The impact of land degradation on landscape function in Mount Fletcher, Eastern Cape

by

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PREFACE

The research contained in this thesis was completed by the candidate while based in the Discipline of Environmental Science, School of Agricultural, Earth and Environmental Sciences of the College of Agriculture, Engineering and Science, University of KwaZulu-Natal, Pietermaritzburg campus, South Africa. The research was financially supported by National Research foundation and Sigwela and Associates Environmental Consultants.

The contents of this work have not been submitted in any form to another university and, except where the work of others is acknowledged in the text, the results reported are due to investigations by the candidate.

Signed:

Date:

DECLARATION 1: PLAGIARISM

I, Nandipha G. Ndamane, declare that:

(i) the research reported in this dissertation, except where otherwise indicated or acknowledged, is my original work;

(ii) this dissertation has not been submitted in full or in part for any degree or examination to any other university;

(iii) this dissertation does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons;

(iv) this dissertation does not contain other persons' writing, unless specifically acknowledged as being sourced from other researchers. Where other written sources have been quoted, then:

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b) where their exact words have been used, their writing has been placed inside quotation marks, and referenced;

(v) where I have used material for which publications followed, I have indicated in detail my role in the work;

(vi) this dissertation is primarily a collection of material, prepared by myself, published as journal articles or presented as a poster and oral presentations at conferences. In some cases, additional material has been included;

(vii) this dissertation does not contain text, graphics or tables copied and pasted from the Internet, unless specifically acknowledged, and the source being detailed in the dissertation and in the References sections.

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DECLARATION 2: PUBLICATIONS

My role in each paper and presentation is indicated. The * indicates corresponding author.

Publication 1: Ndamane, N.G.*, Rouget, M., Renteria, J. and Sigwela, A. Assessing the utility of landscape function analysis as a tool for evaluating the functional status of rangelands in Mount Fletcher, Eastern Cape. In preparation.

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Signed: Nandipha G. Ndamane

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ABSTRACT

The severity of natural vegetation degradation has become a serious challenge, causing negative impacts on the vegetation ecosystems, livestock population, and productivity, landscape organization and river systems. The research project focussed on the impact of land degradation on the landscape function and vegetation cover. The study was addressing two main aims. The first aim was to assess the landscape function analysis (LFA) method as a tool to determine the landscape functioning and differentiate the condition of the rangeland into various levels of degradation caused by over-grazing. The second aim was to determine the effects of excluding grazing herbivores using on ecosystem functioning.

Monitoring is an important part of the restoration process, it allows restoration practitioners to assess success and to adapt management strategies and restoration methods, so as to evaluate change in their restoration objectives. The landscape function analysis method was applied in this study. The LFA method is a field based technique that examines the landscape level of ecosystem function and determines the functional status of rangelands. The LFA consists landscape organization and soil surface assessment indices which reflect the ability of the landscape to capture and retain resources. Data were collected inside and outside of the exclosure plots to determine whether there were differences in some measured parameters (landscape organization index, total patch area, number of patches/10 m, average inter-patch length, stability, infiltration and nutrient cycling) between the non-grazed (exclosure) and continuously grazed area.

The vegetation cover from the exclosure plots was more improved as well as landscape functioning. These results demonstrated that grazing exclusion is an effective measure for maintaining the landscape functioning and improving above ground cover. The adoption of livestock exclusion practice had a profound impact on vegetation recovery and in turn on litter accumulation and improvement of soil fertility. The landscape organization indices and the soil surface assessment (SSA) indices played the most important roles in contributing to the knowledge of the landscape functioning. The study found that LFA method can be used as a tool to detect the landscape functioning and differentiate between intact and degraded areas.

Keywords: Exclosure plots, Landscape function analysis, Monitoring, Restoration.

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CHAPTER 1: INTRODUCTION

1.1 Background

Grasslands are highly dynamic ecosystems that provide goods and services to support flora, fauna, and human populations worldwide. South Africa’s grasslands are a remarkable and irreplaceable biodiversity asset of global significance (Zaloumis, 2013). The grassland biome is one of the most threatened biomes in South Africa, with 23% under cultivation, 60% irreversibly transformed and only 2% formally conserved (O’Connor and Kuyler, 2008). Grasslands are critically important water production landscapes and also provide the natural resources and ecological infrastructure that support most of South Africa’s important economic activities, and millions of rural livelihoods (Egoh et al., 2016). However, these very economic activities development threaten grasslands (Neke and Du Plessis, 2004).

Grasslands produce forage for livestock, which in turn support human livelihoods with meat, milk, wool, and leather products (White et al., 2000). Grasslands provide habitat for breeding, migrating, and overwintering birds and ideal conditions for many soil fauna, and rangelands for wild herbivores (White et al., 2000). These ecosystems cycle water and nutrients, and build and maintain stabilization mechanisms for soil (Sekercioglu, 2010). Grassland vegetation as well as the soil itself, serve as large storehouses for carbon, helping to limit global warming (Acharya et al., 2012; Jones and Donnelly, 2004). These large landscapes support recreational activities such as hunting, wildlife-watching, and tourism more generally, and offer aesthetic and spiritual gratification (Sharrock et al., 2015). Figure 1 shows the goods and services provided by grassland to humans.

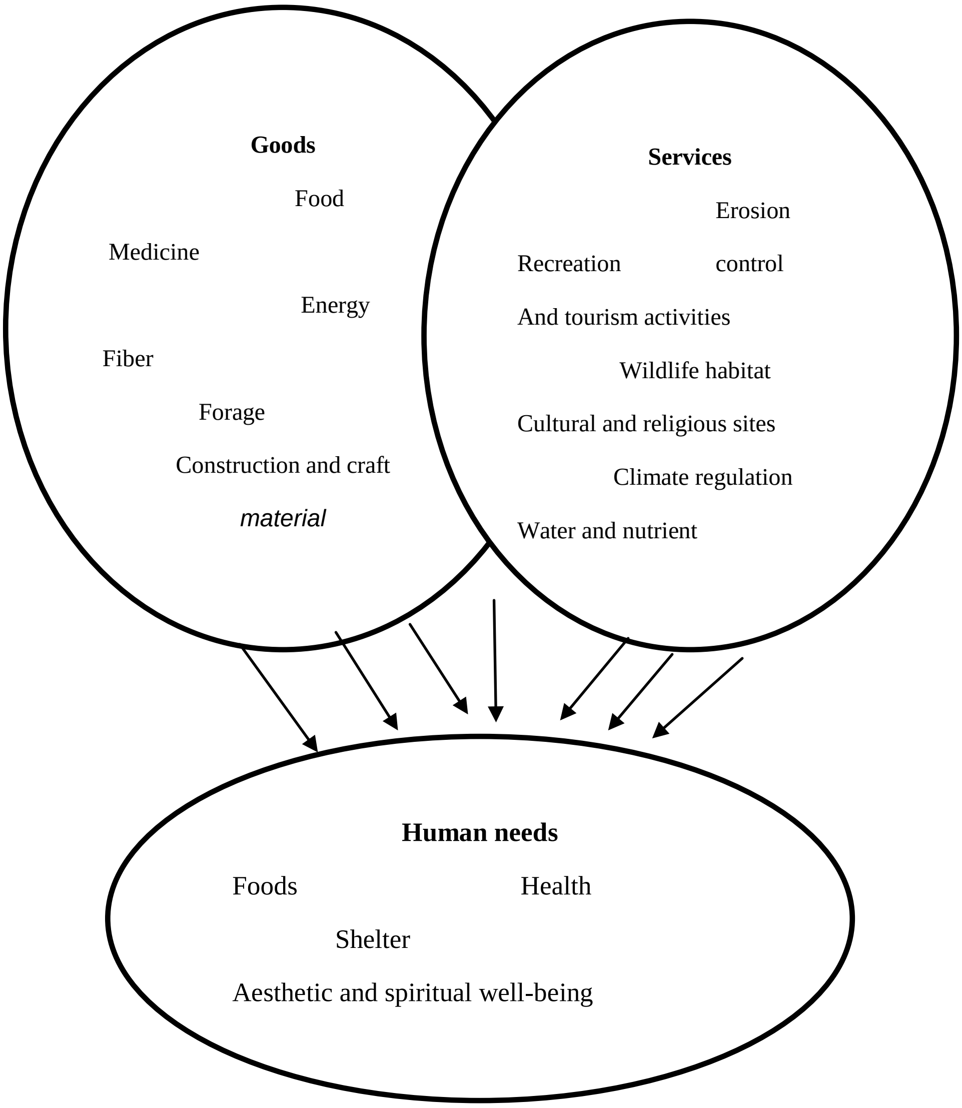

Figure 1.1: Goods and services provided by grasslands (White et al., 2000).

The conversion of natural ecosystems for cultivation, afforestation, grazing pastures and mining is one of the most significant causes of the decline in ecosystem health in South Africa (McNeely, 2010). Land-cover change results in the loss of natural habitat, with secondary consequences of degradation and fragmentation of remaining habitats, all of which result in losses of biodiversity, declines in ecosystem health and changes in the provision of ecosystem services (Petz et al., 2014). The stressed ecosystem is characterized by a “distress syndrome” that is indicated not only by reduced biodiversity and altered primary and secondary productivity but also increase disease prevalence, reduced efficiency of nutrient cycling, increase the dominance of exotic species and increase dominance by smaller, shorter-lived opportunistic species (Ludwig et al., 1999).

Degradation of grassland due to overgrazing and poor land use threatens biodiversity and ecosystem services (Egoh et al., 2009). The functionality of these grasslands are affected by bad management practices such as overgrazing and inappropriate burning regimes (Turpie, 2003). To prevent continuing degradation on these rangelands, it is essential to conduct restoration operations to improve the vegetation, and stabilize the soil surface to reduce water runoff, erosion and improve ecosystem function. If the vegetation cover of the area is improved through restoring the degraded vegetation, the grazing quality for livestock will be enhanced, winter flows of rivers will be improved as well as biodiversity.

Given currently high rates of species extinction and potential loss of ecosystem goods and services, there is a clear need to understand the consequence of loss of biodiversity for the functioning of the ecosystems (O’Connor and Crowe, 2005). As a result of human actions, the structure, and functioning of the ecosystems is degraded, which in turn threatens food security and the maintenance of biodiversity (Corvalan et al., 2005). Many of the earth’s ecosystems are unhealthy, their functions, particularly those that are vital to sustaining the human community, have become impaired (Rapport et al., 1998). Grasses form the template on which communities and ecosystems are assembled and on which food webs are built (Maron and Crone, 2006). Consumers, as major constituents of most ecosystems and chronic agents of plant damage, have great potential to fundamentally alter plant abundance and distribution (Maron and Crone, 2006). Ecosystems will continue to degrade under the pressure of increased demands unless preventative and restorative strategies are applied to achieve the health and integrity of regional ecosystems (Rapport et al., 1998).

Many studies have focused on biodiversity and there are vast arrays of methods to do this, but there are considerably fewer studies on ecosystem functioning especially at the landscape scale. Kwok et al. (2011) point out that the landscape function analysis (LFA) method is an increasingly popular field based monitoring procedure that is used to assess the functional integrity of rangeland ecosystems worldwide. The procedure comprises a suite of measurements that quantify the spatial arrangement and characteristics of the resource patches in the landscape (Kwok et al., 2011; Maestre and Puche, 2009; van der Walt et al., 2012). These patches are comprised of grass tussocks, logs, shrubs, and tree hummocks that are known to capture resources such as seeds, water, nutrients and organic matter, and are the site of maximum resource retention, productivity and biotic diversity (Kwok et al., 2011). The LFA has been used in mined sites and degraded land rehabilitation in environments ranging from desert to the wet tropics (Tongway and Hindley, 2004). It can be used as a diagnostic tool to compare the status of one landscape to another or to provide evidence on the rate and trend of recovery occurring on a disturbed landscape and as influenced by management interventions (Tongway and Hindley, 2004).

The current study forms part of an ongoing rehabilitation monitoring program in watershed areas of uKhahlamba in Mount Fetcher, in the Eastern Cape Province, South Africa. The main aim of the rehabilitation program was to improve landscape functioning and the livelihood of the communities in the area. As was the case with all South Africans homelands, the economy of Mount Fletcher is dependent on migrant labour and subsistence farming (Prasad et al., 2011). With a high dependence on subsistence farming, uncontrolled stocking rates lead to an increase in the levels of overgrazing and soil erosion. The majority of soil erosion occurs within the rangelands of the area. The proposed watershed services project is intended to integrate the replenishment of natural capital stocks. These include, but not limited to, topsoil, vegetation and freshwater fauna. If the vegetation cover is improved, the grazing quality of livestock will be enhanced, river flows in which people depend on will be improved, and biodiversity and ecosystem services will increase.

The National Environmental Management Act (1998) highlights the rights to a protected environment for the benefits of the present and future generations, through promoting the protection, preservation and sustainable utilization of natural resources. The historical challenges of effective management on rangelands has had a negative impact on ecosystem functioning. The loss of vegetation cover has resulted in poor infiltration, increased run off and severe erosion. As utilization of the vegetation increases, primarily through domestic herbivore, so the mean size of vegetation patches decreases and the proportion of bare ground increases (Maron and Crone, 2006). This transformation represents homogenisation of the land surface, both at a patch and landscape scale (Martínez et al., 2010). The smaller patches are exposed to greater environmental fluctuation and dysfunctionality of soil resources, further reducing environmental heterogeneity (Stokes et al., 2009).

1.2 Justification

The primary land use in the research area is subsistence farming. The presence of vast mountainous grasslands provides the potential for livestock farming which provides investment opportunities to the farming community. The uncontrolled stocking rate has led to continued levels of overgrazing and degradation. This study forms part of a rehabilitation program aiming at reducing landscape degradation and improving landscape function. Rehabilitation is the process of repairing damaged ecosystems to create processes that contribute to ecosystem services, function and productivity (Haagner, 2008). The severity of natural vegetation degradation has become a serious challenge, posing the negative impacts on the vegetation ecosystems, the livestock population, and productivity, landscape organization and river systems. Land degradation is often characterized by a reduction in the total vegetation cover and the availability of palatable plant species, increased availability of undesirable and unpalatable plants as well as depletion of soil quality and nutrients (Dong et al., 2014).

In most instances, degradation is caused by the shortage or lack of alternative grazing land which put too much pressure on existing vegetation cover, therefore perennial grasses are consumed, trampled and decline, so the roots cannot enter deeper into the soil and adequate moisture is not available (Mofidi et al., 2013; Yong-Zhong et al., 2005). Biotic soil crust (cryptogam cover) which covers much of soil in native system, get trampled, churned up and decline (Yong-Zhong et al., 2005). The cryptogam cover (lichen and algae) consists of nitrogen fixers and soil stabilizers, and their presence also encourages retention and infiltration of water. Therefore, if the cryptogam cover declines, this lead to an increase in erosion and runoff of water, and a decrease in nitrogen input. Different management approaches have resulted in a negative impact on the landscape functioning.

Restoration is defined as the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed (Becker, 2013; de Abreu, 2011). One of the ways in minimizing land degradation is undertaking the restoration. The rate at which natural ecosystems are being destroyed has highlighted the importance and the need for restoration (Becker, 2013). Restoration offers an opportunity to improve ecosystem functionality, accelerating succession and restoring community structure.

Monitoring of restoration projects is critical as it can provide information as to whether action must be taken in order to keep the site on a successional and sustainable trajectory (Machmer and Steeger, 2002). Most restoration programs lack monitoring systems. Monitoring ecological restoration provides an opportunity to test ecological and restoration theories, and to consider the community context, contributing to adaptive management and maintenance protocols (Machmer and Steeger, 2002).

This study forms part of a restoration program aiming at reducing landscape degradation and improving landscape function. This study also contributes to our understanding of monitoring the success of restoration interventions. Fencing is one of the common ways of evaluating restoration success (Lechmere-Oertel, 2003). Exclosure plots were installed to study the ecosystem function comparing the degraded and intact area. The exclosure plots (fenced) represented the treatment and the continuously grazed area (not fenced) represented the control. The exclosure plots were installed by community members.

In some of the exclosure plots, both active and passive restoration were applied. Passive restoration usually costs less than active restoration (Benayas, 2005). Although passive restoration is usually cheaper, it can be slow in low productive ecosystems (Benayas, 2005). An additional benefit for active restoration is the creation of employment associated with ecosystem management in rural areas (Benayas, 2005). A disadvantage active restoration is that it can be expensive.

