Contrasting Biodiversity Values in four states of Eastern Province Thornveld

Imogen May Duncan

Thesis presented in fulfilment of the requirements for the degree of Master of Science at Rhodes University

Supervisors:

Dr S Vetter & Professor RM Cowling

February 2010

Abstract

Land use and land transformation are major threats to biodiversity. Only a small percentage of land and thus biodiversity is protected within reserves. The majority of biodiversity lies in the hands of private and communal farmers and in order to protect biodiversity they must perceive it as having some value and have the means and incentive to conserve it. This study examined two things: (i) the relationship between biodiversity and measures of ecosystem health, range condition, primary production and presence of useful plants that would be expected to be of relevant use to land users, (ii) the perceptions of farmers of vegetation states that differ in the abovementioned attributes.

Within the Eastern Province Thornveld of the Smaldeel area, four different vegetation states were selected for the study, namely park-like grassland with scattered *Acacia karroo* (“savanna”), heavily infested *Acacia karroo* grassland (“acacia”), thicket-grassland mosaic (“thicket”) and heavily utilised thicket-grassland in communal lands (“communal”). The four states are a consequence of different patterns of browsing and fire, in both pre-colonial and recent times. Different ecological attributes were assessed and compared for each state and the relationships between the different attributes determined.

Ecosystem health, in terms of stability or resistance to erosion, infiltration/water-holding capacity, and nutrient cycling were compared using Landscape Function Analysis. The agricultural value of the different landscapes was measured using range condition assessment techniques. Plant species richness and other measures of diversity, along with their conservation and usefulness values, were compared between states. Plant productivity and biomass were compared using satellite data. The thicket state was found to be the most functional due to the added habitat complexity provided by the vegetation. It was the most biodiverse, the most useful and contained many, but not all of the important conservation species. The communal state had high biodiversity and was be fairly resilient to heavy usage, not showing the expected signs of land degradation. The savanna state, although thought of as the optimum state for cattle production, was not significantly different from the other states in terms of agricultural potential, but had the lowest values for plant diversity, browse potential, abundance of useful plant species and biomass. The acacia state had the highest and least stable values in terms of biomass production, however it was found to contain species of conservation importance.

The preference that four groups of land users, namely men and women from commercial and communal farming areas, expressed for the four vegetation states was assessed using semi-structured interviews in conjunction with A3 colour photographs. The men and women from the communal areas and the men from the commercial areas valued the thicket state highly for its farming potential. The male commercial farmers also valued the savanna state highly as they perceived it as being most productive for cattle farming. Both the thicket state and the savanna state were found aesthetically pleasing by all the user groups, in line with theories of preference for modified savannas and for familiar environments.

There appears to be potential for preserving biodiversity on farmland. The farmers in this study, with their very utilitarian perspective, were found to intuitively gauge the health of the landscape and recognise biodiversity as indicating good farming land. The commercial farmers were strongly influenced by economic motives and thus attracted to the savanna state, but also recognised the opportunity for a wider variety of farming activities in the thicket state. The communal farmers have a high dependence on the land for their livelihoods and preferred the thicket state for its overall usefulness. The views of the farmers indicate that the opportunity for conservation is good, however much of the thicket state lies in the communal land, where the open-access land use system makes managing for biodiversity difficult.

Dedication

This thesis is dedicated to family and friends who supported me throughout the whole process, and to my children who are my pride and joy.

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Acknowledgements

My sincere thanks and appreciation go to the following people:

Professor Richard Cowling and Dr Susanne Vetter for all their guidance and support throughout this study.

Professor Winston Trollope for sharing his knowledge and for hours of hospitality, and his technicians at the University of Fort Hare for all their advice and assistance with fieldwork.

Department of Livestock and Pasture Science, University of Fort Hare, for access to the research farm for data collection.

Tony Dold and Michelle Cocks for their knowledgeable discussions, organisation of matters in the communal areas, great company and all-round inspiration and Tony for supplying "usefulness" values.

David Hoare for NOAA data and Anthony Palmer for MODIS data and their expertise on the subject.

Sarah Hutchinson for her company in the field and Nomtunzi Sizane for her company in the field and translations on the interview days.

All the farmers in the Eastern Cape for access to their farms to collect data and all those who agreed to be interviewed and also for their unrivalled hospitality.

This study was financially supported by the University Joint Research Council.

CHAPTER 1

General Introduction

1.1 Introduction

1.1.1 Biodiversity

Biodiversity or biological diversity is a term that in its broadest sense covers the variety of life on Earth. More specifically, biodiversity as defined by the International Convention on Biological Diversity is the “variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.” The International Convention on Biological Diversity stems from global concern about the changing state of the planet due to the demands on its natural resources as a result of modern living.

In South Africa, the issue is addressed by the National Environmental Management: Biodiversity Act (Act 10 of 2004) that identifies that all “people and organizations should act with due care to conserve and avoid negative impacts on biodiversity, and to use biological resources sustainably, equitably and efficiently” as well as the Conservation of Agricultural Resources Act (1983), which focuses on the conservation of natural agricultural resources listed as the maintenance of the production potential of the land; combating and preventing erosion; combating and preventing the weakening or destruction of water resources; and protection of vegetation and the combating of weeds and invader plants. In addition South Africa is a signatory to the International Convention to Combat Desertification and therefore committed to combating land degradation.

It can be argued that the Earth’s biodiversity has an economic value stemming from the provision of ecosystem services, such as the availability of clean air and water, essential to human well-being and the maintenance of our modern agricultural systems (Dobson et al. 2006). Research has shown that reducing plant diversity, leads to a reduction in the provision of ecosystem services, decreasing productivity and promoting a loss of nutrients from the ecosystem (Tilman et al. 1996; Tilman et al. 1997; Hector et al. 1999). Ecosystem stability is thought to be affected, with ecosystem services becoming more variable with a decrease in diversity (Tilman & Downing 1996; McGrady-Steed et al. 1997; Naeem & Li 1997). This argument may not be as straightforward as it first may seem. Ecosystem services may differ in their sensitivity to anthropogenic disturbance, with species or groups of species fulfilling a basic functional criteria being more or less resilient in the face of change (Ridder 2008). In order to maintain the ecosystem services on which we depend, it is becoming increasingly apparent that we will need to preserve the Earth's biodiversity, but managing the land for the sole purpose of preserving ecosystem services may not always be in line with the goal of conservation of species. Ecosystem function may not depend on a full complement of diversity, making many species within an ecosystem redundant (Schwartz et al. 2000) and conservation based solely on economic motives perhaps devalues biodiversity in terms of its aesthetic beauty, cultural importance and evolutionary significance (McCauley 2006).

In South Africa, landholders and communities through their land use practices and different management techniques, shape the landscape around them. That humans influence landscape ecology is well understood (Naveh 2000). In changing the landscape farming practices not only affect biodiversity through the direct utilization of useful plants and forage and browse to sustain domestic livestock populations, but also indirectly cause changes to other ecosystem functions or services. In a review of Australian publications a relationship was found between biodiversity and functional integrity across various spatial scales within the ranching community, (Ludwig et al. 2004). The ability of a landscape to maintain its structural and functional integrity in the face of disturbance, or its resilience (Gunderson & Holling 2001) is a measure of landscape health. A change to a new state from the original state consequently being viewed as a form of land degradation.

1.1.2 Land tenure

Farming in South Africa takes place under two distinct land tenure systems and each has different consequences for the environment and thus on biodiversity. In the study region commercial farming focuses mainly on cattle ranching. Stocking rates are controlled and veld is managed and assessed to maintain optimum condition for commercial beef production. Conversely, under communal tenures, subsistence farming is thought be responsible for widespread land degradation especially in the more arid areas, mainly as a result of over-stocking, although past land use practices, such as cultivation and unpredictable rainfall events are also thought to be major influencing factors (Scogings et al. 1999).

Given that a only about 6% of land in South Africa is under formal conservation and that most biodiversity is on commercial and communal farmland, the fate of biodiversity lies mainly in the hands of subsistence and commercial farmers. These stakeholders lie at the heart of a global effort to protect and preserve the Earth's biodiversity. In some areas more recent expansion of the farming industry into game hunting and eco-tourism is contributing to conservation efforts, encouraging conservation of more biodiverse areas. In the communal areas, in addition to the utilisation of the land for livestock production the population is also dependent on land for building and fuel wood, medicinal plants and other non-marketable goods. The over-harvesting of species such as *Pelargonium sidoides* in the study area for sale to international pharmaceutical producers further increases pressure on natural resources (Lewu et al. 2007). Conditions favouring degradation in these areas are still not well understood (Scogings et al. 1999). Vetter (2005) cites increasing human population pressure, encroachment of rangelands by other land use, control of livestock diseases and the breakdown of traditional resource management structures as agents that contribute to the degradation problem. With the future of communal rangelands remaining uncertain biodiversity in these areas will potentially remain under threat.

1.1.3 Study aims and objectives

Since biodiversity is mainly in the hands of landowners and thus dependent on their perception of the land and the value they ascribe to it, this study aims to address the following questions:

1) How does biodiversity relate to other attributes of the vegetation that are of direct benefit to farmers, such as ecosystem health, grazing and browse potential, primary production and availability of useful plants? This topic is addressed in Chapter 2.

2) Do land users recognise biodiversity intuitively as having value by selecting more biodiverse vegetation for farming or recreation, or are they more swayed by cultural influences and personal experiences? This topic is addressed in Chapter 3.

These key questions have implications for engaging land users in biodiversity conservation and this is addressed in Chapter 4. If biodiversity does correlate with other measures that are positively viewed by farmers, or they have a preference for biodiverse landscapes and/or place a high value on them, then there is a place for conservation on the land and in their minds. However, if landscapes that are biodiverse do not correlate with high farming potential then the situation will present a challenge to conservation and other (e.g. financial) incentives may have to be sought.

1.1.4 The Smaldeel – A case study

The Smaldeel area of the Eastern Cape, South Africa, which encompasses savanna and thicket clump mosaic vegetation, was largely classified by Acocks as False Thornveld of the Eastern cape (Acocks 1953) and is characterised by small *Acacia karroo* trees and the occasional invasive Thicket species such as *Diospyros lycioides*. Key grass species are *Themeda triandra, Sporobolus fimbriatus, Digitaria eriantha* and *Eragrostis curvula*. The majority of land is farmland and as such has undergone transformation to varying degrees. Commercial beef production in the area has favoured the creation of large open areas of grassy savanna-like vegetation over areas of mesic bush-clump savanna. Mechanical removal of unwanted bush species, fire regimes and the use of browsers such as goats to reduce and prevent the encroachment of unwanted species into the grazing areas have been common management practices. Yet recent changes in the stocking policies of many commercial and subsistence farmers in response to an increase in small stock (goat and sheep) theft has resulted in a noticeable increase in bush encroachment by *Acacia karroo* in both the commercial and communal areas. Thick stands of these trees affect the species composition and thus the nutritional value of the grass beneath and as such are a worry to commercial and subsistence farmers alike.

