, is it the communal or private?
…………………………………………………………………
B.6 When is the protected area used for grazing? (during drought/winter/spring/summer/autumn)
………………………………………………………………………………………………

C. RANGELANDS
C.1. Do you have access to rangeland? Yes or ☐ No
C.2. How did you obtain access? (Tick)

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

C.3. At what time of the year would you experience a shortage in grazing? (Winter, summer, autumn, spring)-specify the month
……
………………………………………………
C.4. What could be the cause of such a shortage?
....
C.5. Who monitors that users of the grazing land adhere to rules and regulations?
....

C.6. Rangeland is access for? (In order of importance: 1-most important 6-least important)

Uses	Yes/No	Season of access(summer, winter, year round)
Grazing/browsing of animals		
Collecting fire wood		
Collecting wood and grass for building and Fencing		
Collecting plants for medicinal purposes		
Collecting dry dung for cooking		
Other (specify)		

C.7.1. Are there times of restricted access to rangelands? Yes or ☐

No ☐

C.7.2.If Yes, Which month/s………………………………………...........................

C.8.1. Does your community have grazing camps? Yes ☐

No ☐

C.8.2. If yes, what is the purpose of camps?

……

……………………………………………..

C.9. Do you manage livestock movement during grazing?

a) Permanently (daily) YES / NO if yes, who?..

b) Monthly YES / NO if yes, who?..

c) In Summer YES / NO if yes, who?..

d) In Winter YES / NO if yes, who?..

e) When rain comes? YES / NO if yes, who?.......................................

f) Free ranging? YES / NO if yes, who?.......................................

Appendix B: Herbaceous and woody vegetation

Eragrostis plana

Source	DF	Type III SS	Mean Square	F Value	Pr > F
HVU	2	410.2357955	205.1178977	10.90	0.0010
Season	1	1.0010417	1.0010417	0.05	0.8205
HVU*Season	2	41.6638258	20.8319129	1.11	0.3546

Themeda triandra

Source	DF	Type III SS	Mean Square	F Value	Pr > F
HVU	2	1972.281016	986.140508	7.62	0.0073
Season	1	312.000000	312.000000	2.41	0.1465
HVU*Season	2	563.097160	281.548580	2.18	0.1563

Cynodon dactylon

Source	DF	Type I SS	Mean Square	F Value	Pr > F
HVU	2	736.2625000	368.1312500	2.85	0.0918
Season	1	9.1125000	9.1125000	0.07	0.7946
HVU*Season	2	4.0125000	2.0062500	0.02	
0.9846					

Cymbopon excavates

Source	DF	Type III SS	Mean Square	F Value	Pr > F
HVU	2	204.2361111	102.1180556	2.13	0.1615
Season	1	1.0208333	1.0208333	0.02	0.8864
HVU*Season	2	39.2361111	19.6180556	0.41	0.6731

Sporobolus africanus

Source	DF	Type III SS	Mean Square	F Value	Pr > F
HVU	2	88.14102564	44.07051282	2.73	0.0973
Season	1	28.34185606	28.34185606	1.76	0.2048
HVU*Season	2	14.47756410	7.23878205	0.45	0.6467

Hyperrhenia hirta

Source	DF	Type III SS	Mean Square	F Value	Pr > F
HVU	2	88.14102564	44.07051282	2.73	0.0973
Season	1	28.34185606	28.34185606	1.76	0.2048
HVU*Season	2	14.47756410	7.23878205	0.45	0.6467

Forbs

Source	DF	Type III SS	Mean Square	F Value	Pr > F
HVU	2	88.14102564	44.07051282	2.73	0.0973
Season	1	28.34185606	28.34185606	1.76	0.2048
HVU*Season	2	14.47756410	7.23878205	0.45	0.6467

Biomass production

Source	DF	Type III SS	Mean Square	F Value	Pr > F
HVU	2	4473462.480	2236731.240	11.60	0.0006
SEASON	1	2477023.829	2477023.829	12.85	0.0021
HVU*SEASON	2	2442261.745	1221130.873	6.33	0.0083