The LFA method was applied in this study. LFA is recommended for the assessment and monitoring of rehabilitation work (Tongway and Hindley, 2004). At the pre-rehabilitation stage, LFA allows the specific processes needing improvement to be identified (Randall, 2004). The LFA can be applied to sites of all sizes, from an individual patch to a hillside and all ecosystems types (Tongway and Hindley, 2004). LFA also offers an insights into how the landscape function at the rehabilitation site changes overtime, and facilitates numerical comparison of restored sites against reference sites (Haagner, 2008; Randall, 2004). The selection and use of analogue or reference sites are crucial to the effective use of LFA (Tongway and Hindley, 2004). Data from these sites provide both goal or target values for the LFA indices in rehabilitation and the landscape organization indices that represent a mature, highly functional landscape (Tongway and Hindley, 2004). An analogue site is one that has many of the attributes of the final rehabilitated landscape and is self-sustaining, particularly with respect to functioning and serves to provide a goal or target for rehabilitation (Randall, 2004).

The LFA methodology uses visually assessed indicators at a landscape scale or small patch scale to provide the information on how the landscapes function to conserve and utilize scarce resources (Tongway and Hindley, 2004). Landscape function indicators such as stability, infiltration and nutrient cycling are simple indicators of ecosystem can be evaluated easily (Rahimi et al., 2013). The analysis focuses directly on the transect line, where information on the soil and measurement of the resource accumulation patches, width and the length of inter-patches are taken (Ludwig et al., 2004; Rahimi et al., 2013). Patches show evidence of resource accumulation and enhance soil properties such as stability, infiltration and nutrient cycling (Tongway and Hindley, 2004). The inter-patch is characterized as the zone where resources are freely transported out of the landscape the basic example is bare soil (van der Walt et al., 2012). This study is envisaged to provide a better understanding of landscape functioning in the particular area. This information will be useful to the farming communities and government representative in monitoring grazing impacts.

1.3 Aims

The purpose of the study is to measure the impact of land degradation on vegetation and landscape functioning based on data and parameters that are easily measurable and to compare ecosystem functioning between exclosure plots and continuously grazed areas using the Landscape Function Analysis (LFA) method.

1.4 Objectives

1. To investigate the suitability of Landscape Function Analysis as a tool to monitor ecosystem functioning by comparing intact and degraded areas

2. To identify suitable indicators to monitor changes in ecosystem functioning of restored areas

3. To assess the recovery of exclosure plots in order to quantify restoration success following herbivore exclusion.

1.5 Outline of dissertation/thesis structure

Chapters contained include the introduction, a literature review, materials and methods, results and discussion, and conclusions. This structure is adopted to provide a comprehensive and logical understanding of the addressed objectives. The structure follows the outline below.

- Chapter 2: This chapter reviews the literature available on the landscape structure, heterogeneity and function. The review looks at issues of management which includes grazing, overgrazing, fire and alien plants. It also covers the types of techniques relevant for monitoring the ecosystem structure and function as well as landscape function analysis method.

- Chapter 3: focuses primarily on landscape function analysis method a tool to monitor ecosystem function by comparing the intact and degraded areas using the LFA indices.

- Chapter 4: assesses the restoration success of the exclusion of herbivores, the effects of continuous grazing and exclusion of livestock on ecosystem function were compared by measuring changes in vegetation cover over time.

- Chapter 5: is short conclusion summarizing the landscape function analysis method and the impact of herbivore exclusion in vegetation cover.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Ecosystems are assemblages of living organisms, the interactions between them and their physical environment (de Groot et al., 2010). Each ecosystem is characterised by its composition (i.e. the abiotic and biotic parts of which it is made), its structure (i.e. how the parts are arranged in time and space) and the ecological processes (i.e. functions such as nutrient cycling and water flows) that maintain the composition and structure and keep it functioning as a unit (Ford et al., 2012). Naturally functioning ecosystems provide a flow of essential services to human community (Rodríguez et al., 2006). Ecosystem services include healthy mountain catchments, rivers, wetlands, and nodes and corridors of natural grassland habitat which together form a network of interconnected structural elements within the landscape (Ford et al., 2012). If the ecosystem is degraded or lost, the flows of services will diminish and ecosystems will become vulnerable to shocks and disturbances, such as the impacts of climate change, unsustainable land use change and natural disasters (Spangenberg et al., 2014).

The landscape is defined as an area of land, at the scale of hectares to square kilometres, which consist of a collection of different, but interacting patches (Hobbs, 2002). The term "ecosystem function" is defined as the capacity of a landscape to provide goods and services, therefore these goods and services are the flows of benefits to society and depend upon both capacity of the landscape to supply these services and the demand from the society for the benefits they provide (Bolliger and Kienast, 2010; Wiggering et al., 2006). Rural landscapes have different functions, such as agricultural production and cultural functions, their space can be used for more purposes than just agricultural production alone (Wiggering et al., 2006). Wiggering et al., (2006) define multi-functionality of the landscape as ‘‘the phenomenon that the landscape actually or potentially provides multiple materials and immaterial ‘‘goods’’ to satisfy social needs or meet social demands’’.

Landscape ecology considers three main aspects of the landscape which include its structure (pattern), function and change (Hobbs, 2002). The three aspects of the landscape are closely interlinked, since structure strongly influences function, which can feedback into structure and landscape change can affect both structure and function (Hobbs, 2002). Any change in the landscape structure, either spatial or temporal, influences the pattern of energy and material flows in the landscape, affects landscape passability and habitability, and ecological stability (Stejskalová et al., 2013). This review focuses on the landscape structure differentiating the patch and inter-patch, their role in ecosystem functioning, I then discuss landscape heterogeneity looking at driving forces behind the heterogeneity. I then discuss landscape function looking at the integrity of landscape and landscape integrity indicators, issues of management towards ecosystem function which include grazing, overgrazing as well as fire and alien plants, then the summary of the techniques that can be used for monitoring ecosystem function, and a more detailed discussion on a landscape function analysis method.

2.2 Landscape Structure

The structure of a landscape is defined by the particular spatial pattern being represented, and it consists of two components: composition and configuration (Griffith et al., 2000). The composition of a landscape is defined by the spatial elements that can be distinguished on a map and are relevant to the landscape function under consideration (McGarigal and Marks, 1995). The composition represents the non-spatial aspect of a landscape since only number and abundance of landscape elements is considered, not their spatial configuration (Griffith et al., 2000). The configuration of a landscape is defined by the spatial character, arrangement and context of the elements (McGarigal and Marks, 1995; Griffith et al., 2000). Together these components define the spatial pattern or heterogeneity of the landscape (Griffith et al., 2000). Changes in the landscape structure, e.g. ploughing of grasslands, , substantial enlargement of fields, construction of roads (its causes landscape fragmentation and barrier effect) have an immediate influence on the movement of organisms in landscape and also on erosion processes, landscape retention capacity or water runoff regime (Stejskalová et al., 2013).

2.2.1 Patch and inter-patch structure

Patches can be a single plant, a group of plants, rock or any object that could keep the resources (Kwok et al., 2011; Ludwig et al., 1999; Sharp, 2011; Siroosi et al., 2012). Patch characteristics reflect the functional integrity or the health of a site (Kwok et al., 2011). Patches play an important role in determining the amount of runoff and sediment in a pasture especially in arid and semi-arid regions (Dowo et al., 2013). The structural features of ecological patches including size, number, and average inter-patch length are important because they are key factors in determining the movement of sediments and organic matter (Tongway and Hindley, 2004). Patches play a key role in ecosystem functioning because they trap and hold rain water and food (Milton, 2004). These obstructions increase the infiltration of runoff and the capture of nutrients in runoff sediment and in wind-blown soil and litter (Ludwig et al., 1999).

Inter-patches are characterized by biological or physical crusts with little or no vascular ground cover or litter, low water infiltration, and high erosion and sediment production; they are self-reinforcing, maintaining their existing condition (Sharp, 2011; Smith et al., 2013). The soil surface in inter-patches is smooth with high runoff, and with few or no microsites for seeds to lodge and germinate (Smith et al., 2013). Runoff removes plant propagules and litter, which depletes the seed bank and soil nutrient store (Smith et al., 2013). The seeds that remain in inter-patches have difficult germination and establishment due to the physical barrier of the soil crust (Smith et al., 2013). Inter-patches interspersed with vegetated patches are a natural feature of many arid and semi-arid ecosystems, but large areas of bare inter-patches indicate dysfunctional landscapes that do not retain water, nutrients and other resources (Ludwig et al., 1999).

Inter-patch allow the concentration of resources and surface run off in down slope patches, resulting in higher biomass production than if resources and surface runoff were spread uniformly across an area (Ludwig et al., 2005). Once inter-patch become too large or too contiguous, the net productivity of the system decreases (Good et al., 2013). Patches and inter-patches reflect the processes occurring within sites, and thus can be found in a range of terrestrial vegetation associations (forest, woodland, shrubland or grassland) and in drainage lines, whether dominated by native or introduced species, or in non-vegetated areas (including tracks, disturbed bare ground or rock dominated landscapes) (Tongway and Hindley, 2004).These patterns enable a site to be described in terms of its landscape function, as data collected from sample plots are extrapolated across other similar landscapes (Tongway and Hindley, 2004).

2.3 Landscape heterogeneity

Heterogeneity is the precursor to biological diversity at most levels of ecological organization and should serve as the foundation for conservation and ecosystem management (Fuhlendorf and Engle, 2001). Rangelands are described as inherently heterogeneous because composition, productivity and diversity are highly variable across multiple scales (Fuhlendorf and Engle, 2001). A heterogeneous patchwork on rangelands can result from a differential timing of disturbances (Fuhlendorf and Engle, 2001). Corresponding from the differential timing of disturbance and correspond out of phase succession among patches (Fuhlendorf and Engle, 2001).

Degradation in the landscape is often unevenly expressed (heterogeneous) because disturbance is spatial localized and, landscape elements differ in their sensitivity to disturbance (Stokes et al., 2009). Landscape heterogeneity is a complex multiscale phenomenon involving the size, shape and composition of different landscape units and the spatial relationship between them (Hobbs, 2002). This spatial heterogeneity is caused by differences in biophysical and socioeconomic conditions supporting different landscape functions (Willemen et al., 2010). Spatial heterogeneity within and among ecosystems is critical to the functioning of individual ecosystems and of entire regions. The landscape heterogeneity has numerous influences on population dynamics, community structure, and ecosystem processes (Turner et al., 2012). Different landscapes have unique characteristics and histories and may respond differently to contemporary and future drivers of change, therefore comparative studies are important (Turner et al., 2012).

Stokes et al. (2009) considered the challenges presented by spatial heterogeneity in the degradation processes and suggested the opportunities for improving the designs of monitoring programs. Different patch types experience different frequencies and intensities of disturbance. For example, patch grazing may develop due to the differential palatability of plant (Stokes et al., 2009). Patch types often differ in their responses to more or less uniform disturbance (Lake, 2000). For example, plants communities may differ in their sensitivity to disturbance due to characteristics of plants comprising the community (Fischer and Lindenmayer, 2007). Landscape degradation may initially be confined to localized portions of a landscape, but expand over time to affect broader areas (Bernett and Saunders, 2010). Vegetation could be used as indicator patches and targeted for exclusive sampling as a sensitive method for monitoring rangeland condition and detecting early warning of vegetation change (Muñoz-Robles et al., 2011). This approach could be used to better harness the extensive knowledge based on patches and, nature of degradation initiating processes in other landscapes (Stokes et al., 2009).

Moderate continuous grazing which has been identified as the most ecologically and economically sustainable grazing management practice for domestic livestock on rangelands can amplify the inherent heterogeneity of rangeland at some scales (Fuhlendorf and Engle, 2001). When natural spatial heterogeneity and topographic variation within rangelands are superimposed on the variation in selective grazing pressure, even low levels of grazing pressure can lead to increased heterogeneity relative to ungrazed conditions (Fuhlendorf and Engle, 2001).

2.4 Landscape Function

Landscape function refers to the way the ecological resources are regulated and utilized within a landscape (Sharp, 2011; Tongway and Hindley, 2004; van der Walt et al., 2012). Those resources include water movement, nutrient cycling and the way the plants and animals use and modify resources (Sharp, 2011). Biogeochemical attributes of the soil and vegetation play an important role in regulating these resources and at the same time, landscape function underpins the capacity for vegetation to persist and provides resources and habitat for species diversity (Mirdeilami et al., 2014). Landscape do not remain in a rigid state, or change in predictable ways, but the key to sustainable landscape function is that changes that occur remain within limits and that flows of energy and material tend to be steady (Ludwig et al., 2005).

Functional integrity has been defined as the ability of landscapes to capture, retain and use critical resources such as water and nutrients (Kwok et al., 2011). Healthy landscapes retain water, soil, nutrients and organic matter in a network of patches (Ludwig et al., 1999). The pastoral damage takes different forms, whereby one impact is the loss of landscape integrity, which is the intactness of vegetation and structural patterns and the process that maintain these patterns (Ludwig et al., 2004). This loss of functional integrity includes the shelter and food provided by vegetation (Ludwig et al., 2004).

Simple indicators of landscape integrity, which directly measure the functional integrity of the landscape, are required for monitoring the state of health or functionality of rangeland (Ludwig et al., 1999). Useful indicators are sensitive to change, convenient and inexpensive to apply by a range of operators and are capable of providing a predictive understanding of landscape function (Ludwig et al., 2004; Ludwig et al., 1999). Two indicators of landscape integrity emerged from fine scale patch hillslope, which includes vegetation patch quality and quantity which reflect the ability of a landscape to retain resources (Ludwig et al., 2004). Vegetation patch quality and quantity as surrogates for resource retention can be measured by the cover and condition of vegetation patches (Tongway and Hindley, 2004).

The landscapes that have high levels of function store resources, through the presence of long-lived features that obstruct or divert water flow such as fine litter, topsoil and seeds from runoff (Bartley et al., 2006; Tongway and Hindley, 2004). Dysfunctional landscapes are those in which there are a few obstructions and resources are removed from the landscape (Sharp, 2011; Tongway and Hindley, 2004). Rangeland systems in good condition are characterized by a large number of highly connected patches that efficiently capture, retain and utilize scarce resources within the landscape (Bartley et al., 2006). There are a number of processes that occur in rangeland systems that increase the dysfunction of these systems, such processes include grazing, introduced pastures, and fire (Bartley et al., 2006).

By assessing patches and inter-patches, monitoring, observing, detecting and recording their changes in the natural ecosystem over time, it is possible to identify ecological threshold using soil and vegetation indices in the ecosystem (Forouzeh and Sharafatmandrad, 2012). A reduction in number, size, spacing or effectiveness of fertile patches may increase run off and erosion in intense rainfall and cause landscape degradation (Bartley et al., 2006; Forouzeh and Sharafatmandrad, 2012). The landscape structure can be assessed by studying the relative distribution of patches. The functional characteristics of rangelands can be predicted by the landscape structure (Forouzeh and Sharafatmandrad, 2012).

2.5 Issues of Management

2.5.1 Grazing

Grazing is the consumption of above-ground grass by animals, either indigenous or domestic (Cingolani et al., 2014). Grazing was considered as one of the key disturbance factors which resulted in grassland degradation, an increase of spatial heterogeneity of the communities, an alteration of community function and loss of species diversity (Gao-Lin et al., 2008). Livestock grazing may be necessary to maintain rangeland ecosystem structure and function when native wild herbivore populations are decimated or extinct, or if livestock presence is ancient in the ecosystem (Cingolani et al., 2014).

In productive grasslands, the absence of grazing can lead to the dominance of a few large competitive plant species, thereby reducing alpha diversity (Cingolani et al., 2014). Removal of grazing pressure causes significant reductions in herbaceous species richness, which can be attributed to the increase in grass biomass in the absence of herbivores (van Coller, 2014). This suggests that large herbivores are essential to sustain low levels of field biomass, allowing more functionally different species to coexist, and that increase of grass biomass appear to negatively influence forbs species richness (van Coller, 2014). Grazing contribute to the stimulation of biomass production through the removal of dead or dying (moribund) plant biomass that might limit new growth (Smith et al., 2011). It is critical to obtain a better understanding of how grazing influences the key properties of ecosystem function and sustainability and, thereby, provide guidelines for improving grassland management practices (Dong et al., 2014).