More recently the area has been divided into different vegetation types by Mucina and Rutherford (Mucina 2006). To the west the vegetation has been re-classified as Bedford dry grassland, grassland consisting of *Digitaria argyrograpta, Tragus koelerioides, Eragrostis curvula* and *Cymbopogon caesius*, interdispersed with *Acacia karroo* woodland vegetation, and to the east as Bhisho Thornveld characterised by the smaller tree *Acacia natalitia*, with the shrubs *Anthospermum rigidum* subsp. *Pumilum, Crysocoma ciliata* and *Felicia muricata* found amongst a grassland consisting mainly of *Sporobolus africanus, Digitaria eriantha* and *Themeda triandra* amongst others. The new vegetation map and the classification of the states on an east west division, suggests that the area is a transfer zone where one vegetation type grades into another. A combination of factors probably causes the change in vegetation. The existence of Thicket species refugia in the western areas (*pers. obsv.*) indicates that Thicket species are able to survive throughout the Smaldeel. As Thicket species are very fire prone (Mucina 2006) the increased fire incidence on the more open areas to the west may account for the change in vegetation. Fire, when used as a management tool in the area, has been successfully used for clearing acacias under 1.5m and bush-clumps to improve the condition of the veld for commercial farming (Trollope & Tainton 1986). The technique is currently employed by several commercial farmers throughout the Smaldeel area, and even used to clear browse on the hills. According to the state and transition model of rangelands (Westoby et al. 1989) the savanna type vegetation could be a resultant stable state following the removal of the Thicket vegetation. Local wisdom could see a relationship between the vegetation types, but views differed regarding the reasons for the distribution. Overall opinion was that once the thicket species had been removed that they wouldn't return, or that they would take more than a lifetime to return to the area.

Areas under commercial tenure vary from open *Themeda triandra* grasslands with occasional *Acacia karroo* (savanna state), to areas of dense *Acacia karroo* scrub (acacia state), to a mesic bush-clump savanna with bush-clumps comprised of shortish evergreen thicket shrubs such as *Scutia myrtina* and *Rhus ssp* (thicket state) (Lubke et al. 1996; Palmer et al. 2001).

Savannas are defined as "having a more or less continuous grass cover but discontinuous tree cover" (Scholes & Archer 1997). Tree cover is limited in these ecosystems by a wide range of environmental, faunal and anthropogenic conditions with grasses playing a vital role as key competitors against sapling recruitment (Bond 2008). It is thought that in areas where the competitive nature of grasses is reduced by over-grazing, tree seedling recruitment increases, although Kraaij and Ward (2006) suggest a more complex interaction between rain, nitrogen and grazing, with rainfall events featuring as triggers for mass tree recruitment. The existence of *Acacia karroo* thickets in the Smaldeel is part of an increase in woody plants in grassy ecosystems that have been recorded as a global phenomenon (Schimel et al. 1995; Asner et al. 2003). In the Smaldeel area the causes are thought to be either due to changes in land use such as increased grazing and decreased use of fire (Trollope & Tainton 1986; Schimel et al. 1995), a reduction in browsing pressure (Belsky 1990), or a change in atmospheric carbon dioxide (Asner et al. 2003).

The land under communal tenure in the Smaldeel, like many similar areas in the Eastern Cape, is characterised by large-scale transformation (Hoffman & Ashwell 2000; Tanser & Palmer 2000; Meadows & Hoffman 2002). Overgrazing by cattle and sheep results in the selective removal of the more palatable perennial species such as *Themeda triandra* and *Sporobolus africanus* by grazers (Teague et al. 1994; Owen-Smith & Danckwerts 1997). A rundown in carbon reserves, due to the continual removal of foliage by heavy grazing, is thought to result in the less competitive nature of *Themeda triandra* under such conditions (Danckwerts 1993). This causes an increase in the occurrence of less desirable perennials such as *Aristida congesta*, annuals and small, unpalatable woody shrubs, typically *Chrysocoma ciliata* and *Pteronia incana*, thus reducing the carrying capacity of the land. Such transformed land (communal state) is found in close proximity to the other states. A summary of the sites and how they were selected on a visual basis is presented in table 1.1.

Table 1.1. Criteria by which sites were visually selected

Site	Criteria
Thicket	Bush-clumps present within grassland, forming a bush-clump grassland mosaic largely free from *Acacia karroo* encroachment and having bushes associated with thicket such as *Rhus* spp., *Portulacaria afra*, *Aloe ferox*, *Putterlickia pyracantha et cetera*.
Communal	Heavily utilised communal land characterised by low woody and herbaceous vegetation, with a closely cropped grass sward and a heavily browsed shrub component.
Savanna	Scattered, large (> 1.5m high) *Acacia karroo* within mixed grassland, with few or no other shrub or tree species obviously present and recognised thicket species mainly absent.
Acacia	Grassland heavily encroached with *Acacia karroo*, where the majority of trees are above head height (1.5m), occasionally forming dense acacia thicket, often interspersed with open patches. Thicket species mainly absent.

The four different vegetation states seen throughout the Smaldeel area have been created side-by-side on experimental plots at the Fort Hare University Farm, using management techniques such as fire, grazing and browsing. It would appear that the states are interchangeable, but less so in the eastern and western extremes of the Smaldeel. The proposed conditions favouring a transition from one state to another (Trollope & Tainton 1986; Trollope 1990; Teague et al. 1994; Trollope 1999; Hester et al. 2006) are outlined in Figure 1.1. Whether or not the vegetation states are all interchangeable has not been fully established, but the majority of transitions are the result of the management techniques employed and the availability of plant propagules for establishment.

The juxtaposition of the sites on the University Farm and the existence of the four vegetation states within the local area allowed for the opportunity to investigate how different measures of biodiversity and ecological “health” compared between the states. The close proximity of the different vegetation states in one area provided an opportunity for the comparison of the different measures of ecological quality with a natural snapshot experiment. The situation in the Smaldeel area proved ideal for reviewing the motives of both communal and commercial farmers within the same landscape and comparing their farming objectives and landscape values.

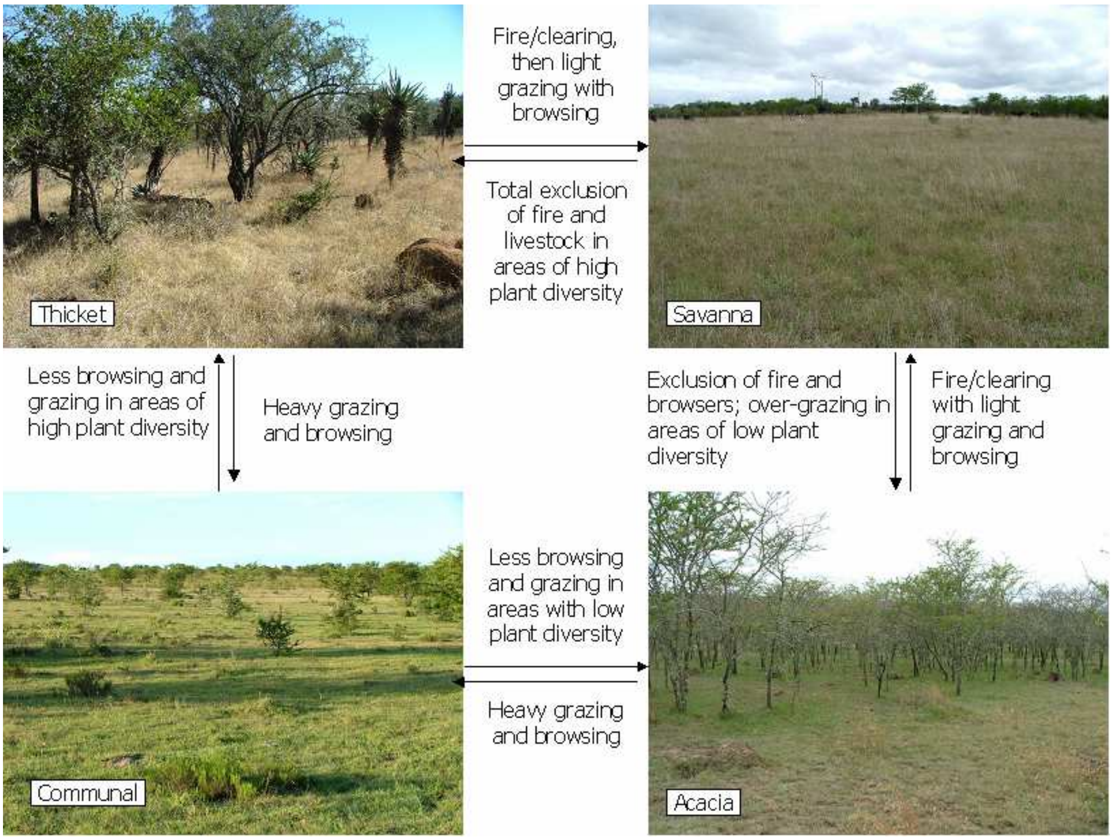

Figure 1.1. The four vegetation states and the proposed conditions for transition.

1.1.5 Measuring ecological quality – a question of perspective

Most groups, be they students, farmers, bird watchers *et cetera*, interested in biodiversity or ecosystem health will assess the landscape using the method that most relates to their particular set of values. On a global scale, species richness is the most widely used and intuitive measure of biodiversity (Magurran 2003), but measures of species richness do not necessarily correlate to farming value. Veld management techniques measure the health of a particular ecosystem along an environmental gradient, with respect to grazing potential, and/or gauge the amount of palatable browse species present in browsing units, for monitoring and management purposes, (Trollope et al. 2004). Other measures of ecosystem "health" include Landscape Function Analysis (LFA) that concentrates on the biogeochemical functioning of landscapes, in particular the way nutrients are cycled, soil infiltration rates, and stability, at the hill-slope scale (Tongway & Hindley 2004). An increasing amount of satellite data is available for the large-scale analysis of plant productivity. The data come from measurements of the reflectance of red and near-infrared bands by the planet, (the Normalized Difference Vegetation Index or NDVI), thus giving an indication of active green biomass (Deering et al. 1975; Jury 1997; Myneni et al. 1997).

The different techniques provide a range of indices or indicators of the present ecological condition of the landscape, but the information only provides one perspective on the landscape, and is of limited value if it cannot be related to other measures of ecological quality.