Point-tuft distance

Source	DF	Type III SS	Mean Square	F Value	Pr > F
HVU	2	1.84683958	0.92341979	7.94	0.0034
SEASON	1	1.68540000	1.68540000	14.49	0.0013
HVU*SEASON	2	0.00893125	0.00446562	0.04	0.9624

Acacia karoo

Source	DF	Type III SS	Mean Square	F Value	Pr > F
HVU	1	217.5625000	217.5625000	1.66	0.2206
SEASON	1	0.5625000	0.5625000	0.00	0.9488

Coddia rudis

Source	DF	Type III SS	Mean Square	F Value	Pr > F
HVU	1	5.04166667	5.04166667	0.51	0.5082
SEASON	1	0.12500000	0.12500000	0.01	0.9151

Lippia javanica

Source	DF	Type III SS	Mean Square	F Value	Pr > F
HVU	1	5.04166667	5.04166667	0.51	0.5082
SEASON	1	0.12500000	0.12500000	0.01	0.9151

Diospyros scabrida

Source	DF	Type III SS	Mean Square	F Value	Pr > F
HVU	1	5.04166667	5.04166667	0.51	0.5082
SEASON	1	0.12500000	0.12500000	0.01	0.9151

Appendix C: Soil nutrients

Dependent Variable: pH

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	4.14033333	2.07016667	111.16	<.0001
Error	57	1.06150000	0.01862281		
Corrected Total	59	5.20183333			

Dependent Variable: Ca

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	34.35956333	17.17978167	24.08	<.0001
Error	57	40.66613500	0.71344096		
Corrected Total	59	75.02569833			

Dependent Variable: Mg

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	0.33680333	0.16840167	0.73	0.4882
Error	57	13.21801500	0.23189500		
Corrected Total	59	13.55481833			

Dependent Variable: Na

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	152.10000	76.05000	0.34	0.7163

Error	57	12917.30000	226.61930		
Corrected Total	59	13069.40000			

Dependent Variable: K

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	60243.1000	30121.5500	26.48	<.0001
Error	57	64840.5500	1137.5535		
Corrected Total	59	125083.6500			

Dependent Variable: P

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	2046.10000	1023.05000	5.53	0.0064
Error	57	10547.15000	185.03772		
Corrected Total	59	12593.25000			

Dependent Variable: Cu

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	3.18790333	1.59395167	17.12	<.0001
Error	57	5.30729000	0.09311035		
Corrected Total	59	8.49519333			

Dependent Variable: Zn

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	31.6766800	15.8383400	6.74	0.0024
Error	57	133.9568800	2.3501207		
Corrected Total	59	165.6335600			

Dependent Variable: Mn

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	149663.8429	74831.9215	69.50	<.0001
Error	57	61376.0633	1076.7730		
Corrected Total	59	211039.9062			

Dependent Variable: C

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	0.21222333	0.10611167	0.49	0.6166
Error	57	12.40425000	0.21761842		

Corrected Total	59	12.61647333			

Dependent Variable: N

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	0.00644333	0.00322167	2.92	0.0622
Error	57	0.06295000	0.00110439		
Corrected Total	59	0.06939333			

Appendix D: Soil seed bank

Dependent Variable: *Cyperus adoratus*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	676.931667	338.465833	3.19	0.0896
Error	9	954.617500	106.068611		
Corrected Total	11	1631.549167			

Dependent Variable: *Centella asiatica*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	345.6266667	172.8133333	8.60	0.0082
Error	9	180.8200000	20.0911111		
Corrected Total	11	526.4466667			

Dependent Variable: *Plantago lanceolata*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	1.68166667	0.84083333	0.36	0.7082
Error	9	21.10500000	2.34500000		
Corrected Total	11	22.78666667			

Dependent Variable: *Conyza albida*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	823.226667	411.613333	5.11	0.0330
Error	9	725.662500	80.629167		
Corrected Total	11	1548.889167			

Dependent Variable: *Ficinia nigrescens*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	49.0116667	24.5058333	1.05	0.3904
Error	9	210.8550000	23.4283333		
Corrected Total	11	259.8666667			

Dependent Variable: *Sporobolus africanus*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	378.906667	189.453333	2.31	0.1547
Error	9	737.330000	81.925556		
Corrected Total	11	1116.236667			