2.5.2 Overgrazing

Land degradation, including overgrazing, is regarded as one of the main environmental problems in Southern Africa (Rutherford and Powrie, 2013). Excessive grazing can increase the occurrence and extent of sparsely vegetated inter-patches thereby increasing runoff and reducing resource retention, reduce the availability of seeds and litter reserves and alter the proportion of plant life forms (Good et al., 2013). High densities of grazing animals may alter the floristic composition and structural characteristics of vegetation, reduce biodiversity, and increase soil erosion (Sankey et al., 2009). Intense trampling by livestock, uneven animal distribution and excessive plant consumption has been indicated to produce irreversible ecosystem degradation, even in productive ecosystems (Castellano and Valone, 2007, Cingolani et al., 2014; Rutherford and Powrie, 2013).

Herbivores act as a primary disturbance, reducing biomass, altering vegetation cover and patchiness in semi-arid systems, which leads to an increase in spatial and physical heterogeneity (Ludwig and Tongway, 1995; van Coller, 2014). The key nutrient is likely to be lost at the landscape scale as grazing increased, rather than just being redistributed, water infiltration decreases due to lack of barriers to trap water and reduce run off (Sparrow et al., 2003). A number of protection and restoration measures, including fencing, reseeding or the use of fertilizers have been put in practice to increase herbage production and protect grassland vegetation (Gao-Lin et al., 2008).

2.5.3 Fire

Fires are a natural feature in many of South Africa’s ecosystems, and they occur regularly in the dry season in fynbos shrublands, grasslands and savannas across the country (van Wilgen, 2015). Grasslands are both fire-prone and fire-dependent, requiring fire to maintain their biodiversity patterns and ecological processes (Bowman et al., 2011). Fire is one of the key agents for shaping many terrestrial landscapes as it removes large quantities of plant biomass, which in turn creates nutrient fluxes that contribute to ecological rejuvenating qualities (van Coller, 2014). Fire is critical for maintaining the health of grassland ecosystems and is also one of the most practical ways of manipulating large areas of grassland for different management objectives

(Bowman et al., 2011). Fire controls woody invasive alien species and indigenous weeds, increases habitat diversity, by forming a mosaic of structurally-differing habitats within the grassland landscape (van Coller, 2014).

2.5.4 Invasive Alien plant species

The invasion of ecosystems by invasive alien species (IAPs) has been identified as a large and growing threat to the delivery of ecosystem services (van Wilgen et al., 2008). IAPs can change ecosystem function and halt succession by outcompeting native plant species either by competing for resources or altering nutrient cycling (Funk et al., 2008). Many alien plants have been introduced to South Africa for a range of purposes, which include crop production, sources of timber, firewood, ornamentals, as well as for use in dune stabilization and as structural barriers and as hedge plants (de la Fontaine, 2013). Grasses are an important component of the naturalized alien flora in South Africa, but are often overlooked due to the major problems currently being experienced, current information shows that 15% of the grass genera and 12% of grass species in southern Africa are naturalized aliens (Milton, 2004).

Grass invasions are becoming important at local and global scales because grass flammability prevents recovery of woody vegetation, maintaining grass dominance, changing microclimate and causing nutrient losses (Gordon and Arne, 2013; Milton, 2004). Poor grassland management, particularly over-grazing and exclusion of fire, leads to infestation by woody invasive alien species (Lesoli et al., 2013). Restoration can change the impacts of invasive species that use up resources, impact the trophic structure and damage ecosystem function (Wood, 2011).

2.6 Techniques used for measuring and monitoring ecosystem function

Ecosystem restoration is a relatively new field that is incorporating techniques from a variety of other disciplines, and a conceptual framework to approach restoration in practice (Machmer and Steeger, 2002). Monitoring increases our understanding of ecosystem function and response thresholds and provides insights about which practices are effective (Haagner, 2008). Monitoring of restoration activities has not been emphasized in the past and there has been a tendency to repeat treatments without questioning their efficacy or applicability to different biogeoclimatic zones (Machmer and Steeger, 2002). There are a number of excellent sources of monitoring information covering a wide variety of terrestrial resources (Gayton, 2001; Ritchlin, 2001). Irrespective of the methods used, it is important that these methods are standardized to ensure repeatability of data collection, and valid comparisons before and after treatment (Machmer and Steeger, 2002). Table 2. 1 provides a summary of methods commonly-used in ground-based monitoring techniques.

Table 2. 1: Techniques commonly used for measuring and monitoring ground cover.

Techniques	Structure	Function	Resources	Source
Remote sensing	Measures the vegetation canopy cover.	Determines the biomass	Expensive and time consuming	Lau et al., (2008)
Landscape function analysis	Characterises the ground cover and spatial heterogeneity	Determines the stability, infiltration and nutrient cycling using the simple indicators	Reliable, easily applied, and inexpensive method	Tongway and Hindley, (2004)
Botanical survey	Describes the structure of plant community, species composition and relative abundance	Partially gives an idea of the function	Expensive and time consuming	Elzinga et al., (1998)
Disc Pasture meter	Measures compressed grass height	Determines the biomass	The pasture disc is simple, inexpensive method	Trollope and Potgieter, (1986)
Line intercept method	Describes the foliar, basal cover and composition	Limited in function	Rapid, accurate for quantifying vegetation cover and not expensive	Herrick et al., (2009)
Step-point	Measures the cover of individual species, total cover and species composition	Limited in function	Simple, rapid and easy to apply	Coulloudon et al., (1999)
Point-intercept	Determines the vegetation cover	Limited in function	Simple, rapid and easy	Coulloudon et al., (1999)
Cover board method	Measures the vertical cover and structures of vegetation	Limited in function	Fast and easily duplicated method	Coulloudon et al., (1999)

2.7 Landscape Function analysis method

Landscape function analysis method is an environmental monitoring technique which is internationally recognized for measuring and monitoring ecosystem function and rehabilitation progress (Lau et al., 2008). This methodology satisfies the requirements for meaningful indicator based methods: it reflects the critical status of ecosystem processes, is unambiguous, and can be used over a wide range of ecosystems (Maestre and Puche, 2009). The basis of LFA is to measure the spatial arrangement, size and relative distribution of patches (obstructions to runoff) with respect to the distribution of infertile (inter-patch) zones in a landscape as they relate to the down-slope transport of resources (Furniss, 2008). The (LFA) categorizes landscape organization and soil surface condition which reflect the ability of the landscape to capture and retain resources (Kwok et al., 2011).

The LFA has been employed for different purposes in different areas. In Australia, LFA has been used to examine changes in the diversity, cover and community structure of biological soil crust and assess the development of ecosystem function in revegetation (Mahmoud et al., 2014). In Iran LFA was conducted to assess the effects of management activities on patch and inter-patch (Rezaei et al., 2006). In Libya, Morocco and Tunisia LFA has been used to investigate changes in landscape function, soil surface condition and vascular plant composition (Mahmoud et al., 2014). In South Africa the research was conducted in mining operation (Haagner, 2008; van der Walt et al., 2012), and LFA has also been used to assess the effects of different management on fine scale biophysical landscape function of urban and exurban grassland fragments (van der Walt et al., 2014).

More precisely LFA target range of surface properties controlling water and nutrient retention, such as surface cover by perennial plants, litter cover and degree of decomposition, surface roughness, soil texture and surface crust stability (Zucca et al., 2013). Water and nutrient retention are considered as essential functions in the semi-arid ecosystem and their monitoring is crucial to the assessment of the vegetation and soil response to restoration intervention (Zucca et al., 2013). So assessing the functionality of patches and inter- patches in rangeland ecosystem functioning provides information for day to day management of rangelands (Forouzeh and Sharafatmandrad, 2012; Mayor and Bautista, 2012).

2.8 Conclusion

The effect of inappropriate land use practice on ecosystem function has been profound. The structure and function of a landscape is determined by interacting patches and inter-patches. Landscape degradation due to inappropriate land use is a key driver of landscape heterogeneity. Restoration of a dysfunctional landscape can only be accomplished by improving natural vegetation patches, as they have the ability to trap and store limited resources (Kakembo et al., 2012). Understanding of landscape pattern and processes increases the ability to work effectively at landscape small scale and being facilitated by tools such as landscape function analysis method.

CHAPTER 3: Assessing the utility of landscape function analysis as a tool for evaluating the functional status of rangelands in Mount Fletcher, Eastern Cape

3.1 Abstract

The severity of vegetation degradation has become a serious challenge, causing negative impacts on ecosystem and landscape functioning. The aim of this study was to assess the landscape functioning analysis LFA method as a tool for determining landscape condition, between intact and degraded areas. The LFA method is a field based technique which examines the functional status of rangelands. Data were collected in intact and degraded areas. Transects were established to measure landscape organization indices of patches and inter-patches (number, length, width) which characterize the landscape structure. Stability, infiltration and nutrient cycling indices were derived from 11 soil surface indicators. A student t-test was used to test whether there were significant differences in landscape organization and soil surface assessment indices between intact and degraded areas. The results indicated that the intact areas were significantly more functional compared to degraded areas based on several indices. We conclude that LFA can be used as a tool to determine the landscape functioning of the rangelands.

Key words: Grasslands, degradation landscape function analysis, landscape organization, soil surface assessment, over-grazing.

3.2 Introduction

People depend on living, healthy ecosystems for the services they provide (Millennium Ecosystem Assessment 2005). This dependence is often more apparent in rural communities, whose lives are directly affected by the availability of common property resources such as food, water, medicinal plants and firewood (McNeely, 2010). Ecosystems services sustain humans all over the world and directly support more than one billion people in the world living in extreme poverty (Egoh et al., 2009). Ecosystem services are defined as the benefits that people obtain from ecosystems and these are usually subdivided into four main categories of services: provisioning (e.g. food), regulatory (e.g. flood attenuation), supporting (e.g. nutrient cycling), and cultural ones (e.g. recreation) (Egoh et al., 2009). Several factors influence the delivery of ecosystem services, including the condition and health of ecosystems. For example, the ability to hold soil and slow-down water run-off is considerably reduced in degraded grasslands due to overgrazing (Castellano and Valone, 2007).

Measuring ecosystem functioning and their ability to deliver key ecosystem services is a key component of natural resource management. Landscape Function Analysis (LFA) is a field-based monitoring procedure, which provides rapid, consistent assessment of ecosystem functioning, using simple visual indicators (Tongway and Hindley, 2004). LFA assesses how well a landscape is working as a biophysical system (Tongway and Hindley, 2004). It is based on recent, cross-scale, cross disciplinary research findings and can be applied to a very wide range of disturbed landscape and climate types and a variety of land uses (Tongway and Hindley, 2004). It is compatible with other monitoring procedures that focus on structure and composition, as opposed to function (Tongway and Hindley, 2004). The method involves assessing and scoring indicators of soil surface conditions, which results in three indices of landscape function which are stability, infiltration and nutrient cycling (Tongway and Hindley, 2004).

The LFA is comprised of a conceptual framework, a field methodology and an interpretational framework. The conceptual framework “Trigger-Transfer-Reserve-Pulse” (TTRP) is the core framework underpinning LFA which examine how scarce vital resources move and are used in or lost to the landscape, in a sequence of processes mainly played out at the soil surface (Haagner, 2008; Tongway and Hindley, 2004; van der Walt et al., 2012) (see

Appendix 1). The TTRP framework represents a comprehensive sequence of landscape processes and feedback loops, enabling the structuring of environmental information pertaining to functioning (Tongway and Hindley, 2004). Through analysis of landscape function, ecologists can judge the landscape's capability to work as a biogeochemical system ranging from being fully functional to entirely dysfunctional (Rezaei et al., 2006). This characterizes systems as highly conserving to leakage of vital resources, or from completely robust to totally vulnerable (Rezaei et al., 2006). The LFA thus provides a rapid field-based assessment technique of ecosystem condition and ecosystem service delivery.

According to the literature available in South Africa, the LFA method has been relatively untested. The LFA has been applied to a few systems, for example mining rehabilitation (Haagner, 2008, van der Walt et al., 2012), urban grassland (van der Walt et al., 2014) and defining function in rangelands (Palmer., 2001) and the present study explores the method in degraded rangelands. The aim of this study was to assess the LFA method as a tool to determine the landscape functioning and differentiate the condition of rangeland into two levels of degradation due to over-grazing. We hypothesized that the landscape function analysis method can be used as a tool to monitor landscape condition, because it can discriminate the levels of degradation. We assessed various LFA indices in determining the function of the landscape, and compared the landscape organization indices and ecosystem processes such as stability, infiltration and nutrient cycling of intact and degraded areas.

3.3 Materials and Methods

3.3.1 Study area

The study site was located within the villages of Kwanokhohlongo, Vuvu and Ezindawo, about 20 kilometres north of Mount Fletcher in the Elundini Local Municipality, of the Joe Gqabi District Municipality, South Africa (Figure 3. 1). The sites lie on the Drakensberg Mountain range which plays an important role as water catchment for the Umzimvubu and Tsitsa Rivers. Umzimvubu River bisects the region and supplies large volumes of water to the Indian Ocean (Elundini Local Municipality 2015). In addition, the area falls within the Maputaland-Pondoland-Albany biodiversity hotspot, characterized by high level of plant and faunal endemism (Department of Economic Development and Environmental Affairs 2009). The vegetation consists of high altitudinal grassland (Mucina and Rutherford,2006) with deep soils occurring on foothills of the mountains suitable for cultivation. The area is characterised by various levels of vegetation degradation related to grazing practices.

Highly disturbed areas were referred to as “degraded” and low disturbed areas were referred to as “intact”. Highly disturbed areas were fenced during 2012 to reduce grazing pressure and monitor vegetation recovery. Degraded landscapes were physically characterized as landscape in which the regulation of resources was reduced by disturbance regime such as grazing, trampling, fire and agricultural activities. Such landscape consisted of soil compaction, low vegetation cover, formation of gullies which results in decreased infiltration and soil erosion. Intact areas were characterized by the presence of more ground cover, availability of resources trapped on vegetation, less bare soil and high infiltration.

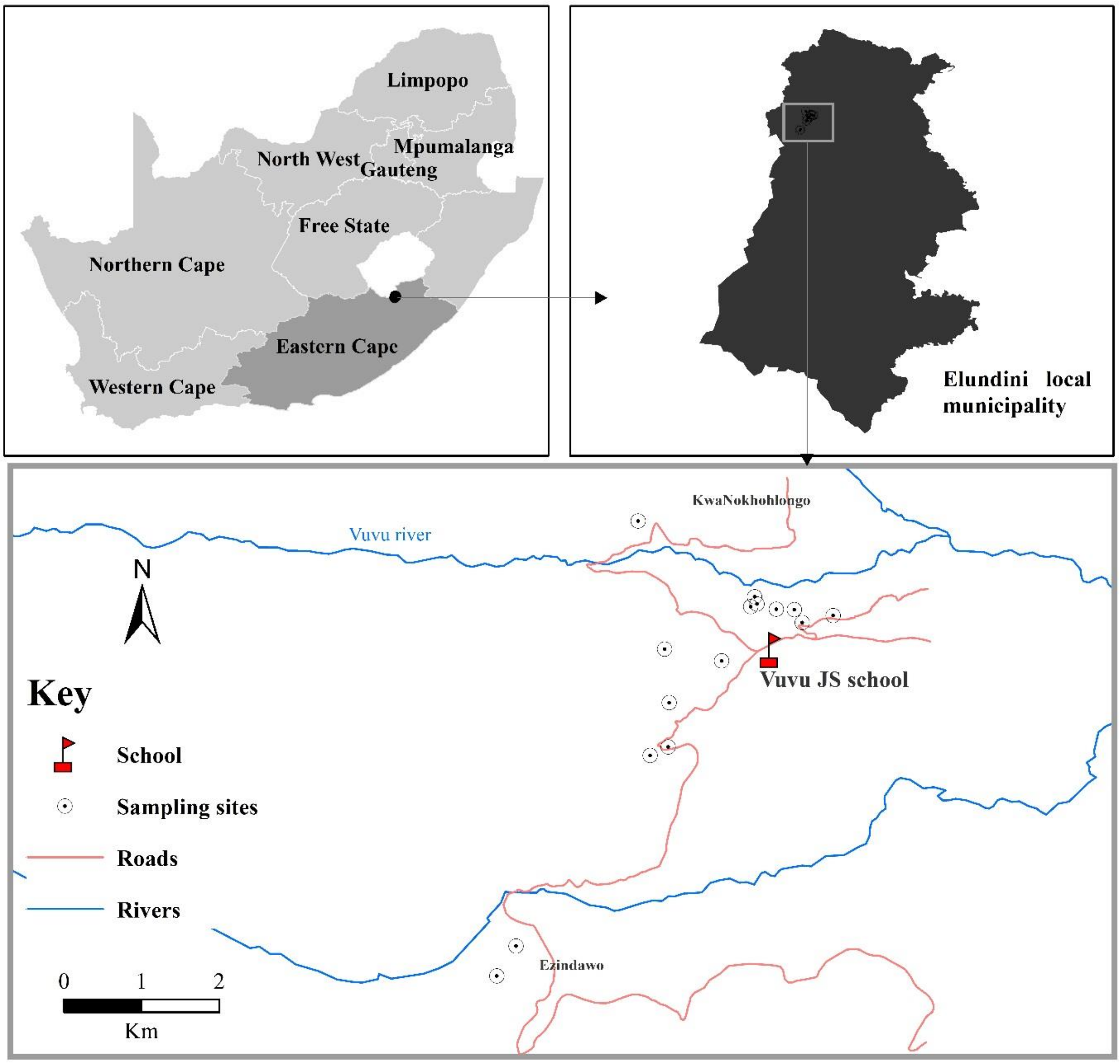

Figure 3. 1: Location of study sites, Elundini municipality and Eastern Cape Province of South Africa.