1.1.6 Valuing biodiversity

Whether or not biodiversity in the area can be successfully conserved relies on land users recognising and placing value on biodiversity. Different societal groups have different value sets and ways of viewing landscapes. It is thought that landscape preferences result from one of two proposed perspectives. The evolutionary perspective suggests that people have an inherited disposition for the preference of open savanna-like environments (Gobster 1995), or a sense of "space". Conversely, it is thought that preference is determined by how one experiences landscape on a personal and cultural level, resulting in a sense of belonging to the landscape (Seamon 1979), or a sense of “place”. It is important to consider how preferences for different landscapes arise and how they relate to measures of ecological quality such as landscape “health”, primary production, species richness and other diversity measures if we want to involve landowners in the conservation of biodiversity.

CHAPTER 2

Contrasting ecological quality measurements in the Smaldeel – A case study

2.1 Introduction

2.1.1 What to measure?

This study set out to measure how biodiversity relates to other attributes of the vegetation that are of direct benefit to farmers, such as ecosystem health, grazing and browse potential, primary production and availability of useful plants.

Agricultural practices often seek to transform landscapes to increase productivity in terms of marketable commodities. A change in vegetation structure and composition is brought about by common agricultural practices such as burning, rotational grazing, browsing *et cetera* in order to achieve the most desirable state for the farming objectives in place. In the Smaldeel area the main objective of commercial farmers is to improve the grazing potential of the land and increase its carrying capacity. The creation of open grassy areas is thought to decrease the biodiversity of the area. Biodiversity and ecosystem services such as productivity, nutrient retention and ecosystem stability are thought to be intrinsically linked (Tilman & Downing 1996; Tilman 1996; Tilman et al. 1996; Tilman et al. 1998; Hector et al. 1999; Gotelli & Colwell 2001a).

Productivity is generally taken to be the total above ground biomass of all plants in an area and is thought to increase with biodiversity as a result of an increase in ecosystem complexity. A species may modify an environment, creating a micro-climate or altering the habitat to allow another species to become established (Turner et al. 1966; Vandermeer 1992) so increasing efficiency regarding resource capture and use (Tilman & Downing 1996; Hector et al. 1999; Fridley 2001) resulting in more biodiverse ecosystems being more productive.

Stability is generally measured by looking at the variation in one or more properties of an ecosystem, such as a change in biomass over time (Doak et al. 1998). Landscapes can also be considered stable, or more resilient, if they are able to maintain their integrity, or original state, in the face of perturbations or disturbance (McCann 2000). The increased stability found more biodiverse ecosystems may be because different species respond differently to environmental variation (Doak et al. 1998; Tilman et al. 1998), or that highly competitive species are able to do well whilst others are performing poorly, so reducing overall ecosystem variance (Tilman et al. 1998). More biodiverse areas may also be more resistant to invading species, due to resources being in short supply as a result of species complementarity (Tilman 1999).

Although land under communal tenure is managed differently, the vegetation is continuously browsed and grazed by large numbers of animals and firewood, traditional medicines and other resources are harvested from the land. Such activities are thought to have a negative effect on the biodiversity of the area through the continual removal of species.

The resulting states, though perfectly acceptable to the farmers, may not be seen as desirable by other societal groups such as nature lovers or the tourist industry. A plethora of methods exist for the assessment of landscapes as a result of the number of different landscape-based disciplines and interest groups, each with their own criteria for valuing the landscape.

2.1.2 Landscape function and ecosystem health

Landscape Function Analysis developed from the need to monitor the “health” of a landscape for individual and governmental decision makers. The concept of landscape function (Ludwig 1997) led to the development of a conceptual framework that represents the biogeochemical processes occurring throughout a landscape. It can be used as a tool for monitoring the processes of degradation or rehabilitation occurring in a landscape. As landscape function refers only to the biogeochemical processes, it is free from social and economic values.

According to the model, loss of landscape function refers to the possible loss of resources such as soil, water and nutrients from the landscape, and an increase in landscape function refers to increased control over said loss. In an effort to understand how a landscape is controlling the movement and distribution of these scarce resources, the method maps out the landscape components as a series of patches and inter-patches. The information can be used to monitor changes in rangeland function (Tongway & Hindley 2004). Different levels of functionality of a landscape exist in response to stress or disturbance and may or may not be acceptable depending on the intended land use and the value set of the person viewing the landscape.

An interpretational framework exists to identify points of potential concern in terms of resilience of the landscape in response to major stress and/or disturbance. It is thought that once a threshold level has been crossed, a change to a different state may occur. Fragile, or less resilient landscapes being more susceptible to change than robust landscapes. In that respect the method is based upon the state and transition model (Westoby et al. 1989).

2.1.3 Rangeland condition

The concept of range condition is defined as “the state of health of the veld in terms of ecological status, resistance to soil erosion and its potential for producing forage for sustained optimum livestock production” (Teague et al. 1994). Rangeland scientists monitor the condition of the range relative to the number of animals it can support, and assessments are based on one of two models.

Traditional range management techniques follow a successional model (Dyksterhuis 1949; Foran et al. 1978; Trollope 1990) whereby any rangeland has a climax state in the absence of grazing. Grazing pressure is thought to counter the successional tendency and in effect reverse the process of succession. Fire is thought to have a similar effect (Bond & Keeley 2005). A relatively stable equilibrium is achieved when the grazing pressure is equal and opposite to succession and this is the main objective of farmers that manage in this way. Drought is thought to act on the model in the same direction as grazing pressure, with high rainfall years having the opposite effect, increasing the tendency of succession towards a climax. The state of the vegetation, using this model, can be aligned in one continuum, from heavily grazed, early-successional, poor condition, to ungrazed, climax, excellent condition.

An alternative state-and-transition model (Westoby et al. 1989) proposes the existence of discrete states of the vegetation with a set of drivers (fire, weather, resting, grazing etc.) that promote changes between states. States are recognised as the result of management practices, two states being considered different when they represent an important difference from a management point of view. States within this model are not aligned on a continuum as it is thought that not all transitions are reversible. Irreversible transitions have the potential to result in a different climax community developing on the land.

Rangelands are valued by farmers for their productivity. On commercial livestock farms production is considered the production of beef, lamb, wool (from sheep) or Angora goat products. Management objectives include the maintenance of favourable species composition in terms of large quantities of high quality plant food material for the maintenance of the highest animal productivity (Teague et al. 1994). In the study area removal of undesirable species (moribund grasses, *Acacia karroo* or entire bush-clumps) by fire is used to change the vegetation state, providing a more desirable species composition in terms of nutritional content, highly valued by the farmers.

In the communal lands especially heavy grazing by cattle and sheep is thought to bring about the selective removal of palatable perennial species such as *Themeda triandra* and *Sporobolous africanus* (Teague et al. 1994; Owen-Smith & Danckwerts 1997). It is thought that *Themeda triandra* is less competitive under these conditions as frequent defoliation causes a rundown in reserve carbon (Danckwerts 1993). The result is an increase in the number of perennials with low nutritional content such as *Aristida congesta*, annuals and small woody shrubs such as *Chrysocoma ciliata* and *Pteronia incana*, a state not considered desirable by rangeland scientists or farmers.

In addition to the provision of food for grazers land is valued for the availability of suitable browse for goats and wild animals of interest to game farming, such as Kudu (*Tragelaphus strepsiceros*). Of particular interest to both communal and commercial farmers is browse under 2m, within reach of most domestic stock and game.

2.1.4 Species richness and diversity measures

Another way of measuring the quality of the land considers the biodiversity value of a landscape, within species, between species and of ecosystems. The total number of species present or species richness is the most commonly used index of biodiversity worldwide (Magurran 2003) as it is one of the most intuitive (Gaston 1996). Higher plant richness is widely used as a measure of biodiversity as plants are primary producers and provide habitat, hence the composition, diversity and structure of plant communities has a big effect on communities of other taxa (Noss 1990; Procheş & Cowling 2006).

Different sets of values held by those with an interest in conservation or nature have led to the development of a suite of measurements that describe different facets of the biodiversity of communities, ecosystems and landscapes (Magurran 2003). Scale is known to affect the outcomes of biodiversity studies (Hamer & Hill 2000), the most documented being the species-area relationship (Preston 1962). Gomez and Piñero (2007) recommend the use of more than one biodiversity index in any study to moderate the limitations of the method used. The diversity indices chosen for the study were species richness, a modified Simpson's index of diversity and a modified Shannon index.

Species richness is the number of species in a sample and is dependent on the sample size. Simpson's index of diversity is a measure of the concentration of a species (Simpson 1949; Pielou 1966), but may be insensitive to rare species in a sample (Magurran 2003). Shannon's index is derived from Shannon's Information Theory Of Communication (Weaver 1949). It is a measure of uncertainty (DeJong 1975), such that as species diversity increases the probability that a particular species is picked at random decreases (Pielou 1969).

In addition indices relating the usefulness value, the conservation value and the phylogenetic diversity were designed so as to represent the states according to different biodiversity criteria.

2.1.5 Primary production and biomass

The productivity of a landscape in terms of biomass has direct economic consequences to farmers. Stocking rates are dependent on forage production, in turn dependent upon abiotic factors such as rainfall that affect grass species composition and primary production (Dye & Spear 1982; O'Connor 1994; O'Connor 1995). Farmers that stock close to carrying capacity may suffer population crashes in times of drought as a result of variable forage production, resulting in lower and more unstable livestock numbers (Vetter 2005).

Vegetation biomass/productivity can be estimated over extensive temporal and spatial scales using satellite data. One widely used measure is the Normalized Difference Vegetation Index (NDVI). NDVI is calculated from the difference in the absorption in the visible wavelengths and reflectance in the near-infrared (Deering et al. 1975; Myneni et al. 1995; Jury 1997) and indicates the presence of photosynthetically active vegetation (Tucket 1979). As such it is a measure of standing biomass or greenness. NDVI derived from the National Oceanic and Atomospheric Administrations's (NOAA) Advanced Very High Resolution Radiometer (AVHRR) has been used to monitor degradation on communal lands in associated areas (Palmer et al. 2001) and in other areas of South Africa (Archer 2004).

Moving Standard Deviation (MDSI) of NDVI is a measure of spatial heterogeneity that according to Tanser and Palmer (Tanser & Palmer 1999) can be used as an indicator of rangeland condition. High MDSI and low NDVI values have been linked to communal degraded rangelands and conversely, low MDSI and high NDVI values have been linked to more productive commercial grazing lands (Tanser & Palmer 1999; Palmer et al. 2001).

Leaf Area Index (LAI) is a dimensionless variable defined as the one-sided green leaf area per unit ground surface in broadleaf canopies. The Moderate Resolution Imaging Spectroradiometer (MODIS) sensors on board the Earth Observing System-Terra platform produce LAI data at 1-km spatial resolution. The LAI values are calculated from measurements for the fraction of absorbed photosynthetically active radiation using the radiative transfer algorithm (Knyazikhin et al. 1998). The calculated LAI has been validated by comparison with ground-based measurements (Yang et al. 2006). Temporal variations in photosynthetic activity relating to possible seasonal changes in vegetation cover can detected with time-series data (Justice et al. 1998). The percentage departure from the long-term mean of each pixel is a measure of ecological stability (Westoby et al. 1989; Walker 1993).

2.1.6 Study aims

The aim of this study was to ascertain how species richness and other diversity measurements relate to other measurements of ecological quality, namely ecosystem function, rangeland condition and productivity, within four vegetation states, in the Smaldeel area of the Eastern Cape. To that end, the states were assessed using the different approaches outlined previously and the resulting indices generated by each method were correlated against one another to identify any potential relationships between the different ecological attributes.

2.1.7 Predictions

Landscape function and ecosystem health

A comparison of the LFA indices between states should reveal if the change in vegetation cover in the Smaldeel corresponds to land degradation and reduced ecosystem services. A change in vegetation cover is thought to occur before changes in other ecosystem functions (Charney et al. 1977) and Wessels (2004) suggests that a change in vegetation cover could be the first sign of land degradation.

The cover provided by bush-clumps is believed to enhance infiltration by increasing total cover and soil organic matter (Teague et al. 1994), so bush clump areas in the thicket state are expected to have higher LFA indices regarding soil processes such as nutrient cycling and infiltration, indicating that more biodiverse areas are more functional. The communal state, like much land in communal areas is generally regarded as degraded (Meadows & Hoffman 2002; Wessels et al. 2004) and expected to show signs of dysfunction and reduced biodiversity compared with less heavily-utilised states.

Rangeland condition

A high density of woody plants, such as that which corresponds to biodiverse bush-clumps in the thicket state and *Acacia karroo* encroachment in the acacia state, would be expected to have a significant negative effect on herbaceous productivity in terms of quality and quantity of forage for grazers (Teague et al. 1994). Grass species composition has been shown to relate to resistance to soil erosion in other areas of South Africa (Snyman 1998) and such a relationship is expected between forage potential for grazers and functionality, with poor grazing areas being dysfunctional.

Best forage production scores are expected in the savanna state, in line with current veld management theory in the area, which defines this state as the agricultural optimum (Teague et al. 1994). Browse quantities are expected to be highest in the thicket and the acacia state vegetation in both the above 2m and below 2m height classes.

Primary production and biomass

Primary productivity, not necessarily the same as the optimum production potential in terms of commercial beef production, has been correlated with species composition (Snyman 1998) and functionality (Ludwig et al. 2002). In the Peddie district, Palmer et al. (2001) found that both MDSI and NDVI values detected the differences between untransformed and transformed vegetation and that these correlated with a change in LFA indices. So primary productivity is expected to be greater in the areas with greater species richness and in more functional landscapes and conversely lower in less species rich, more dysfunctional landscapes.

Savannas have typically lower LAI (0.5 to 1.0) than forests (Scholes & Archer 1997) so the savanna state, although presented as the optimum condition by rangeland scientists (Teague et al. 1994) may emerge as being the least productive due to the sparse tree coverage and low biodiversity. Lowest NDVI and highest MSDI values would be expected for the communal areas, in line with similar studies done in the Eastern Cape (Palmer et al. 2001). The least stable states in terms of annual variation in production are those most likely to lose leaf area, i.e. the acacia state, as communal and thicket states have a greater abundance of evergreen trees and bushes.

2.2 Methods

2.2.1 Study area and site selection

The sample area selected for the study was the Smaldeel area of the Eastern Cape, lying between the towns of Bedford and Middledrift. The area is characterised by gently to steeply undulating hills, with Glenrosa and Mispah moderately fertile soils, with high silt and fine sand content, derived from the shales and sandstones of the Beaufort and Ecca series. Rainfall is known to be highly variable, with a peak in March and a lower peak in October (Marais 1978). Although the area is thought to have fairly constant abiotic characteristics satellite data suggest that the sites lie along an environmental gradient, table 2.1.

Table 2.1. Summary of environmental variables across the sites, altitude (m), annual precipitation (mm), coefficient of variation for annual precipitation, rainfall concentration (%) and heat units.

Site	State	Altitude (m)	Annual precipitation (mm)	Coefficient of variation for annual precipitation	Rainfall concentration (%)	Heat units
1.1	Thicket	414	573	32	26	231
1.2	Thicket	440	473	32	28	238
1.3	Thicket	476	486	32	31	235
2.1	Communal	480	541	31	30	227
2.2	Communal	518	536	31	28	215
2.3	Communal	553	542	30	30	226
3.1	Savanna	658	459	31	31	218
3.2	Savanna	674	428	31	31	215
3.3	Savanna	664	453	32	30	217
4.1	Acacia	746	561	28	31	200
4.2	Acacia	768	482	32	31	207
4.3	Acacia	612	454	32	30	221

The acacia and savanna sites were found at a slightly higher altitude, were drier and received less heat units, but given that the variation between states was not great the abiotic factors were considered to be constant enough for the sites to be considered similar. Dankwerts (1981) showed that the difference in range condition rather than rainfall predicts grazing capacity. Rainfall was regressed against the other indices in order to check for any effect of rainfall within the area.

The coordinates for the sample sites are shown in Table 2.2 and the positions of the sites in Figure 2.1. The Fort Hare University Farm, located just outside the town of Alice (Figure 2.1) is set centre-east within the sample area.

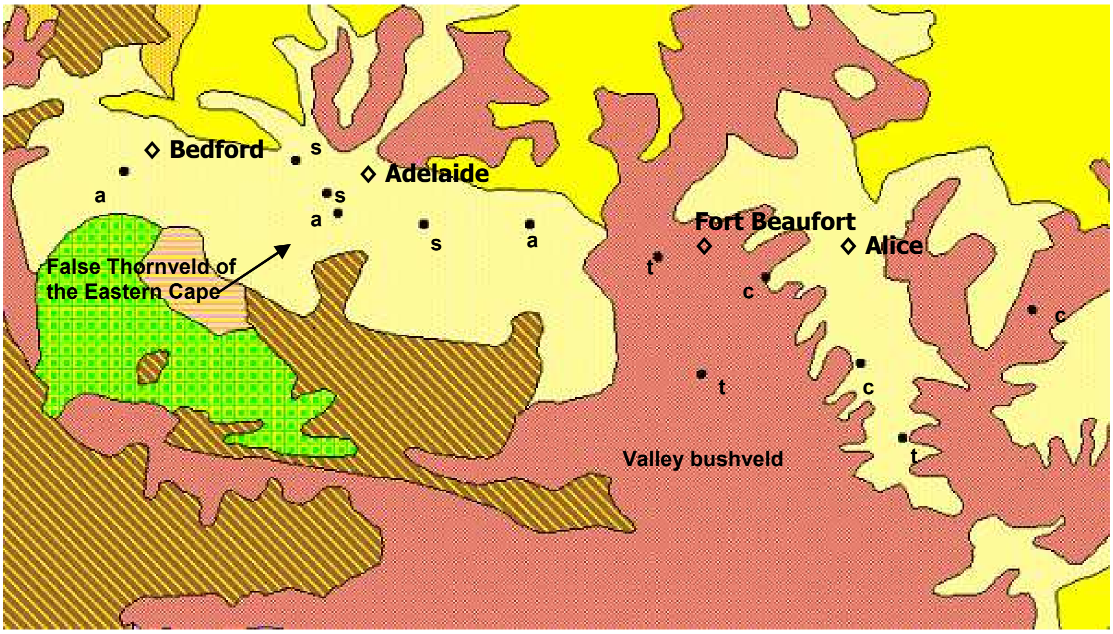

Figure 2.1. Location of the study sites within the Smaldeel area of the Eastern Cape (t = thicket, c = communal, s = savanna and a = acacia vegetation state).

Experimental plots at the University Farm have demonstrated that different vegetation states can be created within the veld type found at the farm, classified by Acocks as False Thornveld of the Eastern Cape (Acocks 1953), using management techniques such as fire, grazing and browsing (Trollope & Tainton 1986). Found on the farm and of interest to this study were the thicket and savanna vegetation states outlined in Chapter 1. On the farm and adjacent to the different management plots an unmanaged site undergoing *Acacia karroo* encroachment was also selected to represent the acacia vegetation state (Chapter 1). This site was lost during the course of the study due to the widening of a nearby road. A small plot of communal land chosen to reflect the communal state (Chapter 1) was selected as close to the University Farm as possible, so that all four states were represented on similar sized (≈ 0.6Ha) plots within a few kilometres of one another.

Larger sample sites were selected across the study area to reflect the four vegetation states created at the Fort Hare University Farm near Alice. Twelve sites were selected throughout the False Thornveld of the Eastern Cape in the Smaldeel area (Table 2.2). The sites were chosen on a visual basis according to the criteria listed in Table 1.1. In this fashion the sites visually represented the sites found on and near the University Farm at Fort Hare.

Each site had to coincide with a 1.1km x 1.1km pixel area as mapped by the National Oceanic and Atmospheric Administration's polar orbiting satellite (NOAA) to allow comparison with primary production measurements from satellite data. The sites had to exhibit a fairly homogenous vegetation state across a large area so that the satellite data only pertained to vegetation in one state. This was a major limiting factor in determining which sites could be chosen.

Table 2.2. Summary of site location details

Site number	Vegetation state	Midpoint of pixel	
1.1	Thicket	26º51'00.180"	-32º58'20.100"
1.2	Thicket	26º38'19.860"	-32º54'19.980"
1.3	Thicket	26º35'40.020"	-32º47'00.180"
2.1	Communal	26º59'00.180"	-32º50'20.220"
2.2	Communal	26º48'19.980"	-32º53'40.020"
2.3	Communal	26º42'19.980"	-32º48'19.980"
3.1	Savanna	26º12'59.940"	-32º41'00.060"
3.2	Savanna	26º20'59.820"	-32º45'00.180"
3.3	Savanna	26º15'00.180"	-32º42'59.940"
4.1	Acacia	26º27'40.140"	-32º45'00.180"
4.2	Acacia	26º02'20.040"	-32º41'40.020"
4.3	Acacia	26º16'20.100"	-32º43'40.320"

The area has since been divided into different vegetation types by Mucina and Rutherford (Mucina 2006). The veld type for savanna and acacia states, found to the West, has been re-classified as Bedford dry grassland and the veld type for communal areas has been re-classified as Bhisho Thornveld. However, Bedford dry grassland and Bhisho Thornveld are considered to be very similar to each other by Mucina and Rutherford (2006) and they grade into each other in the Smaldeel. The veld type for the Edendale and Double Drift thicket sites has been re-classed as Great Fish Thicket, but the sites border very closely Bedford dry grassland and Bhisho Thornveld. Communal state sites were only found to the east of Fort Beaufort for political reasons, the area being former Ciskei homeland. As one of the prerequisites for site selection was homogeneity over a 1x1km area, thicket sites of this size were hard to find to the west, where only small pockets of Thicket species were occasionally spotted.