3.3.1.1 Climate

The region is well known for its temperature fluctuations ranging from 11 to 42 degrees centigrade (Elundini Local Municipality 2015). On average there are 150 days of frost during the year, usually between March and November with snow in the higher lying areas (Elundini Local Municipality 2015). The higher mountain peaks in Elundini receive between 800 mm and 1200 mm of rain per annum (Elundini Local Municipality 2015). The rest of the area receives between 600 mm and 800 mm per annum with rainfall mostly occurring during midsummer with an average monthly rainfall of 2 mm in July and 117 mm in January (Elundini Local Municipality 2015).

3.3.1.2 Topography, hydrology and soils

The municipal area has a distinctive topographical character with mountain ranges along the western side overlooking a central plateau, giving way to an escarpment sloping down towards the eastern side (Elundini Local Municipality 2015). Much of Elundini has slopes steeper than 1:8 as it forms part of the southern Drakensberg range (Prasad et al., 2011). The mountainous terrain also limits accessibility and therefore hampers service and infrastructure delivery in the Region (Prasad et al., 2011). The mountains form a watershed and separate the eastern and western parts of the Joe Gqabi district (Elundini Local Municipality 2015). Topography influences the type of land use activities that occur (Elundini Local Municipality 2015). Agriculture is accordingly limited to specific land pockets in the central, southern and eastern portion where topography, water and soils are suitable for agriculture and residential uses (Elundini Local Municipality 2015). Soils are generally shallow and weakly developed (Bredenkamp *et al*., 1996). Habitat degradation is high in the communal areas of Elundini largely due to the overstocking of livestock and inappropriate grazing methods (Hoffman and Todd, 2000).

3.3.1.3 Vegetation

The area is home to three grassland types: Lesotho Highland Basalt Grassland, East Griqualand Grassland and Southern Drakensberg Grassland (Mucina and Rutheford, 2006). The vegetation is dense sour grassland with redgrass *Themeda triandra,* spear grass *Heteropogon contortus,* hairy trident grass *Tristachya leucothrix,* weeping love grass *Eragrostis curvula* and silky grass *Elionurus muticus* as some of the dominant species (Mucina and Rutheford, 2006). Common thatch grasses *Hyparrhenia hirta* and cats tail drop seed *Sporobolus pyramidals* are often prominent (Mzobe, 2013).

3.3.2 Field sampling

3.3.2.1 Landscape organization

The information that may be obtained from LFA includes physical landscape attributes and certain soil surface attributes which reflect landscape functionality (Van der Walt et al., 2015). In the context of LFA, landscape organization is defined as an arrangement of zones that reflect run on (patch and resource accumulation) and run off (inter-patch and resource loss) processes (Rezaei et al., 2006). Ground-based measurements of landscape integrity using LFA are now established as part of rangeland monitoring programmes in Australia (Ludwig et al., 2004). LFA closely examines the condition of vegetated soil surface (patch quality) and measures the cover and number of perennial vegetation patches (quantity) (Ludwig et al., 2004). The obstruction of patch and inter-patch are useful indicators which shows the ability of a landscape to retain resources (Ludwig et al., 2004). The landscape organization data represent the physical characteristics of a landscape and consist of four key variables explained in Table 3. 1. The four variables strongly reflect capability of landscape to capture and store resources (Petersen et al., 2004).

Table 3. 1 Landscape organization indices (Tongway and Hindley., 2004)

Landscape organization	Description
Number of patches per 10 meters	Represent a linear density of patches
Total patch area	Represent the width and length of patches
Landscape organization index	Represent the proportion of the length of all patches measured along the transect divided by the total length of the transect
Average inter-patch length	Represent the average distance of unobstruced resource transport as run off

A total number of 132 sites were sampled from April 2012 to February 2013 (Table 3. 2) within the villages of KwanoKhohlongo and Ezindawo. One transect was sampled per site. The timing of the sampling was important as seasonal variation can occur for some indicators.

Data were collected in both intact and degraded areas for comparison of landscape functioning. Along a 30m transect the number of patches and inter-patches identified were recorded and described as landscape zones. The entire length of transect was classified into a series of patches and inter-patches (Figure 3. 2). Five kinds of patches and inter-patches were distinguished in terms of their similarity and function: grass patch (GP), grass-forb patch (GFP), grass-shrub patch (GSP), sparse grass patch (SPG) and one type of inter-patch bare soil (BS) (Figure 3.3). The width of each patch was measured except for the inter-patch consisting of bare soils. The patch width was assessed by looking for evidence of resources trapped down slope around the edge of the patch. Inter-patch consisted of empty space that show no evidence of accumulation of resources hence the width could not be determined.

Table 3. 2 Number of sites sampled

Seasons	Intact areas	Degraded areas	Months
Summer	23	23	November - February
Autumn	4	4	March - April
Winter	24	24	May - August
Spring	15	15	September - October

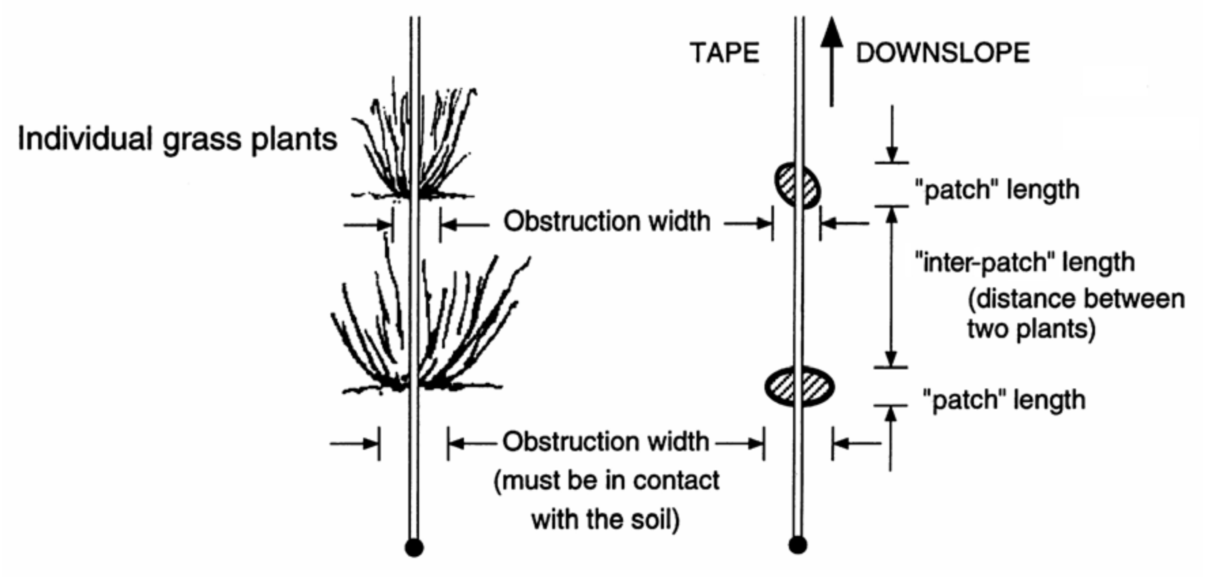

Figure 3. 2: An illustration of how a landscape organization (patch/ inter-patch) along a line transect was measured (Tongway and Hindley, 2004).

3.3.2.2 Patch and inter-patch description

The grassy patches (GP) were the most frequently encountered patch types and showed considerable variation in appearance. GPs were characterised by living, perennial grass plants and had strong root tufts. Grassy forb patches (GFP) were also frequently encountered during data collection which were characterized by the presence grass and herbaceous vegetation. Grassy shrub patches (GSP) were encountered less often, GSP were characterized by the presence grass and shrubs. Sparse grass patch comprised of annual grasses and semi-annual grasses. The sparse grass patches (SGP) were also separated from grass patch on the basis of vegetation structure, diverting water or nutrients and extent of litter cover (van der Walt et al., 2012). Bare soil (BS) occurred in both disturbed and undisturbed areas, and were the main inter-patches that separated patches from each other Table 3.3.

Figure 3. 3: Different types of patches and inter-patch encountered during sampling: A) grass patch (GP), B) grass forb patch (GFP), C) grass shrub patch (GSP), D) sparse grass patch, E) bare soil.

Table 3. 3 Patch/Inter-patch description

Patch/Inter-patch Identified	Code	Description
Grass patch	GP	The GP differed in appearances and consisted of individual grass creating a dense tuft or a network of overlapping individuals forming a larger patch
Grass forb patch	GFP	A GFP is a complex patch characterised by the presence of grass and herbaceous plant growing closely together to form a dense patch
Grass shrub patch	GSP	GSP is a complex patch consisting of the combination of grass and shrub growing close together to form a single dense patch
Sparse grass patch	SGP	SGP has lower basal cover compared to grass patch. According to van der Walt et al. (2012) "SGP are of particular interest, as they are on the cusp of increased density (grass patch) or of declining to a litter or even bare soil inter-patch classification when more rapid resource loss might occur"
Bare soil	BS	No vegetation cover exist, only bare soil

3.3.2.3 Soil Surface Assessment

A soil surface assessment (SSA), comprising of eleven indicators was done in each patch and inter-patch identified based on five replicates per patch/inter patch (Table 3.4). Every soil surface indicator was evaluated and given a score based on the guidelines and images from the LFA field guide manuals (Tongway and Hindley, 2004) appendix 2). The eleven indicators were then combined into three LFA indices namely stability, infiltration and nutrient cycling representing landscape functioning described by Haagner (2008), Kwok et al., (2011):

- Stability is the ability of the soil to withstand erosive forces, and reform after disturbance.
- The infiltration index shows how the soil partitions rainfall into plant available water and runoff water that is lost from the system.
- Nutrient cycling index provides information about how efficiently organic matter is cycled back into the soil.

Table 3. 4 Soil indicators and their relationship to landscape functioning indices (stability, infiltration and nutrient cycling (Haagner, 2008, Lau et al., 2008, van der Walt et al., 2012)

Indicator	Process Addressed	Stability	Infiltration	Nutrient cycling
1. Soil cover/rainsplash protection	Indicates how well soil surface is protected from the impact of raindrops, which influences erosion and crust formation	✓		
2. Perennial vegetation cover	Estimate basal cover of perennial grasses and canopy cover of trees/shrubs		✓	✓
3. Litter, origin, degree of decomposition	Has strong influence on soil stability and nutrient cycling	✓	✓	✓
4. Cryptogam cover	The presence of algae, fungi, mosses, on the soil surface indicate soil stability and nutrient cycling	✓		✓
5. Crust brokenness	Broken crust indicate innately unstable surfaces	✓		
6. Soil erosion, type and Severity	Indicate nature of soil erosion and its severity	✓		
7. Deposited material	Indicate the nature and amount of alluvium transported and deposited	✓		
8. Soil surface roughness	Indicate surface roughness for the ability to retain and capture mobile resources		✓	✓
9. Surface resistance to disturbance	Assess the effect of mechanical disturbance	✓		
10. Slake test	Soil stability when subject to rapid wetting	✓	✓	
11. Soil surface texture	Classifies soil texture, which influences permeability		✓	

3.4 Data Analysis

Preliminary analysis of LFA data were then put into spreadsheet designed by Tongway and Hindley (2004), which automatically calculates the emergent index values and tabulates output. The data outputs summarized various landscape function indices reflecting the landscape organization (number of patch zones per 10 metres, total patch area, landscape organization index and average inter-patch) and soil surface assessment (stability, infiltration and nutrient cycling). To determine the significance difference of the landscape organization and soil surface assessment indices as well seasonal variation among the indices t-test was done in R-package comparing the intact and degraded areas (R Development Core Team, 2016).

.

3.5 Results

3.5.1Landscape organization

Out of six landscape organisation indices, four showed significant differences between intact and degraded areas (Figure 3. 4). The mean value of the number of patches per 10m, the total patch area, and landscape organization index was higher on the intact area compared to the degraded area and significantly different with $P < 0.05$. The inter-patch length was higher in the degraded areas than in the intact areas.

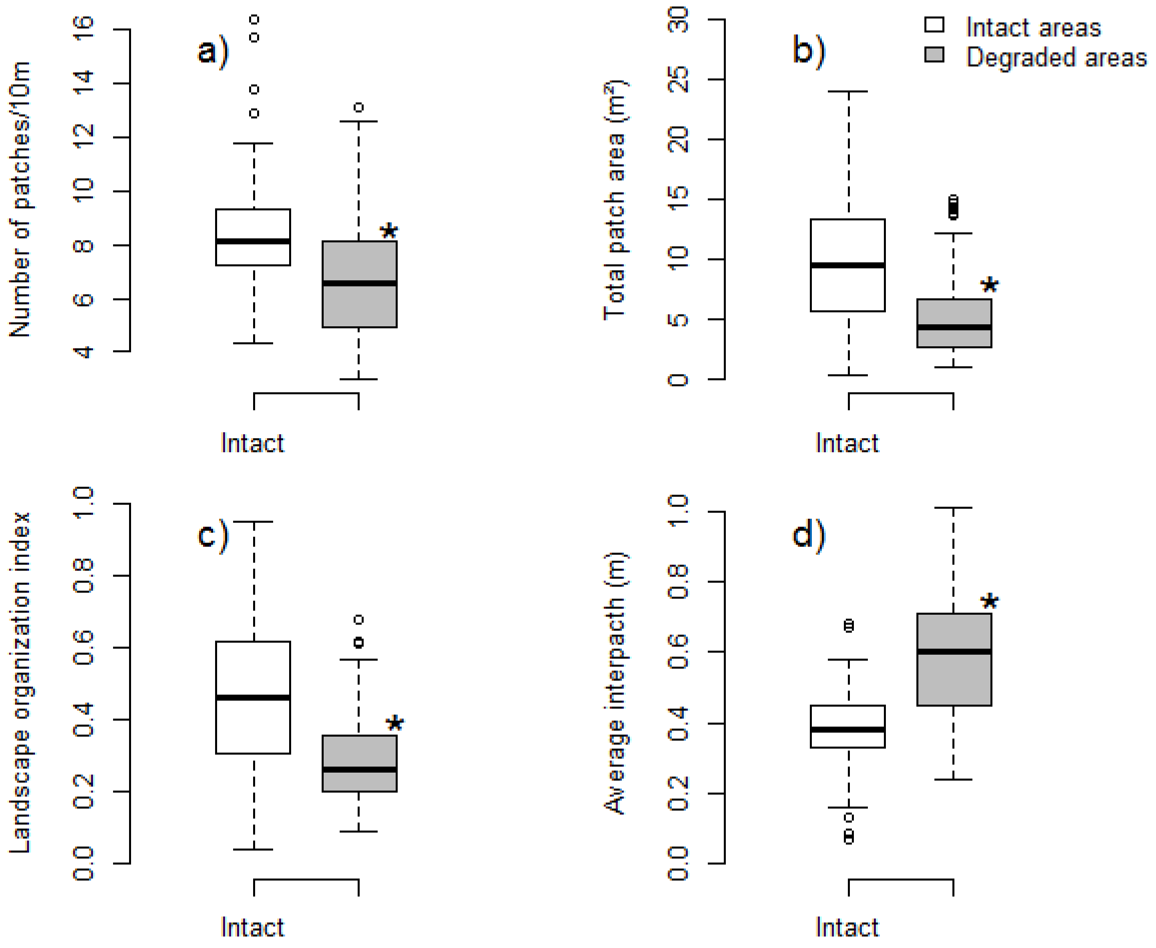

Figure 3. 4: Values of (a) number of patches, (b) total patch area, (c) landscape organization index, and (d) average inter-patch length between intact and degraded areas. * indicate significant statistical difference at P < 0.05.

3.5.2 Soil surface assessment

Grass patch, sparse grass patch, grass forb patch and combined zones had high stability due to stable crust which was covered by dense vegetated patches preventing the soil surface from being exposed to erosion and resource loss (Figure 3. 5). Bare soil contributed less to infiltration due to the absence of vegetation cover which would slow down and capture resources being transported through the landscape making it available for infiltration (van der Walt et al., 2014). Patches contributed more to infiltration due to the presence of vegetation cover. Stability values ranged between 50-70 %, infiltration values ranged between 20-40 % and nutrient cycling values ranged between 10-30 % both in the intact and degraded areas.

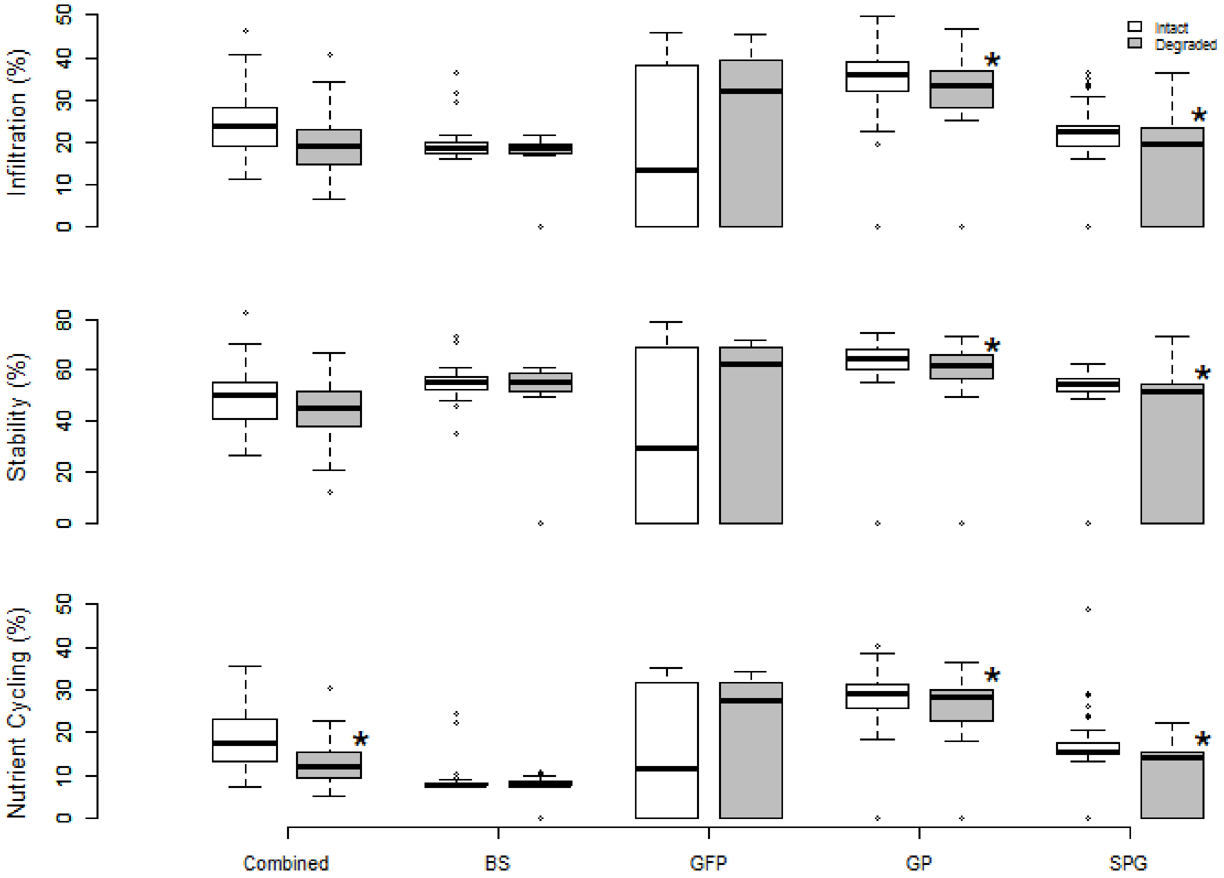

Figure 3. 5: Values of infiltration, stability and nutrient cycling for each landscape patch/inter-patch identified (GP, GFP, GSP, SGP, BS), and the entire landscape (combined). * indicate the significant statistical difference.

The total landscape functionality seems to increase with a decreased inter-patch length. Negative correlation was observed between total SSA functionality and average inter-patch length in the intact area. The degraded area did not show any relationship between average inter-patch length and total SSA (Figure 3. 6). The intact area indicated to be significant correlation with P < 0.05 and R-square = 0.332, the degraded area was not significant correlation.

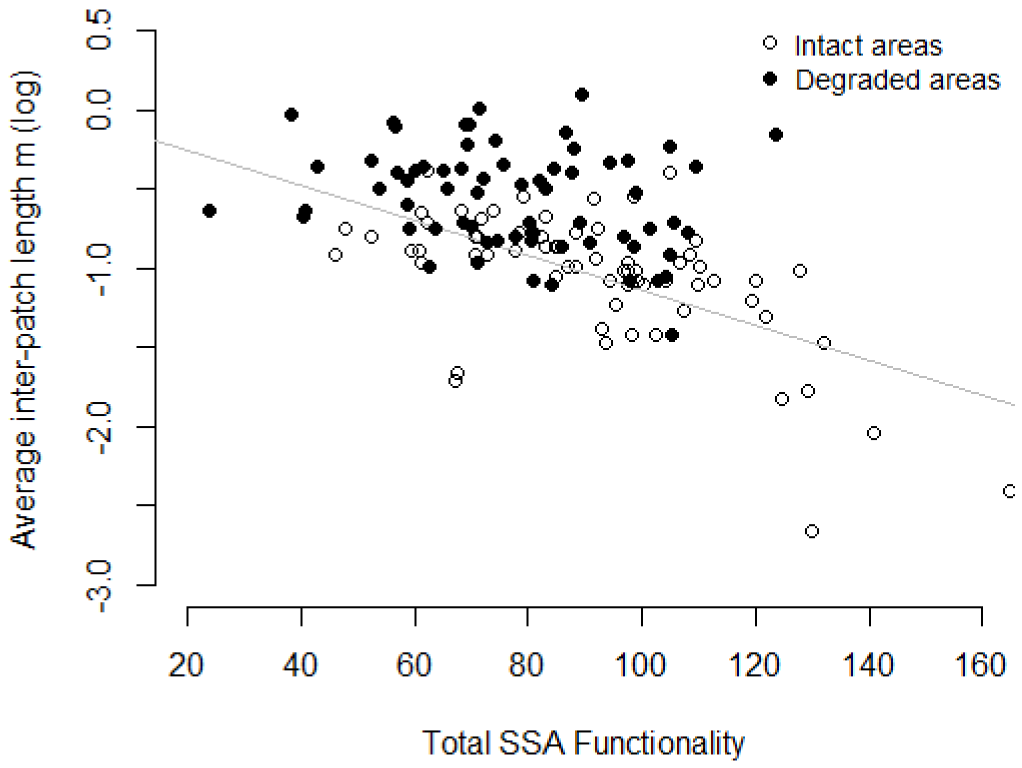

Figure 3. 6: The relationship between the average inter-patch length and total SSA functionality indices for intact and degraded area. Unfilled circle represent intact areas and filled circle represent degraded areas.

3.5.3 Seasonal Variation

The intact areas LFA indices were always higher than to degraded areas except with the average inter-patch which was higher in the degraded areas, some of the differences were significant. The winter season showed high landscape organization index which indicates that there were more patches during this season. However the SSA indices (stability, infiltration and nutrient cycling) indicated a decrease in winter. Winter season from the results indicated to be a suitable period for sampling as most differences were significant between intact and degraded areas for four of five indices (except for infiltration).

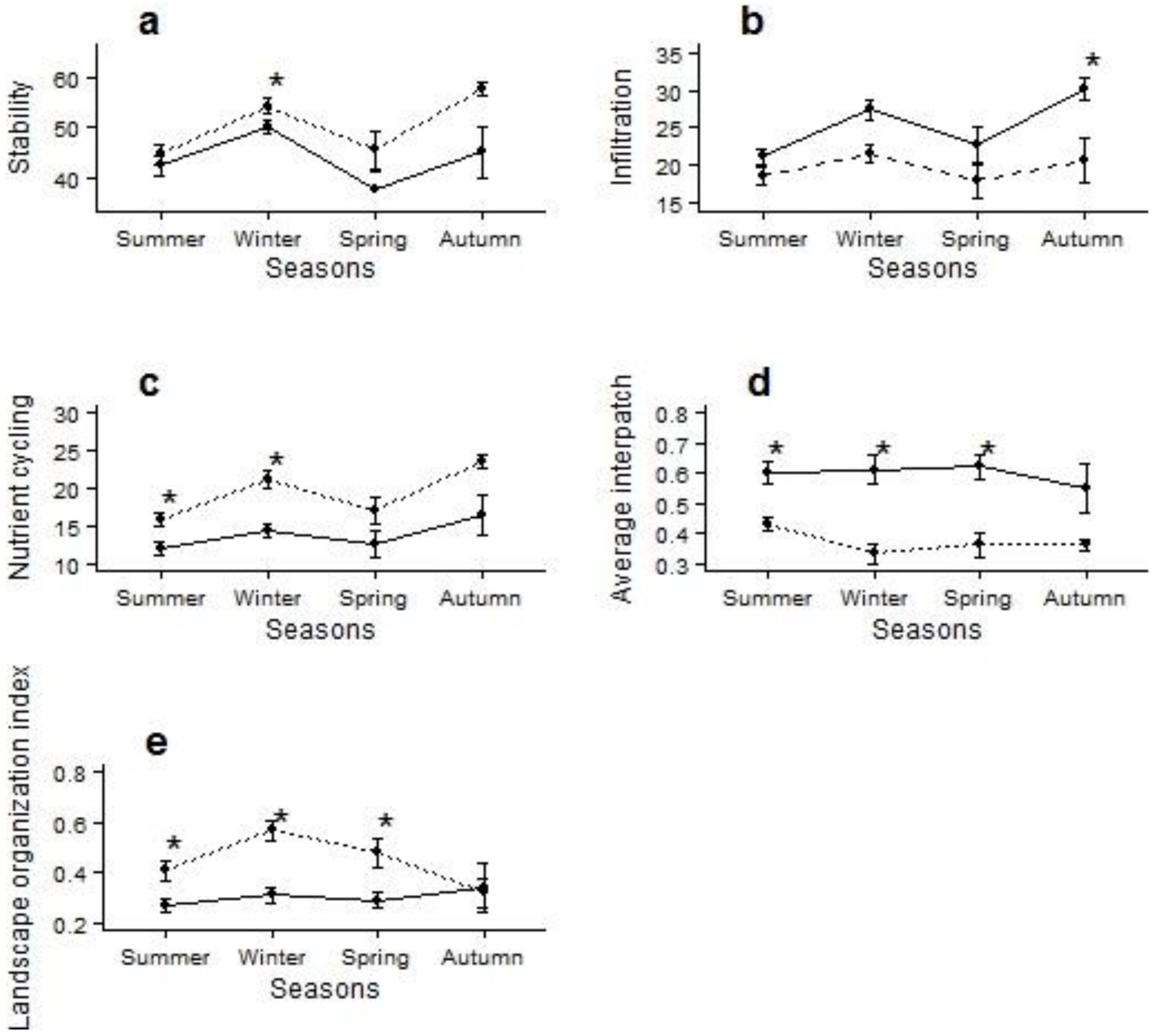

Figure 3. 7: Seasonal variation between landscape organization and soil surface assessment indices. * indicate the significant statistical difference, broken line indicate intact areas and solid line indicate degraded areas.

3.6 Discussion

3.6.1 Landscape organization

We found clear differences between the intact and degraded areas in terms of landscape structure and functioning. Dysfunctional grasslands are characterized by a high number of inter-patches resulting in little regulation of overland flow, and the transport of mobile resources out of the landscape (Tongway and Hindley, 2004). The average inter-patch indicated the possibility of the resources being leaked out of the system due to lack vegetation cover or fewer patches to retain resources (Ludwig et al., 2004). The presence of disturbance (grazing, trampling and fire) might be the cause of smaller vegetation patches and inter-patches (Ludwig et al., 2004). The degraded area may be functioning less than the intact area, due to the increased bare ground, reduced ground cover and decreased surface roughness.

The absence of inter-patches in a landscape contributes more to the landscape functioning because the resources are stored within the system with fewer chances of erosion. Patches act as obstructions for slowing down and capturing overland flow, providing soils with physical stability (Yao et al., 2009) and thereby prevent soil erosion. Significant differences between the patches and inter-patch in both intact and degraded area is evident (Palmer et al., 2001). The intact area displayed fully functional resources control with fewer inter-patches. The difference between the intact and degraded area reflects an increase in heterogeneity of resource control appearing at varying intensity (Palmer et al., 2001).

3.6.2 Ecosystem Function

High stability values indicated the presence of organic matter that was being incorporated into the soil, thus improving soil structure and the presence of roots which bind the soil (van der Walt et al., 2012). Studies done by Furniss (2008), and McIntyre and Tongway (2005) found that the stability index value remained constant and high. This corresponds with the current study where stability was high including the disturbed sites. Stability in all landscape zones showed a most stable crust, which indicated that the soil is in good condition. Dowo et al. (2013) noted that high stability also means that the soil maintains its cohesion even when wet, thereby preventing erosion. The crusted soil, with no biological residues visible soil fauna, are unlikely to occupy such poor quality soil due to its hardness and lack of organic substrate (Ludwig et al., 2004), both in the intact and degraded area there was no evidence of fauna presence in the bare soil.

The intact areas had high vegetation cover which played a role in preventing run off and increasing the infiltration rate. Litter cover, degree of decomposition and basal cover are known to be the basic functionality indicators that determine the capacity of infiltration (van der Walt., et al 2014). Nutrient cycling on the intact area was favoured by the widespread vegetation cover that contributes to litter accumulation which allows the cycling of organic materials. The degraded areas with low vegetation cover and less litter accumulation led to low levels of nutrient cycling. Bare soil contributed less to nutrient cycling due to the absence of vegetation cover and litter cover, the low basal cover allows important resources to be lost from the system, instead of being integrated into the soil (van der Walt et al., 2012).

Rezaei et al., (2006) argued that high infiltration index did not mean that the soil could store infiltrated water. Similarly, a high stability index does not mean high soil production, but high resistance to erosion, but if high stability occurs with high nutrient cycling and landscape organization indices, this generally reflects extensive vegetation cover (Furniss, 2008; Rezaei et al., 2006). The soil surface assessment indices represent surrogates for, not direct measurement of stability, infiltration, and nutrient cycling and are suitable surrogates of environmental degradation (Furniss, 2008; McIntyre and Tongway, 2005).

3.6.3 Seasonal Variation

Landscape function analysis is a dynamic process that fluctuates over time. There is a strong seasonal variation in landscape vegetation structure and function. This large seasonal variation emphasizes the importance of monitoring in the same season each year (Pauw, 2011). Increased vegetation cover would increase infiltration by acting as a barrier to surface flow increase and increased in soil moisture would result in high soil biological activity (Furniss, 2008). Winter season is where the disturbance is most visible, both seasonal vegetation growth and annual species are absent (Furniss, 2008). In winter patch decreases in size because of insufficient moisture to sustain the whole patch. The scale of patch/ inter-patch may change in response to rainfall (Tongway and Hindley, 2004). Varying seasonal condition over time ultimately results in a band of values that acts as a target region for rehabilitation (Sharp, 2011). The Landscape Function Analysis method, therefore, provides a means to identify the change in landscape processes that are easily and quantitatively measured, and can be compared overtime (Sharp, 2011).

3.6.4 The applicability of Landscape Functional Analysis

The methods selected for monitoring were limited to those describing composition and structure (Tongway and Hindley, 2004). Functional attributes of the ecosystem were not directly addressed, and these methods were not designed to prescribe rehabilitation (Tongway and Hindley, 2004). Landscape function analysis is suitable for measuring and monitoring different landscapes types and land uses, as such it complements the existing methods that assess the condition (Pauw, 2011; Tongway and Hindley, 2004). The LFA is a rapid, easy and effective method for measuring the structural characteristics and landscape function (Siroosi et al., 2013), it is also recommended as a key component for ecosystem function analysis (Kapalanga, 2008). The method is repeatable and consistent and is specifically assigned to meet individual expectations. Additionally, LFA can be easily communicated and learned. LFA approach is good to help managers to know trends, current status and what is being lost from the system (Kapalanga, 2008).