2.2.2 Landscape function and ecosystem health

Data collection

Landscape Function Analysis (LFA) (Tongway & Hindley 2004) assesses landscape quality in terms of rangeland function, in particular how landscapes conserve and utilise scarce resources. It is based upon a conceptual model presented by Ludwig and Tongway (Ludwig & Tongway 1997), which is a systems-based framework for the way in which rangelands function. The method generates six landscape organisation indices from landscape organisation data that help explain the scale of the resource regulating features in the landscape. The data reveal whether the landscape is regulated at fine scale (sparse tussock grasses) or at coarse scale (tree patches); whether it is by live plants, dead wood or litter as well as the nature of inter-patches and their size, which can be used to monitor changes in possible resource loss and hence land degradation. It also generates indices for some ecosystem properties, namely nutrient cycling, infiltration rates and soil stability from soil surface assessment data (SSA).

In each of the 12 sites LFA data were collected for the mid-slope region, as defined by McDonald et al. (McDonald et al. 1990), in order to allow comparison between sites as LFA values would be expected to change with terrain shape. Steep slopes in particular were avoided as these would be areas of considerable resource loss and therefore not comparable with areas on gentler slopes. The mid-slope region was chosen as mid-slope was the only landform present on each of the sites, although with varying steepness.

Two or three 50m transects (where no further transect significantly reduced the variance (Tongway & Hindley 2004)) were located on the mid-slope region of each site, distanced so that they were spread over 500m, landscape allowing. Transects were aligned with the maximum slope to reflect the direction of surface or resource flow. Along each transect the length, obstruction width (at right angles to the transect line) and classification of patches and the length and classification of inter-patches was noted as a continuous record. Thus data were collected for a total of 33 transects, providing information on the number of obstructions to overland flow, obstruction width, and the mean distance and range between obstructions (inter-patch length) per unit length of transect. The patch and inter-patch types recorded in the field, with their associated definitions, are shown in Table 2.3.

Table 2.3. Patch and inter-patch definitions used in the Landscape Function Analysis

Patch/inter-patch type	Definition
Grass small shrubs	Mainly grassland, with annuals and any shrubs below 50cm found growing individually
Low shrub patch	A mixture of shrub species or more than one of the same species, in a close group <2m in height
Acacia canopy patch	From one edge of an acacia canopy to another, for a single or group of acacias of any size
Closed bush clump	A bush clump >2m in height and generally more complex in terms of species and structure than the low shrub patches
Grass succulent patch	Very small patches where grasses and succulent species are closely associated only found on exposed shale
Bare clay	Clay inter-patch with a definite crust
Bare shale	An inter-patch consisting of loose shale

Once the landscape continuous log record was compiled five 1m query zones were selected for each patch and inter-patch type. Each query zone was located centrally within each patch/inter-patch. Where the patch/inter-patch was too small, a suitable fraction of 1m was identified. For the SSA the following eleven indicators that act as surrogates for environmental variables or processes were observed and recorded within each query zone: rainfall protection, perennial vegetation cover, litter, cryptogam cover, crust brokenness, soil erosion type and severity, deposited materials, soil surface roughness, surface nature (resistance to disturbance), slake test and soil texture following the landscape function analysis guidelines (Tongway & Hindley 2004). Any wet soil samples were taken to the laboratory and dried out prior to further analysis.

Calculation and aggregation of the indices

Continuous log record data were used to calculate the following landscape organisation indices for each individual transect: number of patch zones per 10m, total patch area, patch area index (total patch area/maximum area (transect length x10)), average inter-patch length and range and the landscape organisation index (sum of patch zones/length of transect). The mean index values were then calculated for each site.

Query zone data collected at each site were aggregated such that any patch type having a length covering less than 5% of the total transect length was combined with the patch type it was deemed most similar to, according to the stability, infiltration and nutrient cycling indices.

Whole site values for the stability, infiltration and nutrient cycling indices were calculated. The mean proportion of each patch and inter-patch type was calculated by adding the respective numbers from each transect and dividing by the number of transects. Then the mean indices for stability, infiltration and nutrient cycling were calculated by adding the mean values for each patch and inter-patch type from each transect and dividing by the number of transects. This resulted in a grand mean for each index for each patch and inter-patch type. Each grand mean for each patch and inter-patch type was then multiplied by the percentage occupied by the respective patch or inter-patch. These were then added together to obtain weighted index values for each site as a whole.

2.2.3 Range condition

Data collection

The condition of both the bush/shrub component and the herbaceous component of the range were assessed using the method developed for the assessment of the range within the Great Fish River Reserve (Trollope et al. 2004) and currently used to assess the range condition on the Fort Hare University Farm where two of the original sites are located. The method is based upon the Point Centred Quarter Method (PCQ) for determining the botanical composition, density and structure of the bush vegetation combined with a step-point survey in the same sample sites to determine the botanical composition and basal cover of the grass sward.

In each of the twelve 1.1km x 1.1km sites, four sets of parallel transects were set up for assessing browse and grass availability, one in each quarter of the site such that the first transect in each quarter started at a point 200m in from the west and 200m in from the north of each quarter of the pixel and was placed running from north to south. This was to avoid any bias in transect placement. Where there was found to be any obstacle to the placement of the transect such as a river bed or a road, the transect was moved east or west (away from the obstacle) by 50m to allow for meaningful results to be collected. For the sites on and located near the University Farm at Fort Hare, a smaller pair of transects was placed running north to south on each of the sites, allowing for the collection of data at 10 recording points per sample site for the bush survey. In addition, the step-point method was used to assess the condition of the grass sward.

For the assessment of the woody component, two parallel transects, 110 m and 120 m long were laid out 25 meters apart, with 12 and 13 recording points respectively located at 10 m intervals on each of the transects, resulting in a total of 25 recording points per set of transects, from which 100 quadrants were sampled. In the first two quadrants the nearest tree or shrub <2m in height, and in the third and fourth quadrants the nearest tree or shrub >2m in height were recorded. All trees/shrubs had to fall within 10m of the recording point. Where there were no trees/shrubs a zero was recorded. For the nearest rooted tree or shrub in each of the four quadrants surrounding the recording point the following parameters were recorded: the distance from recording point, species, overall height and the height of the lowest browsable material. All small shrubs, including those classed as karroids, were also included in this part of the survey, as the method does not state a minimum size for inclusion. Both large and small shrubs were later divided into palatable and non-palatable species. In this way 48 browse vegetation surveys were carried out (four at each site, twelve for each vegetation type) within the chosen pixels along with the four smaller surveys on and around the University Farm.

For the step-point method for assessing basal cover and botanical composition of the grass sward, points were located by walking the length of each of the pair of transects with a thin rod, which was touched to the ground approximately every 2m at 1m from the transect, such that a total of 100 points were recorded. At each point the species and the distance to the basal portion of the nearest rooted herbaceous plant was recorded. The concept of the point to tuft distance was developed by Hardy & Tainton (1993) and serves as an index of the basal cover of the grass sward.

Calculation of the indices

Browse species were divided into palatable/non-palatable species and given a 1/0 ranking for the browse condition assessment. For browse species encountered during the survey, but not prescribed a 1/0 ranking in the range condition assessment method (Trollope et al. 2004) the opinion of an expert in the field (A. R. Palmer, *pers. comm.*) was sought, to allow an appropriate rank to be given, Appendix B. Palatable species were ranked 1-3, where 2 = most desirable, 1 = least desirable but flowers and new shoots will be eaten, 0 = eaten during times of stress (usually high bulk), assuming that all species were equally available for selection in each location. Species found during the survey were then given a final rank of 1 (palatable), if stated such in the original method, or given a 2 or 1 by the expert. Otherwise, they were ranked 0 (unpalatable).

Field data and palatability rankings were then used to calculate the following variables for each set of transects: species composition, frequency and density (plants per hectare) in both height classes (<2m and >2m), physiognomy (height structure) for all species combined and separate palatable and unpalatable species, phytomass (tree equivalents per hectare) for all species combined and separate palatable and unpalatable species and browsing units per hectare (palatable species only).

Grasses and herbaceous plants were classified as increaser or decreaser species, in order to indicate the ecological status of the species along a grazing gradient; grass forage and fuel factors were calculated by multiplying the frequency of each species with its respective forage or fuel factor (Trollope 1999) and then totalling for the site and expressing the overall forage and fuel factors as the percentage of a benchmark site for False Thornveld of the Eastern Cape (Danckwerts 1981; Trollope 1999). From the forage potential of the grass the grazing capacity of the site was calculated and expressed as hectares per animal unit. The point-to-tuft distance for the site was calculated by taking the average of the 100 points.

The method for generating the indices was adapted for the smaller sites at the University Farm, where data were recorded at 10 sampling points only and duly modified. For the step point survey 50 points were sampled at each of the smaller sites. This allowed data from all transects to be compared.

2.2.4 Species richness and diversity measures

Data collection

Biodiversity data were collected following the method used by Proches and Cowling (2006) for sampling diversity at different spatial scales. In each of the twelve 1km² sites, eight 10 x 10m plots were sampled in pairs placed along a 1km transect that ran North to South down the midline of the site. The first and fourth pair were placed at opposite ends of the transect, with 100m between the first and second pair and also between the third and fourth. The percentage cover for each of the species present was recorded on a scale ranked 1-3, where 3 > 10% cover, 2 = 1%-10% cover and 1=<1% cover. This allowed for a quick and simple distinction to be made between rare and common species within a 100m² area, where percentage cover would be difficult to gauge accurately. The most abundant species were mainly identified in the field; remaining species were collected and later identified in the Schonland Herbarium, Grahamstown. Over 99% of plants were identified to the species level in this way. A total of 96 quadrats were sampled, allowing data to be compared at a small scale (100m²) and at a larger scale (800m²) by pooling the results at each site.

Calculation of diversity indices

(i) Species richness, Shannon index and Simpson's index of diversity

The field data (rank 1-3) were firstly transformed to (0.1,1,10) to reflect the order of magnitude of the species abundance. At a small scale, the data were used to generate values for the following: species richness (S), a modified Shannon index (H'log e) and a modified Simpson's index of diversity (1-λ), for each 100m² quadrat: using PRIMER v6 (Clarke & Gorley 2006).