3.6.5 Limitations

The limiting factor of this technique is the spatial scale at which it is performed typical at transect between 20 and 100m long (Lau et al., 2008). The scale of the site and location of transect may be an issue as transect might only take into account a very small section of the entire landscape (Randall, 2004). Data may show that the site is doing well, and there may be erosion or gullies that were not captured on the transect point. This issues raises the need to continue site inspection and carefully analyze the location of the proposed transect (Randall, 2004). Although it might be less time-consuming than empirical techniques, it still involves many person-hours to collect field data and interpreting the results can be tricky and relatively complex (de Abreu, 2011).

3.6.6 Landscape Function analysis in other systems

Intact and degraded states of the same vegetation type may support similar biomass and have same levels of cover during the growing seasons (Thompson et al., 2009) which limits the use of LFA in other rangeland systems. LFA was also found unsuitable for detecting changes in critical landscape functional attributes that drive vegetation change within the succulent karoo biome (de Abreu, 2011; Petersen et al., 2004). Other studies which used and tested the abilities of LFA method in South Africa concluded that the LFA was not suitable for detecting changes in landscape function within the Nama-karoo biome and Bushveld vegetation in the Eastern Cape (de Abreu, 2011; Palmer et al., 2001, Petersen et al., 2004). Therefore, when applying the LFA method to such systems other techniques such as the Quick Rangeland Health Assessment method should be considered (de Abreu, 2011).

3.7 Conclusion

The study found that LFA method can be used as a tool to detect the landscape functioning and differentiate between the intact and the degraded areas. The different types of patches and inter-patch were identified in all sites as the main factors determining the differences in the functionality between the sites (intact and degraded). The landscape organization indices and the SSA indices played the most important roles in contributing to the knowledge of the landscape functioning. The LFA indices are successful in studying and evaluating the soil surface conditions and its properties as well as the dynamics of vegetation cover in different environments, however, some of the indices measured varied greatly according to season and landscape conditions. The intact areas were more functional compared to the degraded areas which indicate that intact area was more vegetated and the measured indices were highly functioning. The information provided by LFA is of great use when comparatively evaluating the functional status of a landscape resulting from the various land uses and management actions. Landscape function analysis indices are the powerful tool to assess the potential of the landscapes to deliver the ecosystem services in changing environment.

CHAPTER 4: The impact of herbivore exclusion on landscape function in Mount Fletcher, Southern Africa

4.1 Abstract

Overgrazing is one of the key factors causing grassland degradation. Fencing to exclude stock is widely regarded as a simple restoration method of degraded rangelands. Excluding livestock is considered as an alternative technique to rehabilitate the disturbed vegetation. The aim of the study was to determine the short term effect of grazing exclusion on landscape functioning and vegetation cover. Data were collected between the years 2012 and 2015, in exclosure and continuously grazed area so as to determine whether there were differences between the areas and the effect of fencing. The landscape function analysis method which uses the landscape organization and soil surface assessment indices reflecting the structural organization and functional status of the area was employed. The results showed that the LFA indices inside the exclosure plots were improved, in terms of ground cover and functioning. The t-test result was significant in some of the indices (landscape organization index, total patch area and infiltration) and not significant in number of patches/10m, average inter-patch, stability and infiltration. The results indicated that grazing exclusion is an effective measure for improving the above ground cover. Fencing is an important first step for conserving threatened grasslands, but more active management may be needed to enhance grasslands recovery.

Keywords: Fencing, grazing, indicators, landscape function analysis, restoration.

4.2 Introduction

Many arid and semi-arid grassland throughout the world have experienced a shift in dominant vegetative composition from perennial grasses to shrubs and bare soil (Castellano and Valone, 2007). Grazing is one of the most important factors influencing community structure and productivity in natural grasslands (Wu et al., 2009; Yong-Zhong et al., 2005). Grazing increases spatial heterogeneity of the communities and alteration of community function (Wu et al., 2009). The effects of overgrazing on the plant community and soil are considered destructive because of the reduction of herbaceous canopy cover, degradation of topsoil structure and compaction of soil as a result of trampling and grazing (Yong-Zhong et al., 2005). According to Bartley et al. (2010) in many grazing areas, land has become degraded, resulting in reduced pasture productivity and also poor water quality. Excess sediments and nutrients can also impact the water quality (Bartley et al., 2010). Intense trampling and grazing by livestock can destroy patches (Ludwig and Tongway, 1995). The loss of small scale patches alters dynamics of runoff and erosion by increasing inter-patch size (Ludwig and Tongway, 1995). Uneven animal distribution and excessive plant consumption can produce irreversible ecosystem degradation even in productive ecosystems (Castellano and Valone, 2007; Cingolani et al., 2014).

Restoration of degraded grassland ecosystems has attracted attention in recent decades and it has become more important to understand the function and ecological structure of the vegetation of restored grasslands (Haagner, 2008; Jing et al., 2013). Grassland restoration usually focuses on several key components: vegetation composition, structure and function, soil composition, and the community succession process (Jing et al., 2013). Grassland restoration aims to achieve a plant community that stabilizes the soil surface against water and wind erosion, is productive for animal production and resilient for grazing (Jing et al., 2013). This usually involves operation such as excluding livestock grazing and planting indigenous species to improve quality and quantity of forage and livestock products.

Rotational grazing has been practised for many decades, with rest periods being based on the growth rate of the pasture and these vary depending on the seasons and weather conditions (Smith et al., 2011; Undersander et al., 2002). The exclusion of livestock through the use of “mesh” fencing to create large scale exclosure has become a common grassland management practice throughout the world (Spooner et al., 2002; Wang et al., 2014; Wu et al., 2009). Grazing exclusion is an effective grassland management practice that aims to prevent degradation and retain ecosystem function (Yan and Lu, 2015). Excluding grazing livestock is considered an effective method and an important way to restore vegetation, increase litter accumulation, improve water infiltration and improve soil fertility in these degraded ecosystems (Jeddi and Chaieb, 2010; Spooner et al., 2002; Yong-Zhong et al., 2005).

A number of techniques have been developed to quantify ecosystem functioning, and they are based on measuring the structural attributes of vegetation and soil surface characteristics (Gaitána et al., 2013). One of these methods that have attracted most attention to date is the landscape function analysis (LFA), developed in Australia by David Tongway and co-workers (Gaitána et al., 2013; Tongway and Hindley, 2004). LFA is a monitoring procedure that assesses how well an ecosystem functions as a biophysical system through the use of visually assessed indicators (Dowo et al., 2013; Lau et al., 2008). Specifically LFA aims on determining ecosystem functioning such as nutrient and water retention (Zucca et al. 2013).

The exclusion of herbivore management strategy is expected to restore vegetation and improve landscape function in overgrazed areas characterised by lower vegetation cover, exposure to erosion and poor landscape function (Jeddi and Chaieb, 2010; Yan and Lu, 2015). The aim of the study was to determine the effects of excluding grazing herbivores using landscape function analysis to detect change in ecosystem functioning. We hypothesized that herbivore exclusion will enable vegetation to recover and attenuate soil erosion. We compared the effects of continuous grazing and exclusion of livestock by measuring changes in vegetation cover and ecosystem functioning using LFA.

4.3 Materials and methods

4.3.1 Study area

The data were collected during April 2012 and May 2015 (Figure 4. 1) in Mount Fletcher (Vuvu location) 30°36’11.93”S and 28°14’32.31” Figure 4.2. A total number of 24 plots with one transect per plot were sampled. Exclosure plots were established in 2012 in order to take out medium to large herbivores that could negatively impact the areas to be rehabilitated, and allowing the vegetation to rest and recover. Data were collected from two areas: (1) the continuously grazed area, which represented the control (12 plots) and (2) the exclosure plots (12 plots), which represented the treatment, this was done in order to evaluate the effect of grazing exclusion. The exclosure plots (treatment) and the continuously grazed area (control) were in close proximity and were located in the same homogenous ecological unit in order to determine the vegetation cover.

Figure 4. 1 The exclosure plots 2012 and 2015

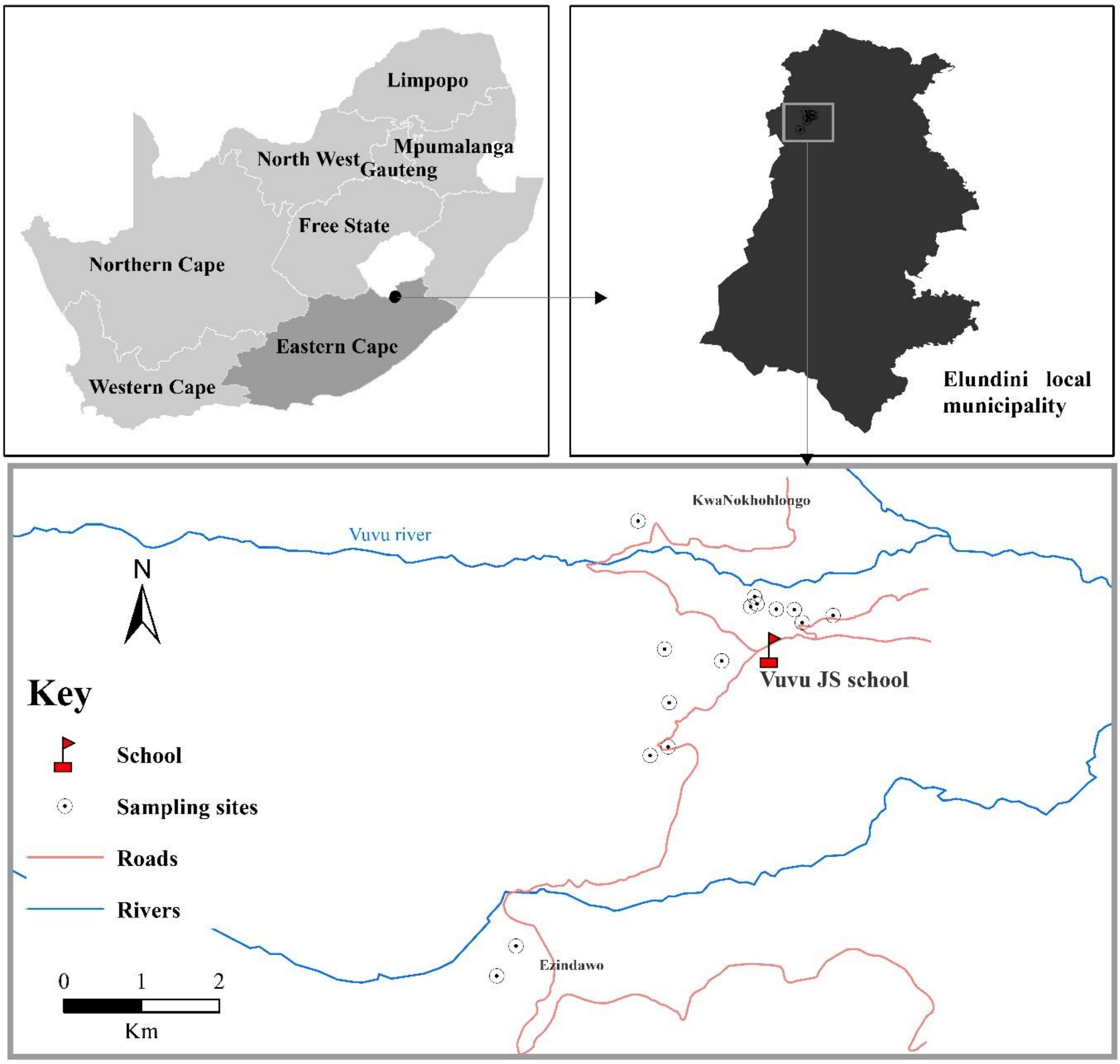

Figure 4.2: Location of study sites, Elundini municipality and the Eastern Cape province of South Africa.

4.3.2 Landscape organization

Data were collected on a 30 m line transect oriented on the direction of resource flow (usually downslope). The transect line was divided into patches (features that divert or absorb runoff and transported materials), and inter-patches (features or typically zones of resource loss), these were recorded according to protocols outlined in Tongway and Hindley, (2004). The size (length and width), characteristics of each patch/inter-patch were identified and scored according to the type of resource regulating structure, the inter-patch width was not measured (Figure 4.3).

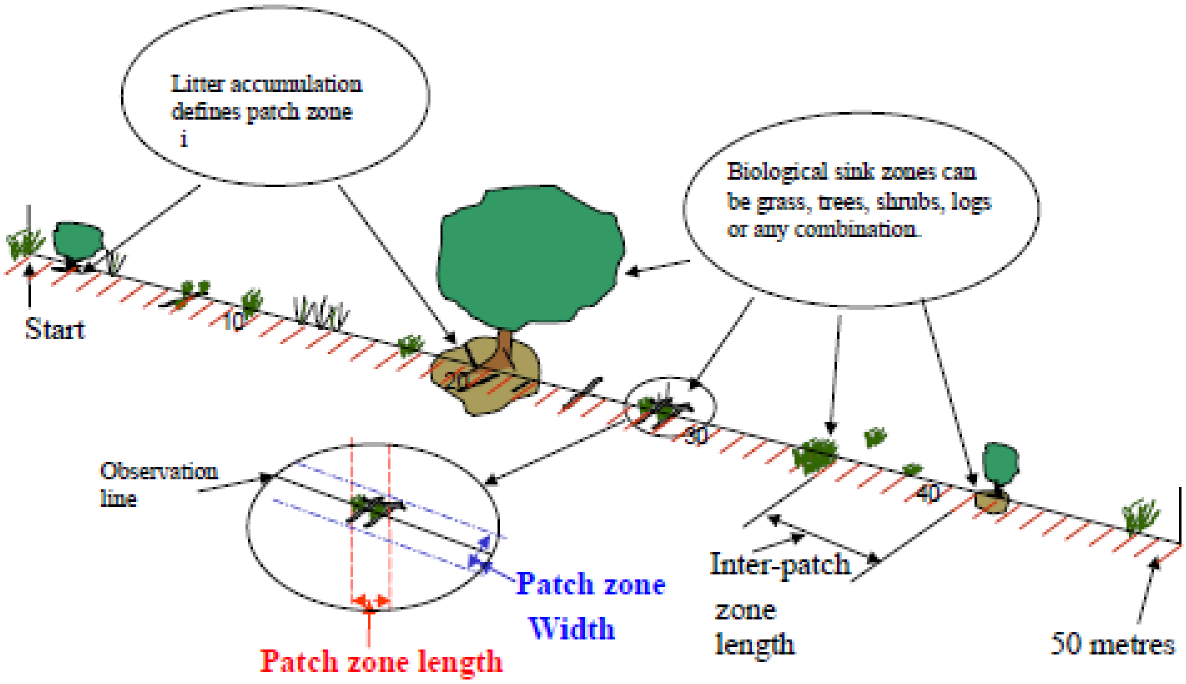

Figure 4.3: An illustration of landscape organization steps, showing the transect set out in the direction of resource flow (Tongway and Hindley, 2004).

4.3.3 Soil surface assessment

In addition to the data representing the landscape organisation, eleven soil surface indicators were assessed for each patch/ inter-patch type identified along the transect. The eleven indicators are: soil cover, litter cover, canopy cover, cryptogam cover, crust brokenness, soil surface roughness, surface resistance to disturbance, erosion type, deposited material, slake test and soil surface texture, (Tongway and Hindley, 2004). The soil surface indicators were assessed into five replicates which represent the query zones located in each patch/inter-patch identified, e.g. five grassy forb patch were selected along the line transect where the soil surface assessment was carried out and every soil surface indicator was evaluated and given a class value based on guidelines and images provided by Tongway and Hindley, (2004). Soil surface indicators were combined into three major indices which are soil stability, infiltration rate and nutrient cycling (Tongway and Hindley, 2004).

4.4 Data analysis

For analysis and comparisons, seven LFA indices (landscape organization index, average inter-patch length, total patch area, number of patches per 10 m, stability, infiltration and nutrient cycling) were selected on the basis of their contribution to functional and structural aspects of landscape. A t-test was used to test whether there were significant differences $P < 0.05$ in selected LFA indices between the exclosure plots and continuously grazed areas for the period of 2012 and 2015. The LFA indices were also analysed using Non-Metric Multidimensional Scaling (NMDS) to examine changes between 2012 and 2015. This ordination technique was used to view the changes over time of the LFA indices. For the NMDS, we included the following variables: landscape organization index, average inter-patch length, total patch area, number of patches per 10 m, stability, infiltration and nutrient cycling, these were a combination of structural and functional indices.