At a large scale, the species and total rank for 800m² was calculated by adding the 0-10 values from each of the eight 100m² quadrats. This was done for each of the twelve 1km² locations. The total rank for each species (0-80) was then used to generate values for the following indices: total species (S), a modified Shannon index (H') and a modified Simpson's index of diversity (1-λ), using PRIMER v6 (Clarke & Gorley 2006).

(ii) Conservation index

Red List assessments of threatened plants of the Albany Centre of Floristic Endemism in the Eastern Cape province of South Africa (Victor & Dold 2003) according to criteria set out by the World Conservation Union (IUCN 2009) were used to rank species having conservation value on a scale of 1-4 as shown in Table 2.4. The abundance (rank 1-3) was then multiplied by the category rank (1-4) to give an overall conservation index for each species in each quadrat. These were totalled to give a conservation index per 100m². These values were totalled for the site to give the conservation index per 800m².

Table 2.4. Table to show species of importance in the Smaldeel area, with corresponding IUCN category and corresponding rank.

Family	Species	IUCN category*	Rank
ALOEACEAE	*Gasteria bicolor* Haw.	NT	2
AMARYLLIDACEAE	*Bulbine frutescens* (L.) Willd.	VU	3
ASTERACEAE	*Pentzia incana* (Thunb.) Kuntze	LC	1
CRASSULACEAE	*Cotyledon orbiculata* L.	LC	1
CRASSULACEAE	*Crassula arborescens* (Mill.) Willd. subsp. *undulatifolia* Tölken	NT	2
EUPHORBIACEAE	*Euphorbia globosa* (Haw.) Sims	EN	4
LEGUMINOSAE	*Sutera campanulata* (Benth.) Kuntze	LC	1

*Abbreviations: NT, Near Threatened; VU, Vulnerable; LC, Least Concern; EN, Endangered

(iii) Usefulness index

The 60 most frequently traded plants in the Eastern Cape province, for traditional customs and rituals as well as medicinal purposes (Dold & Cocks 2002) were used as a basis for determining a usefulness index for plots and sites. In addition, extra information on the usefulness of each species found during the survey was provided by a known expert on traditional plant use in the study area (A. P. Dold, *pers. comm.*). Species were ranked as follows: Very Important = 3; Important =2; Least Important = 1; Not Used = 0, as shown in Appendix C. The abundance (rank 1-3) was then multiplied by the usefulness rank (1-3) to give an overall usefulness index for each species. These were totalled to give a usefulness index per 100m² quadrat. These values were totalled to give a usefulness index per 800m².

(iv) Genus richness

The occurrence of taxonomically distinct species increase in an assemblage adds to the biodiversity value of an area. Several studies suggest that higher taxon richness is a good surrogate for phylogenetic distinctness (Williams & Humphries 1996; Crandall 1998; Gaston & Rodrigues 2002). The number of genera present in each plot was totalled to give genus richness (genus richness/100m²). The genus richness for the entire site was also calculated (genus richness/800m²).

2.2.5 Primary production and biomass

The mean, maximum, duration of high NDVI (indicative of high standing green biomass and active growth over a time period (Rouse 1974), temporal CV in NDVI (the variation in a pixel value over time) and MSDI (the standard deviation in pixel values for a pixel and the surrounding 8 pixels) for an 18-year period were compared for the four vegetation states.

In addition, the monthly mean and standard deviation for the LAI of each vegetation state was calculated for the period 2000-2008 using MODIS data at the 1km² resolution.

2.2.6 Statistical analyses

(i) Species composition data

For the browse/grass species abundance data non-metric Multi-Dimensional Scaling (MDS, using Bray-Curtis similarity and square-root transformed data) was used to spatially represent species composition relationships between sites. For the biodiversity data MDS was done using the untransformed data, as the scaled field data (0,01,1,10) were considered already transformed. Mantel-type Monte-Carlo analysis (ANOSIM) was used to identify any significant differences in species composition between vegetation states and checked against a CLUSTER analysis dendrogram. Finally, a similarity percentages analysis (SIMPER) was used to determine which species were responsible for the similarities and differences found, using PRIMER v6 (Clarke & Gorley 2006).

(ii) Comparison of indices between states

To test for significant differences between vegetation states for the satellite data, LFA, grazing and browse potential, biodiversity, conservation and usefulness indices the data were first tested for normality using the Shapiro-Wilks test (more powerful when $n<50$) and then Levene's and Bartlett's tests for equal variances to see if they met the assumptions for ANOVA. One-way ANOVA tests, or Kruskal-Wallis tests where data did not meet the assumptions for ANOVA, were then carried out to see if there were any significant differences between vegetation states for each of the indices.

Where the overall effect of vegetation was found to be significant, Fischer's least significant difference procedure (parametric) or Statistica V9.0 default non-parametric *post hoc* tests (Siegel & Castellan Jr 1988) were used to identify between which of the four vegetation states there was a significant difference in values for that index. Analyses were performed using Statgraphics Plus 5.1 and Statistica V9.0.

(ii) Correlations between different indices

Pearson product-moment correlation coefficient (r, for normally distributed data) and Spearman's rank correlation coefficient (Spearman's rho, for non-parametric data) analyses were used to test whether a selection of ecological quality indices from each method correlated with each other. For the browse and veld indices mean values for the site were used. For the diversity indices collected at two spatial scales, the results from 800m² were used to better represent the actual diversity of the 1km² site. The indices were also regressed against mean annual precipitation taken from an 18-year period of satellite data to look for any rainfall effects.

2.3 Results

2.3.1 Landscape function and ecosystem health

(i) Landscape Organisation indices

The patch area index was higher for communal and savanna vegetation, compared with the thicket and acacia vegetation types ($F = 8.25$; $df = 3$; $p<0.01$), (Figure 2.2a). The inter-patch range differed significantly between the four states ($H = 8.19$; $df = 3$; $p<0.05$).

However, the multiple pairwise testing did not detect significant differences between states at the 5% level (Figure 2.2b). The number of patches per 10m, the landscape organisation index, the average inter-patch length and the total patch area showed no significant differences between vegetation states.

(ii) Soil Surface Assessment Indices

Due to the aggregation of the results, the grass/succulent patch type data, being less than 5% of any transect, were combined with the most closely related patch type (grass and small shrubs) and no longer appear individually in the analysis section. Soils were found to be the same on all sites and for all patches with the exception of the grass/succulent patch type and bare shale inter-patches found in less than 5% of transects on one thicket site.

ANOVAs revealed no significant differences between the four vegetation states for the stability index, infiltration index and the nutrient cycling index (Figure 2.3a-c). The indices were most variable in thicket, probably due to it being the vegetation state with the greatest variation of patch type and size. The relative contribution of each patch type to the overall SSA values (Figure 2.3d) differed little between communal and savanna; thicket has a relatively high proportion of closed bush clump, whereas acacia has a higher proportion of acacia canopy patch, consistent with what would be expected. Highest scores for the stability, nutrient cycling and infiltration indices were found for closed bush-clumps and small shrub patches within the thicket state, where leaf litter tended to be found in a state of moderate decomposition. The frequency of each patch type within the different vegetation states is shown in Figure 2.3.

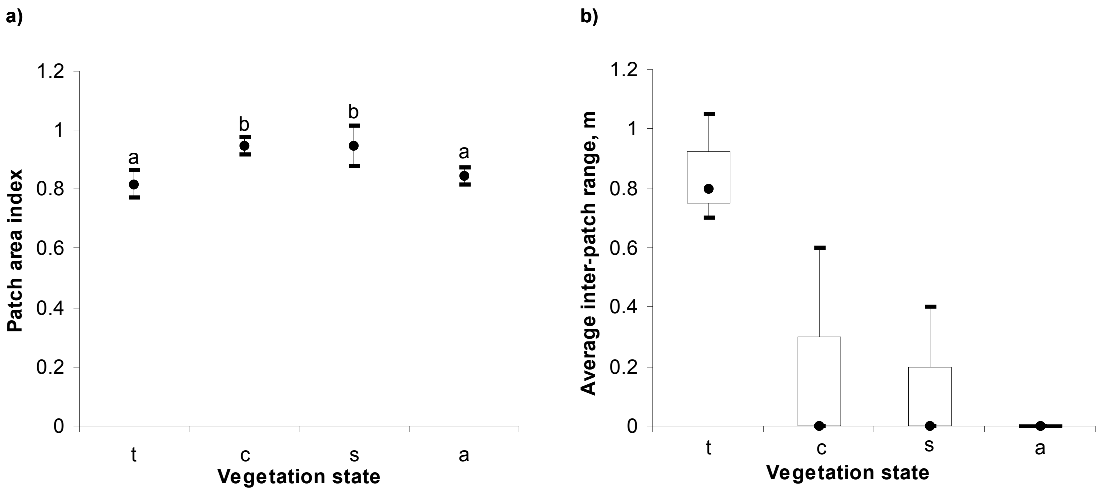

Figure 2.2. Mean and 95% confidence limits for the patch area index and medians, first and third quartiles and ranges for the average inter-patch range shown for the different vegetation states. Results of *post hoc* tests indicated using a and b; t=thicket, c=communal, s=savanna, a=acacia vegetation states.

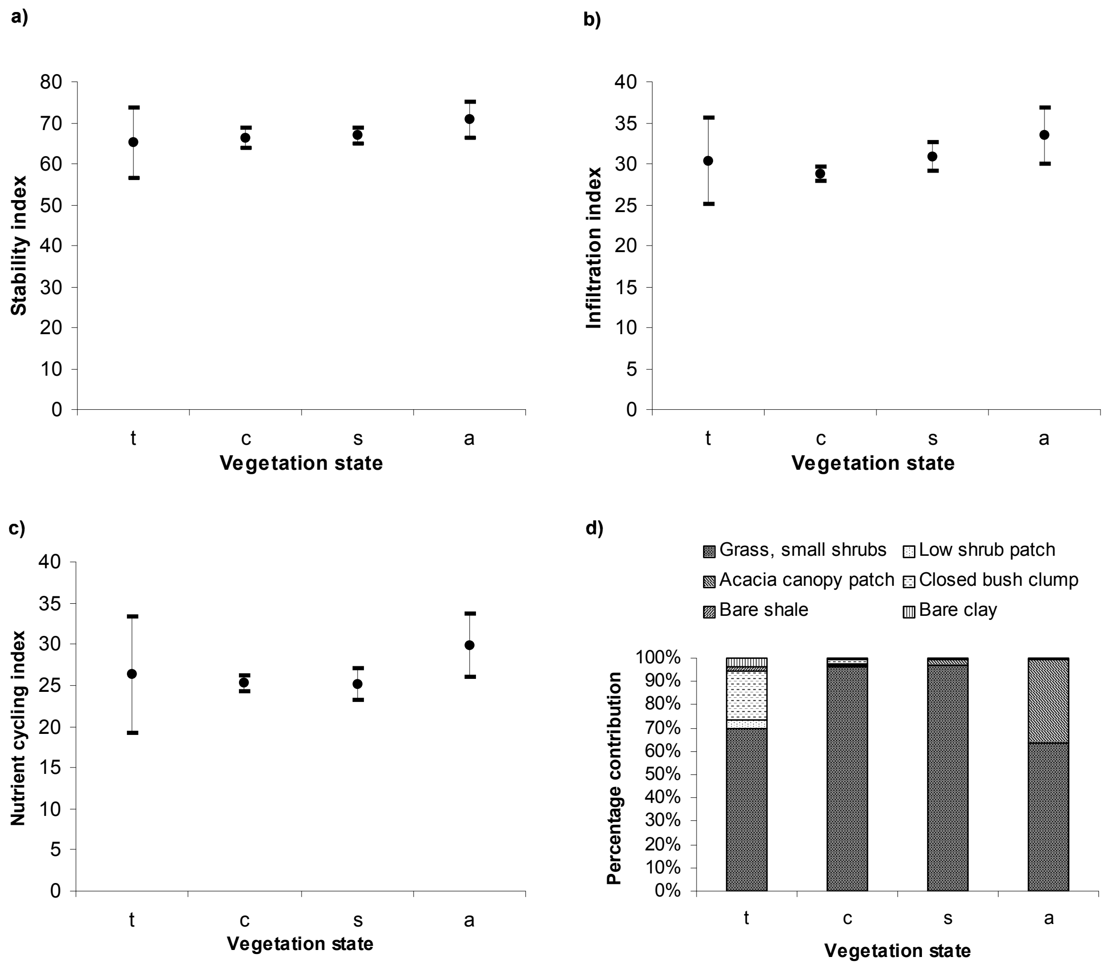

Figure 2.3. Values for the three SSA (shown are the means and 95% confidence limits) and the frequency of each patch type in the different vegetation states. t=thicket, c=communal, s=savanna, a=acacia vegetation states.

2.3.2 Range condition

(i) Browse data variables and species composition

(a) Browse variables

Savanna had significantly less woody vegetation for all browse data variables compared with one or more of the other vegetation states. The savanna state had significantly lower numbers of all woody plants compared with the other vegetations states ($H = 25.3$; $df = 3$; $p<0.05$, Figure 2.4a). Savanna also had a significantly lower density of browse under 2m compared with thicket and communal vegetation, but not with acacia ($H = 15.1$; $df = 3$; $P<0.05$, Figure 2.4b) and a significantly lower density of browse over 2m compared with thicket and acacia vegetation, but not with communal ($H = 23.7$; $df = 3$; $P<0.05$, Figure 2.4c). The savanna state also had less unpalatable tree equivalents compared with thicket ($H = 12.2$; $df = 3$; $P<0.05$, Figure 2.4d), but significantly less palatable tree equivalents ($H = 20.6$; $df = 3$; $P<0.05$, Figure 2.4e) and browsing units under 2m ($H = 21.5$; $df = 3$; $P<0.05$, Figure 2.4f) compared with all the other states.

(b) Browse species composition

The MDS analysis of all woody plants recorded in the browse survey revealed the woody plant composition in the thicket state to be the most different from the other vegetation types, (Figure 2.5a). This was verified by the cluster analysis dendrogram (Figure 2.5b). The Mantel-type Monte Carlo analysis showed an overall significant effect of vegetation state on woody plant composition (Global $R = 0.487$, $p<0.001$) and pairwise tests showed that all four vegetation states differed significantly from each other with $p<0.001$ in terms of their woody composition with the exception of communal and acacia vegetation states, which differed at $p<0.05$.

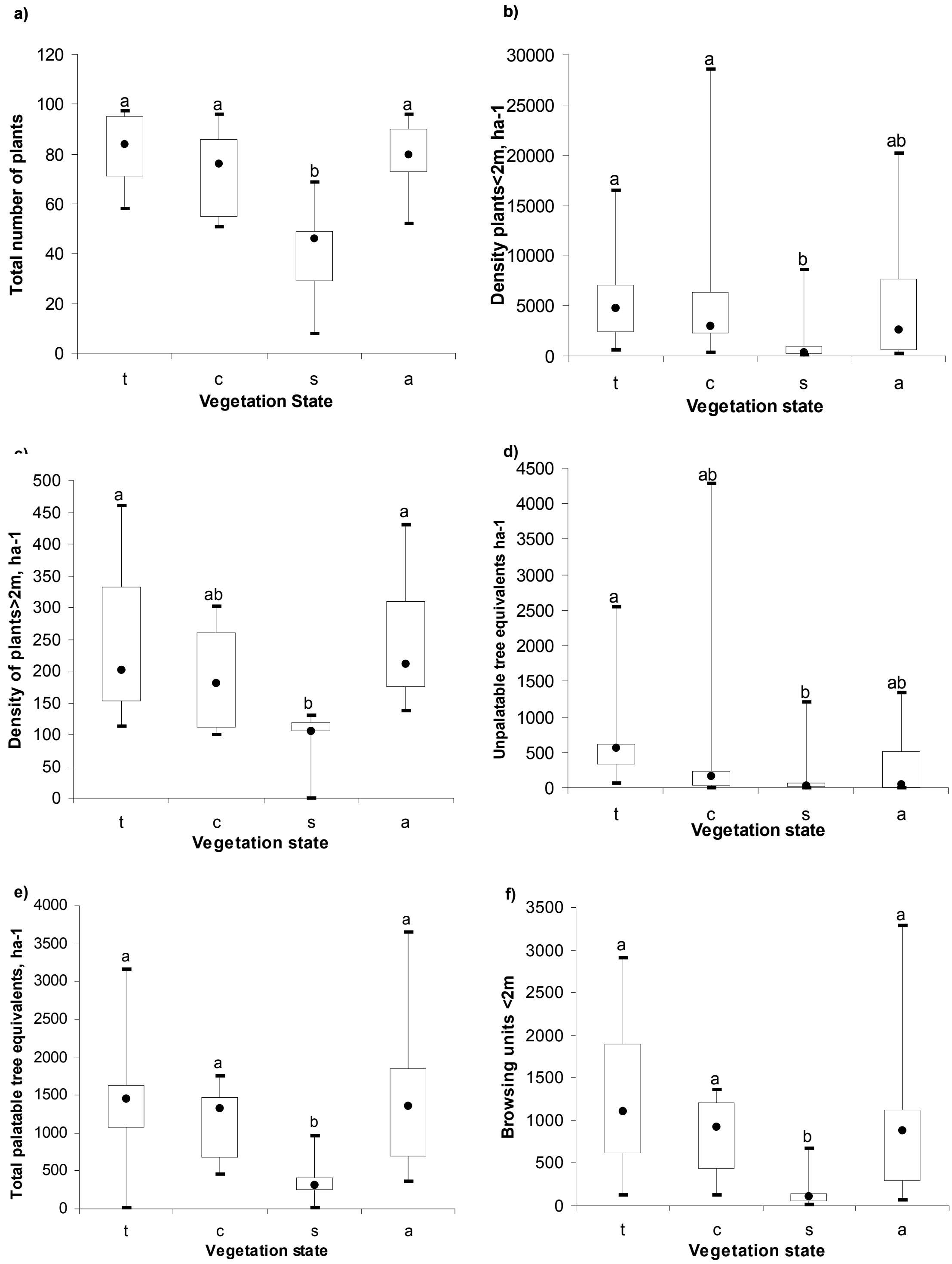

Figure 2.4. Medians, first and third quartiles and ranges shown for the total number of plants, the density of plants<2m, the density of plants>2m, the unpalatable tree equivalents per hectare, the palatable tree equivalents per hectare and the browsing units under 2m, for the four vegetation states. Results of *post hoc* tests indicated using a and b; t=thicket, c=communal, s=savanna, a=acacia vegetation states.

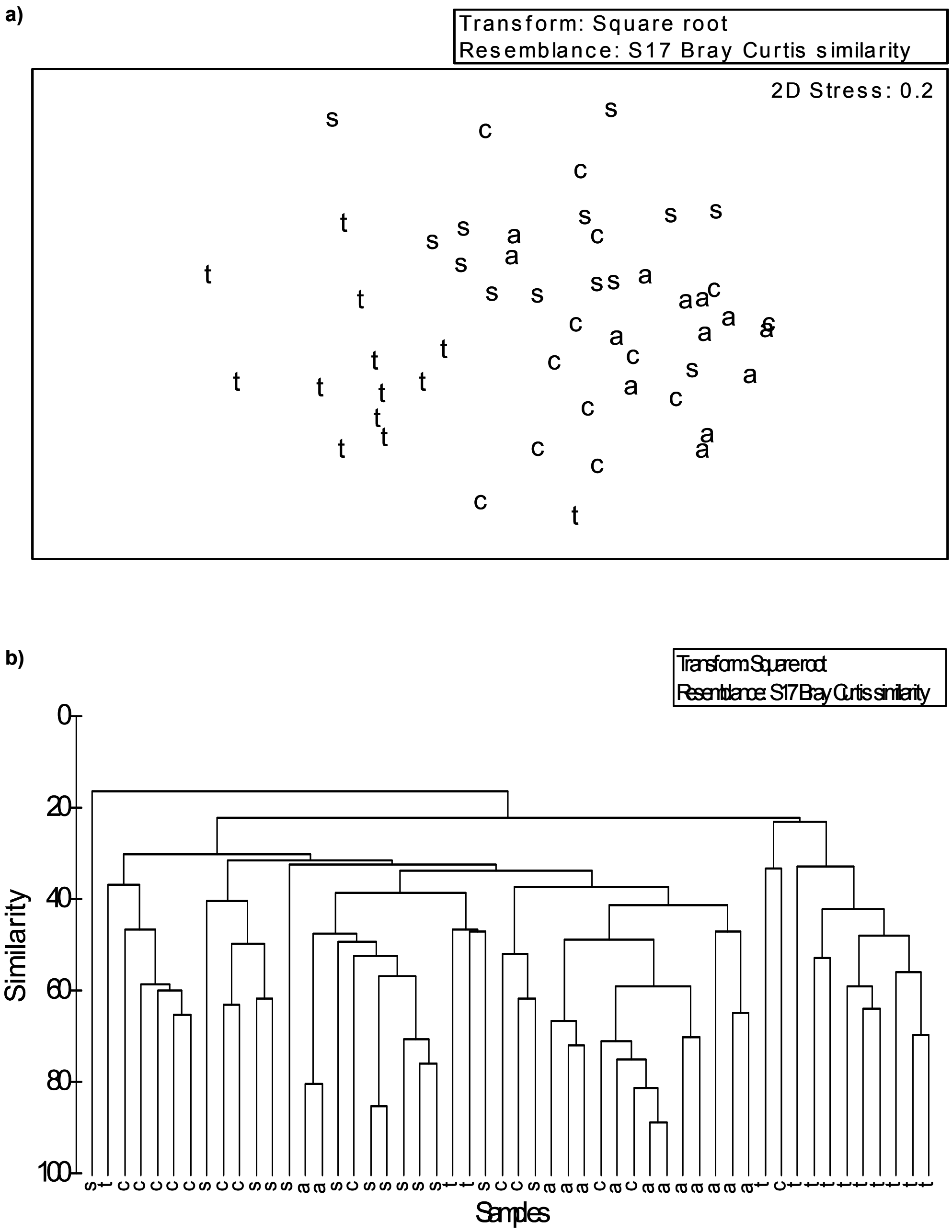

Figure 2.5. MDS ordination plot and a cluster analysis dendrogram to show the similarities between browse species assemblages found in the different vegetation states (thicket =t, communal =c, savanna =s, acacia =a)