4.5 Results

4.5.1 Landscape organization

Landscape organization index was significantly different between the years, for both exclosure and continuously grazed areas (Figure 4.4). Landscape organization indices improved by 2015 in the exclosure plots, and nearly reached the same values as the control (continuously grazed areas). The total patch area increased significantly by 2015 on the exclosure, with the continuously grazed area there was no significance on the total patch area.

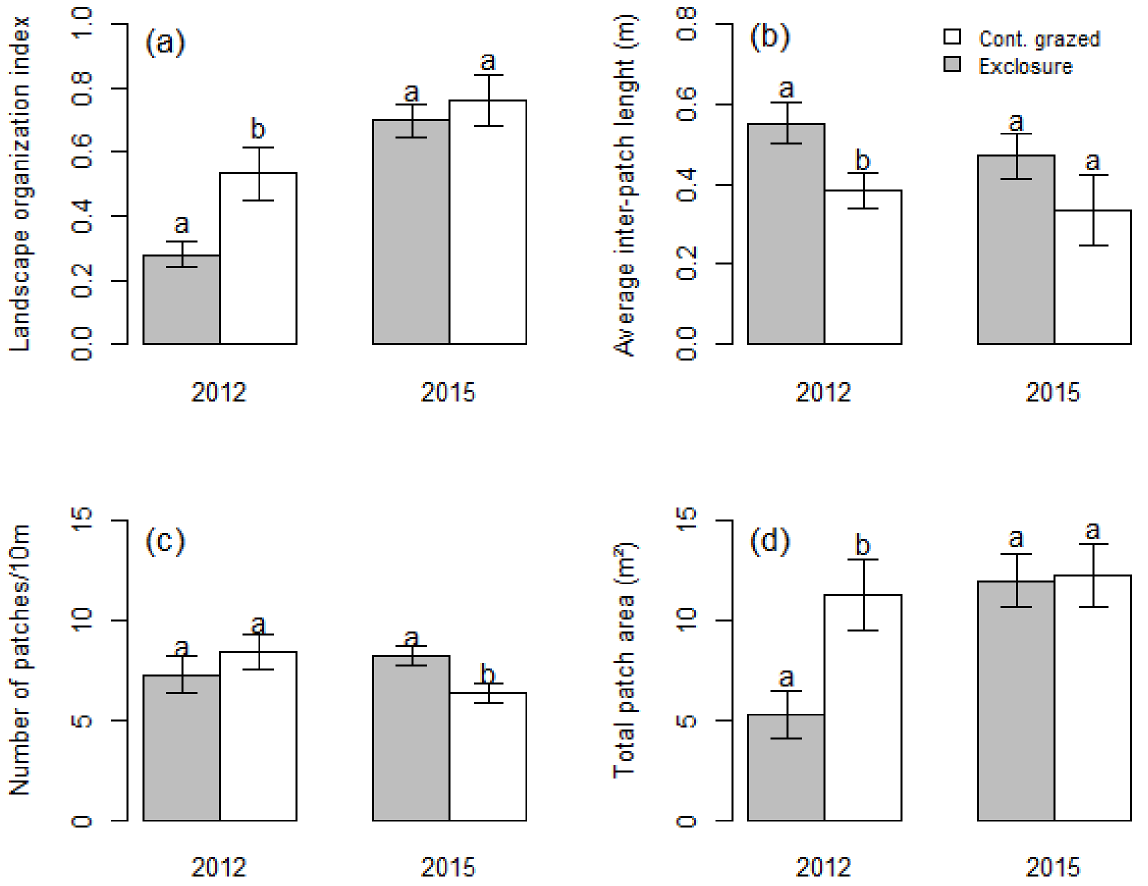

Figure 4.4: Values of selected LFA indices between the exclosure plots (EX) and continuously grazed areas (CG) for 2012 and 2015. a) Landscape organization index, b) Average inter-patch, c) Number of patches/10m and d) Total patch area. Different letters represents significant differences $P < 0.05$ in the LFA indices while similar letters show non-significant differences.

4.5.2 Soil surface assessment for exclosure plots and continuously grazed areas

There was an improvement of ecosystem functioning for exclosure plots. Nutrient cycling, stability and infiltration have increased from 2012 to 2015, mostly in grass forb patch (GFP) and grass patch (GP) Figure 4.5. No major differences were found in other types of patches. We also found slight variations in ecosystem functioning for continuously grazed areas (control) but most of these were not significant (Figure 4.6) .

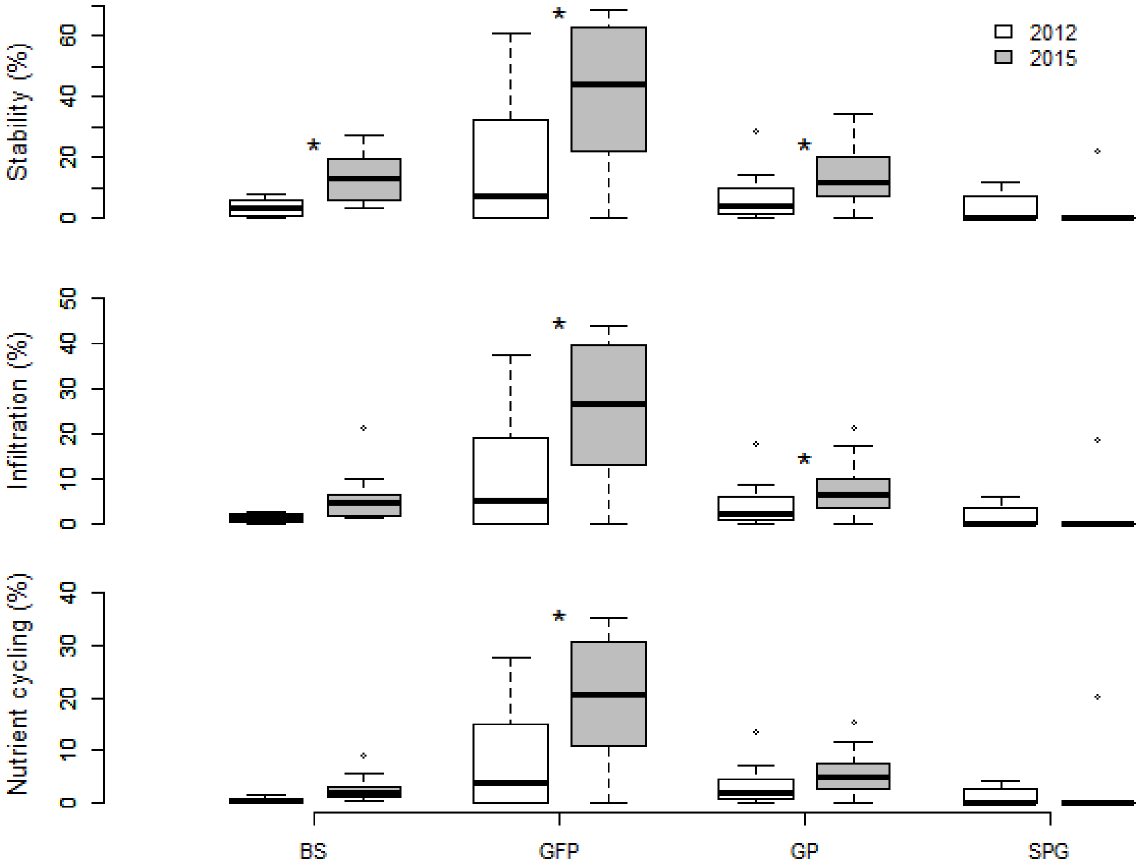

Figure 4.5: Comparison of stability, infiltration, nutrient cycling per landscape zone (grass patch (GP), grass forb patch (GFP), sparse grass patch (SGP) and bare soil (BS).* indicate significant difference P < 0.05.

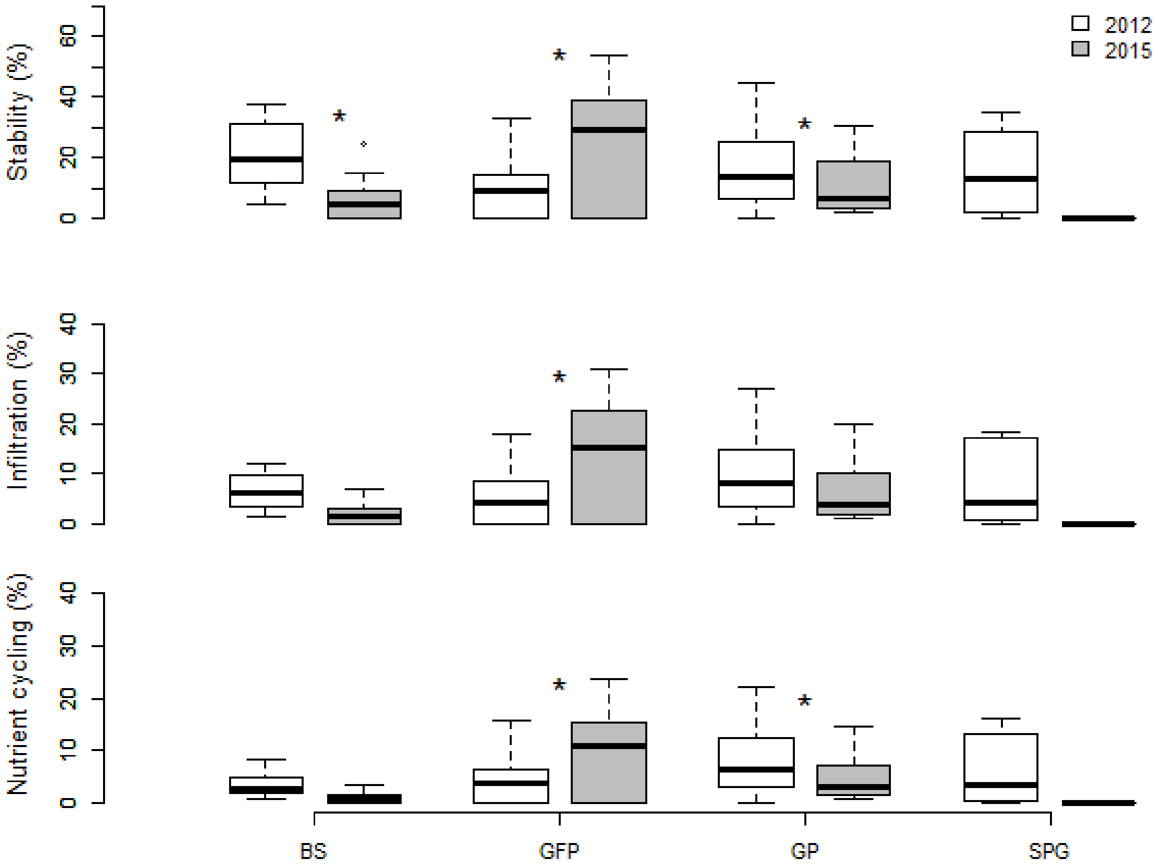

Figure 4.6: Comparison of stability, infiltration, nutrient cycling per landscape zone (grass patch (GP), grass forb patch (GFP), sparse grass patch (SGP) and bare soil (BS). * indicate significant difference P < 0.05.

4.5.3 Non-Metric Multidimensional Scaling

Direct comparison of the landscape organisation and soil surface assessment indices (landscape organization index, total patch area, number of patches/10m, stability, infiltration and nutrient cycling) showed that the change has taken place during the time of the survey Figure 4. 7. The NMDS output of the LFA indices exhibits some grouping by site, the numbers represent the sites number and how it has changed between the years. In 2015 the indices moves towards the right side and in 2012 towards the left side within the exclosure plots this indicate that there is an improvement of the indices both structural and functional. Within the continuously grazed areas the indices in 2015 moves towards the left side becoming closer to 2012 this indicate that there is uniformity of the indices which this might indicate a negative impact in the continuously grazed areas.

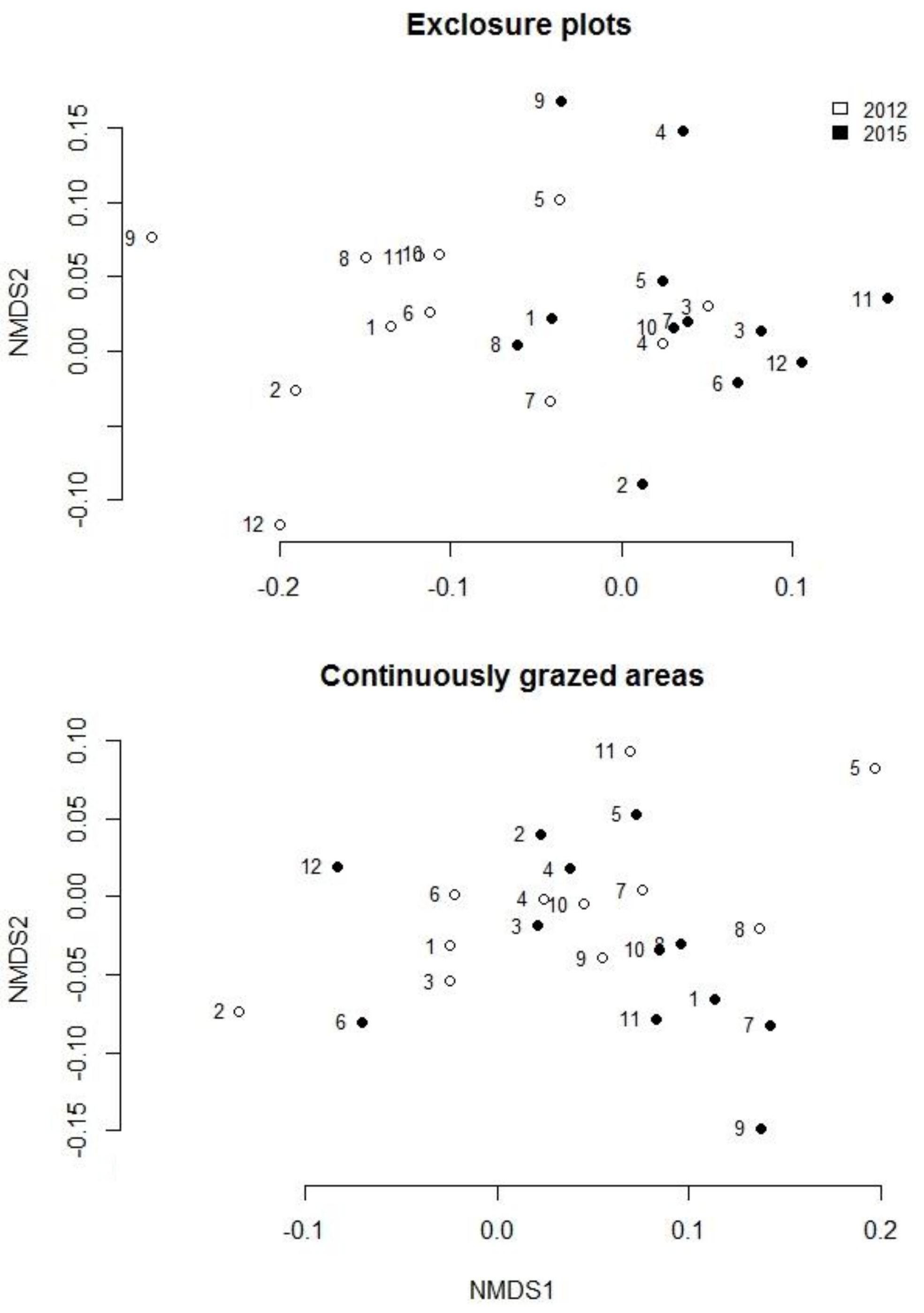

Figure 4. 7: Multivariate analysis based on LFA indices (landscape organisation index, average inter-patch, total patch area, number of patches per 10 m, stability, infiltration and

nutrient cycling**.** between exclosure plots and continuously grazed areas for the period between 2012 and 2015.

4.6 Discussion

The results of the present study support previous studies that found benefits of grazing exclusion (Spooner et al., 2002). The adoption of livestock exclusion practice had a profound impact on vegetation recovery and in turn on litter accumulation and improvement of soil fertility (Yong-Zhong et al., 2005). The increased ground cover following exclusion of livestock effectively protected soil from loss by wind erosion (Yong-Zhong et al., 2005). According to Good et al., (2013), grazing exclusion in pasture patches maintained the high amount of vegetation cover. The increase in grass cover concurrently increases water infiltration whereas the reduction in grass cover concurrently reduces water infiltration and nutrient cycling (Castellano and Valone, 2007). The study showed that vegetation cover changes more rapidly by increasing the number of patches, as compared to landscape functioning which takes time to change. Based on the results there was a slight change with landscape functioning, further monitoring is needed to understand how long will it take for the landscape to function fully.

The landscape organization and soil surface indices had improved in the exclosure plots by 2015, which shows that the effect of grazing exclusion became more pronounced over time. The response of vegetation cover to grazing exclusion varied between patches and inter-patches, vegetation cover increased following grazing exclusion in patches but not in inter-patches (Good et al., 2013). The results of the study indicated inter-patches did not respond to grazing exclusion. Physical crusting of the soil surface leading to reduced infiltration increased runoff, and low nutrient retention may maintain inter-patches in an unproductive state by preventing the occurrence of seedlings (Good et al., 2013; Smith et al., 2013).

The effects of grazing on inter- patches may have stabilized and the effect of ongoing grazing on the system is uncertain (Good et al., 2013; Smith et al., 2013). Such uncertainties also suggest that longer-term studies of grazing exclusion will be necessary to determine the impact of current grazing regimes on vegetation cover (Good et al., 2013). Three years of grazing exclusion from this study might not have been adequate time to capture the long-term trajectory of inter-patches. Loss of perennial patches characterizes landscape systems that are becoming dysfunctional (Kakembo et al., 2012; Ludwig et al., 1999). The continuously grazed area showed some slight changes which indicated that if grazing continues without proper management there will be a problem in future.

Vegetation patches play an important role in resources capture, accumulation of organic matter and utilization of runoff (Good et al., 2013; Kakembo et al., 2012; Ludwig et al., 1999). Fencing exclusion resulted in an increase in the continuous dense cover of grasses, this has allowed high retention of soil moisture, improved stability, and enhanced infiltration and improved nutrient cycling. The decrease in the infiltration was associated with a decrease in the grass cover (less patch density and greater inter-patch length) which would increase the surface water run-off (López et al., 2013). Similarly, a decrease of the nutrient cycling process would be associated with soil and organic matter loss due to erosion and lower contribution of vegetation due to less grass cover and biological activity (López et al., 2013). An increase in stability index could be due to the protective effect of the soil cover to erosive agents and high connectivity of patches (López et al., 2013).

4.7 Conclusion

The restoration of degraded grassland ecosystems is a complex and a long term ecological process (Yan and Lu, 2015). Vegetation cover is an important index for measuring the protective function of vegetation to the ground. The composition of patches and inter-patches and the relative contributions of these to the landscape function were well discerned from the data. It was established that ground cover played the greatest role in maintaining the landscape function. These results demonstrated that grazing exclusion is an effective measure for maintaining the landscape functioning and improving above ground cover in the exclosure plots. However, the continuously grazed area did not show much change. Long term observation may be necessary to assess the ecological effects of grazing exclusion management strategies in the degraded areas. Therefore, there is a need for continued research on the role of herbivore exclusion on grassland restoration, management, and utilization in future.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

5.1 Introduction

South African grasslands are facing increased habitat loss and fragmentation and have become one of the most threatened vegetation types in South Africa making them a priority for conservation efforts (Parr et al 2014 et al., 2014). Restoration can be used both as a tool in the conservation of grasslands and to improve our understanding of this system (Zaloumis and Bond, 2011). Restoration is a useful tool in conservation and can be used to help towards preserving threatened ecosystems when formal conservation protection is not possible (Neke and Du Plessis, 2004). As with all rangelands, the question remains of how to balance the demands of human livelihood with sustainable management (Lechmere-Oertel, 2003). The major challenge faced by land managers is to optimize the level of utilization for the benefit of grassland to remain fully functional to satisfy the needs of today and future generations (Kemp and Michalk, 2011).

According to Siroosi et al. (2012) patch size may change overtime reflecting either improvement or degradation in a landscape function. If inter-patches are present they can usually be assigned to a descriptor (e.g grazing, trampling) (Sharp, 2011; Smith et al., 2011). Patches may also degrade to form inter-patches when resources such as vegetation cover are lost, conversely inter-patches may improve in landscape function, if obstructions such as vegetation that trap resources become established (Sharp, 2011).

Landscape function analysis method is based on vegetation patch quality and quantity as surrogates for resource retention, and LFA can simply be measured by the cover (intactness) and condition (quality) of vegetation patches zones (Ludwig et al., 2004). Ground-based measurement of landscape integrity using the LFA procedure is now established as part of many agencies' rangeland monitoring programs (Ludwig et al., 2004). LFA closely examines the condition of vegetation soil surfaces (patch quality), and it measures the cover and number of perennial vegetation patches (quantity) (Ludwig et al., 2004). The LFA analyses presented a clearer picture of the processes that shape and maintain the landscape function of the area. It was established that vegetation played the greatest role in maintaining landscape function.

The landscape organization and the soil surface assessment indices were important in all habitats.

The results have indicated that an understanding of landscape structure, sheds light on landscape functioning. Additionally, an understanding of landscape patchiness and the process that maintain them has important implications for land management (Ludwig et al., 1999). Landscape organization index is the proportion of all patches and is considered as a good indicator of vegetation cover (Rezaei et al., 2006). From the current study the landscape organization index was higher on the intact areas which show that the intact areas had more patches compared to degraded areas. Patches in the intact areas indicated to have high levels biological assimilation, accumulation and decomposition (Ludwig and Tongway, 1995).

Dysfunctional landscapes are recognized by reductions in small-scale patchiness and bare soil, where patches are habitats for large suites of the organism (Smith et al., 2013). The degraded areas from the current study, indicated a dysfunctional landscapes which have lost the spatial organization of vegetated fertile patches and much of their reserve as nutrients and organic matter. Furthermore, the landscape loses its ability to capture, store and recycle water and nutrients (Lechmere-Oertel et al., 2005). The key nutrient is likely to be lost at the landscape scale as grazing increased, rather than just being redistributed, and water infiltration decreased due to lack of barriers to trap water so as to reduce run off (Sparrow et al., 2003). Heavy grazing intensity reduces plant biomass, which overrides variable selection pressure by livestock and inherent landscape heterogeneity, with the result being a homogenous structure in which most plants have been defoliated (Ludwig and Tongway, 1995).

Herbivore exclusion was applied in the study, the results are indicated in chapter four. Fencing was applied to assess the effectiveness of excluding herbivores in a landscape and to determine the changes in ground cover and landscape functioning. The results indicated that values of LFA indices inside the exclosure plots were greater than to the previous indices highlighting the important role of fencing. All the landscape values obtained from the exclosure plots were higher than those of the continuously grazed area due to dense vegetation cover of grasses. This has led to high retention of soil moisture, enhanced infiltration, high volumes of below ground biomass and nutrients in the soil from the breakdown of annual biomass (Kanmantoo, 2013).

Studies which tested the utility of LFA techniques in South Africa have reported mixed outcomes. Some studies remarked the suitability of LFA for detecting changes in landscape functional attributes in rehabilitation of mines e.g (Haagner, 2008; van der Walt et al., 2014) while others found LFA unsuitable for detecting changes within the succulent Karoo biome, Nama Karoo and within bushveld vegetation in the Eastern Cape (de Abreu, 2011). This study supports the use of LFA in grassland systems of the Eastern Cape.

The LFA indices which are based on subjective scored ordinal data are very complex to interpret (de Abreu ., 2011). The LFA landscape organization indices are however based on continuous data (de Abreu, 2011) and in the current study LFA was found useful in characterizing the site in terms of resource capture and loss. The soil surface assessment (stability, nutrient and nutrient cycling) showed inconsistent results from the study and did not seem useful for measuring differences in water and organic matter retention. Therefore SSA indices need to be validated with other experiments (de Abreu, 2011; Rezaei et al., 2006; Tongway and Hindley, 2004).

5.2 Conclusion

The important idea in landscape development has always been that people are part of the landscape and those landscapes are changed for their benefit. Living organisms cannot survive independently from their environment, but are continually influenced by it and in turn affect the environment. Productivity and stability of a rangeland ecosystem are determined by the potential of biotic and abiotic components as well as the manager’s ability to utilize driving forces as a system to decrease risks. For sustainable animal production, the rangeland ecosystem must be managed in such a way that output never exceeds input and erosion must be limited. The success of a landscape management program is determined by the involvement of the community. Therefore it is important to educate and empower the communities about the ecological processes and linkages within the landscape and on how to restore their land.

5.3 Recommendation

The current study forms part of an ongoing rehabilitation monitoring program in watershed areas of uKhahlamba in Mount Fetcher, in the Eastern Cape Province, South Africa. This study can be used as a baseline for future studies. It is recommended that annual monitoring of landscape functioning is conducted, using the LFA method, as it can supply very useful information on the status and development of ecosystem functioning in restored sites over time.

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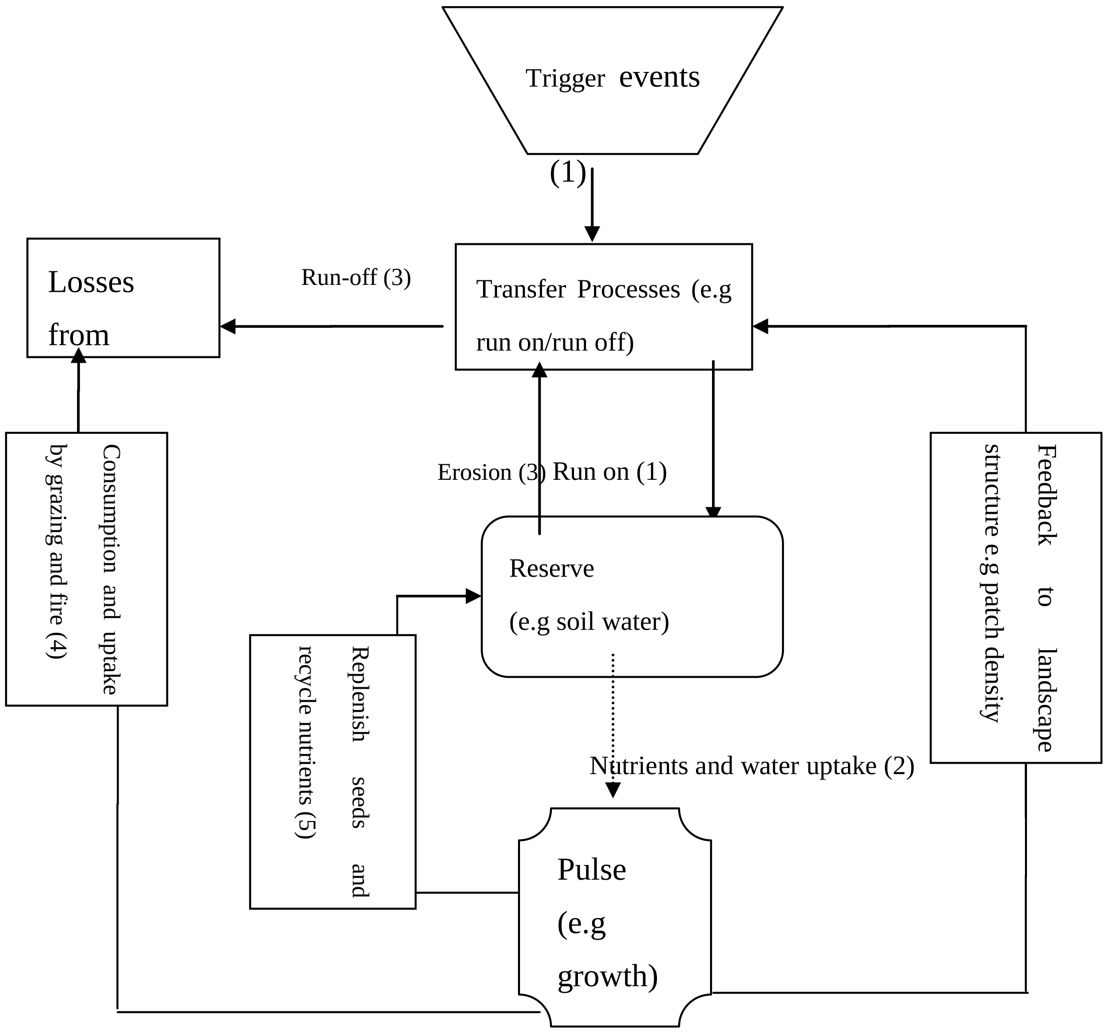
APPENDIX 1: The trigger-transfer-reserve-pulse (TTRP) conceptual framework representing the sequence of ecosystem processes and feedback loops.



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APPENDIX 2: Scoring method of the eleven soil surface assessment (SSA) indicators

1. Rainsplash protection

Projected Cover	Class	Interpretation
1% or less	1	No rainsplash protection
1 to 15%	2	Low rainsplash protection
15 to 30%	3	Moderate rainsplash protection
30 to 50%	4	High rainsplash protection
More than 50%	5	Very high rainsplash protection

2. Perennial vegetation cover

Basal and Canopy Cover	Class	Interpretation
1% or less	1	Very low root biomass
1 to 10%	2	Low root biomass
10 to 20%	3	Moderate root biomass
More than 20%	4	High root biomass

3. Litter, origin and degree of decomposition

% Cover of plant litter	Class
<10	1
10-25	2
25-50	3
50-75	4
75-100	5
100 up to 20 mm thick	6
100, 21-70 mm thick	7
100, 70-120 mm thick	8
100, 120-170 mm thick	9
100, > 170 mm thick	10
Litter Origin	**Symbol**
local	l
transported	t
Litter Decomposition	
Nil decomposition	n

Slight decomposition	s
Moderate decomposition	m
Extensive decomposition	e

4. Cryptogam cover

BSC Cover	Class	Interpretation
Not applicable	0	No stable crust present
1% or less	1	No contribution
1 to 10%	2	Slight contribution
10 to 50%	3	Moderate contribution
More than 50%	4	Extensive contribution

5. Crust brokennes

Crust Brokenness	Class
No crust present	0
Crust present but extensively broken	1
Crust present but moderately broken	2
Crust present but slightly broken	3
Crust present but intact, smooth	4

6. Soil erosion type and severity

Erosion Severity	Insignificant	Slight	Moderate	Severe
Erosion Type	Class	Class	Class	Class
Sheeting (E)	4	3	n/a	n/a
Pedestal (P)	n/a	n/a	2	1
Terracette (T)	n/a	n/a	2	1
Rill (R)	n/a	n/a	2	1
Scalding (S)	n/a	n/a	n/a	1

7. Deposited material

Deposited Material	Class
Extensive amount present. Greater then 50%	1
Moderate amount of material present 20 to 50%	2

Slight amount of material present, 5% to 20% cover	3
None or small amount of material present, 0-5%	4

8. Soil surface roughness

Surface roughness	Class	Interpretation
<3 mm relief in soil surface.	1	Smooth: little or no detained materials
Shallow depressions 3-8 mm relief.	2	Low but visible detention
Deeper depressions 8-25 mm	3	Moderate visible detention
Deep depressions that have a visible base	4	Large visible detention
Very deep depressions or cracks >100mm.	5	Extremely high retention

9. Surface resistance to disturbance

Surface Nature	Class	Interpretation
Non -brittle	5	Surface has no physical crust
Crust is very hard and brittle	4	Needs a metal implement to break the surface, forming amorphous fragments or powder. The sub-crust is also very hard, coherent and brittle.
Moderately hard	3	Surface is moderately hard, may have a physical crust, and needs a plastic tool (e.g. pen-top) to pierce, breaking into amorphous fragments or powder; the sub-crust is coherent.
Easily broken	2	Surface is easily penetrated with finger pressure (to about first knuckle joint). Surface may have a weak
Loose sandy surface	1	Surface is not crusted, easily

		penetrated y finger pressure to about second knuckle joint

10. Slake test

Observed Behaviour	Class	Interpretation
Not Applicable	0	No coherent fragments available e.g. loose sand
Very unstable	1	Fragments collapses in less then 5 seconds.
Unstable	2	Fragment substantially slumps in 5-10 seconds but a thin surface crust remains: >50% of the sub-crust volume slakes
Moderately stable	3	Surface crust remains intact with some slumping of the sub-crust but less then 50% of the volume
Very stable	4	Whole fragment remains intact with no swelling.

11. Soil surface texture

Texture	Class	Interpretation
Silty clay to heavy clay (very slow infiltration rate)	1	Very slow infiltration rate
Sandy clay loam to sandy clay (slow infiltration rate)	2	Slow infiltration rate
Sandy loam to silt loam (moderate infiltration rate)	3	Moderate infiltration rate
Sandy to clayey sand (high infiltration rate)	4	High infiltration rate

Supplementary references

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