The top five species that contributed to within state similarity in the four vegetation types are shown in Table 2.5. *Acacia karroo* was the most abundant species in all vegetation states and contributed in varying degrees (most in the acacia state and least in thicket) to their within-group similarity. Key species that characterise the sites are those having a high contribution to within state similarity, whilst maintaining a low standard deviation and thus a low ratio of average similarity to percentage contribution. As well as *Acacia karroo* being a key species, the thicket state was characterised by the presence of *Asparagus striatus*, *Grewia robusta* and *Putterlickia pyracantha*, the communal state by *Asparagus suaveolens* and *Coddia rudis*, the savanna state by the presence of *Felicia muricata* and *Felicia filifolia* along with *Asparagus suaveolens* and the acacia state by *Asparagus suaveolens* and *Lycium ferocissimum*.

Table 2.5. The top five browse species that most contributed to the similarity within states.

Vegetation state	Average similarity	Species	Average abundance (%Frequency)	Percentage contribution	Ratio similarity/ contribution
Thicket	37.21	*Acacia karroo*	10.41	14.64	1.68
		Asparagus striatus	7.86	12.58	1.73
		Grewia robusta	8.03	9.69	1.21
		Putterlickia pyracantha	6.41	8.39	0.92
		Felicia filifolia	7.96	6.64	0.66
Communal	35.68	*Acacia karroo*	41.17	54.05	1.96
		Asparagus suaveolens	5.15	8.50	0.87
		Coddia rudis	4.58	8.32	0.85
		Indigofera sessilifolia	3.08	3.86	0.54
		Lycium ferocissimum	4.75	3.47	0.57
Savanna	39.20	*Acacia karroo*	30.17	42.95	1.83
		Felicia muricata	7.09	14.80	1.11
		Felicia filifolia	13.90	11.19	0.63
		Asparagus suaveolens	8.22	9.25	0.82
		Helichrysum rosum var. arcuatum	6.71	7.64	0.56
Acacia	45.82	*Acacia karroo*	63.57	74.41	2.57

(ii) Herbaceous component

(a) Grass assessment variables

The percentage of decreaser, increaser II or increaser I species did not differ significantly between the four vegetation states. The communal vegetation state had the greater incidence of increaser II species and fewer decreaser species than the other states (Figure 2.6a).

The communal state vegetation had a significantly lower fuel potential compared with both the savanna and acacia state (F = 2.93; df = 3; P<0.05, Figure 2.6b). The mean point-to-tuft distance was higher and more variable in the thicket vegetation state compared with the communal vegetation state (H

= 13.0; df = 3; $P<0.05$, Figure 2.6c), which indicates that overall basal cover was lower and more variable in this state compared with the others. However, all vegetation states fall into the category of low potential for erosion, as the mean point-to-tuft distance was substantially less than 10cm for each state.

No significant differences between vegetation states were found for grazing capacity. The grazing capacity was most variable in the communal and acacia vegetation states, (Figure 2.6d).

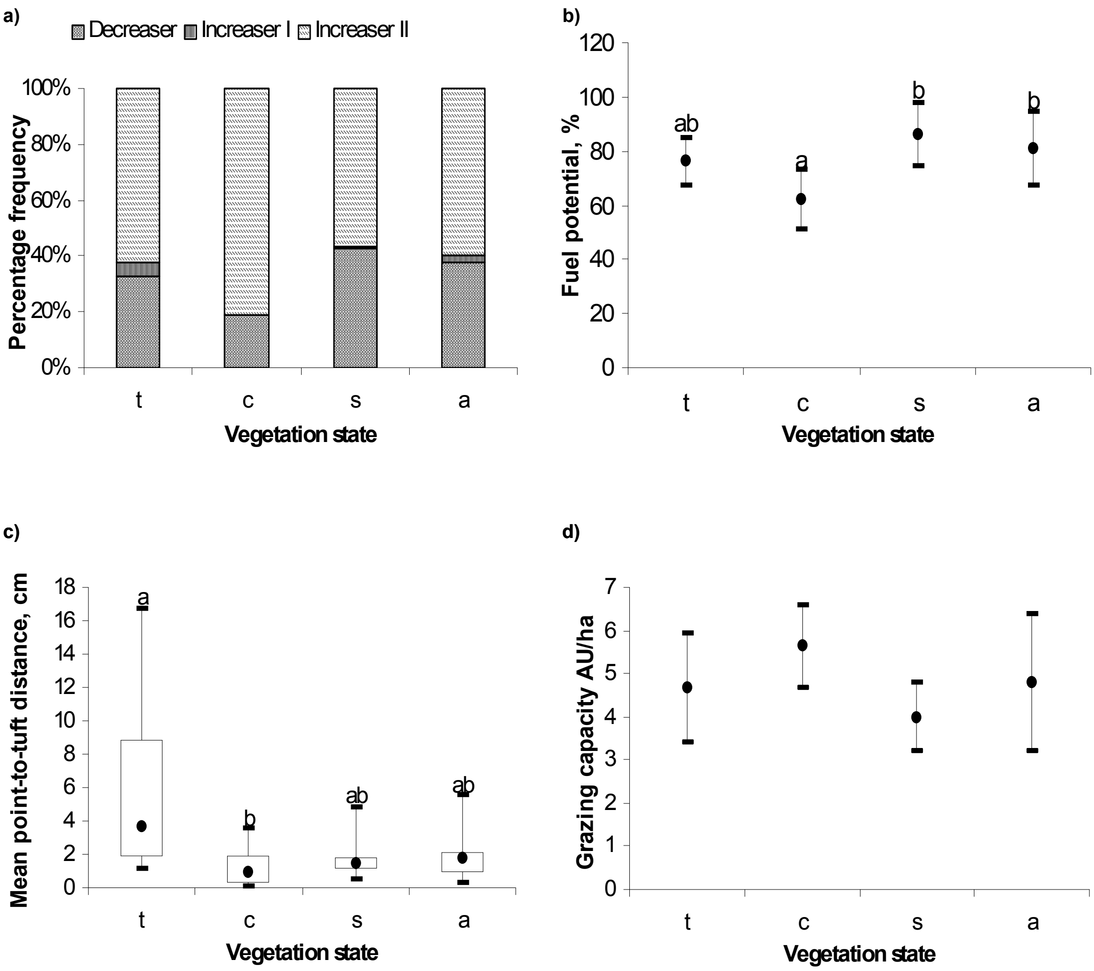

Figure 2.6. The percentage frequency of increaser I and II and decreaser species in the four vegetation types and the mean and 95% confidence limits for the grazing capacity per hectare and the fuel potential and medians, first and third quartiles and ranges for the mean point-to-tuft distance shown for the four vegetation types. Results of *post hoc* tests indicated using a and b; t=thicket, c=communal, s=savanna, a=acacia vegetation states.

(b) Grass species composition

The MDS analysis and the cluster analysis dendrogram did not reveal clear differences in grass composition between states. The Mantel-type Monte Carlos analysis showed that grass composition differed significantly between states (Global R = 0.141, $p<0.001$). Pairwise tests showed the grass composition in the savanna vegetation state to be significantly different from all the other states (Table 2.6), with the thicket state differing from communal and acacia vegetation at a $p<0.1$.

Table 2.6. Pairwise Monte Carlo analysis to test for differences in grass species composition between the four vegetation states. Probability values (p) are given and significant results ($\alpha = 0.05$) are highlighted in bold.

	Thicket	Communal	Savanna	Acacia
Thicket	xxx			
Communal	0.051	xxx		
Savanna	**0.001**	**0.006**	xxx	
Acacia	0.056	0.084	**0.033**	xxx

The five grass species which contributed most to within-state similarity for all four states are listed in Table 2.7.

Table 2.7. The top five grass species that most contributed to the similarity within states

Vegetation state	Average similarity	Species	Average abundance (%Frequency)	Percentage contribution	Ratio similarity/ contribution
Thicket	48.64	*Digitaria eriantha*	23.38	30.31	2.54
		Sporobolus fimbriatus	14.23	21.85	2.05
		Themeda triandra	15.54	11.16	0.77
		Cynodon dactylon	6.62	9.42	1.06
		Eragrostis obtusa	5.54	9.36	0.95
Communal	54.86	*Digitaria eriantha*	30.36	33.38	4.41
		Themeda triandra	15.62	13.31	1.19
		Sporobolus fimbriatus	7.85	13.29	1.48
		Eragrostis curvula	13.23	9.53	0.95
		Cynodon dactylon	8.74	9.23	0.73
Savanna	59.13	*Themeda triandra*	41.62	36.34	1.97
		Digitaria eriantha	23.00	27.10	3.41
		Eragrostis curvula	12.92	12.01	1.11
		Forbs	5.62	9.71	1.21
Acacia	50.59	*Themeda triandra*	32.31	26.58	1.10
		Digitaria eriantha	14.92	23.05	2.97
		Sporobolus fimbriatus	11.92	17.84	1.87
		Eragrostis curvula	8.69	16.53	1.60
		Cynodon dactylon	10.31	5.00	0.55

Key species for all the states were very similar. *Themeda triandra*, *Sporobolus fimbiatus* and *Digitaria eriantha* contributing to the within state similarity for all four vegetation states, differing only in their percentage contribution. *Eragrostis obtusa* seemed to be a key species in the thicket state and forbs contributed to the within group similarity in the savanna state.

2.3.3 Species richness and diversity

(i) Taxonomic representation

A total of 242 plant species belonging to 169 genera in 68 families were found in 96 x 100 m^2. The best-represented plant families were Asteraceae (25), Poaceae (22), Crassulaceae (12), Fabaceae (12), Liliaceae (11) and Aizoaceae (10). The best-represented genera were Crassula (Crassulaceae; 10 species), Asparagus (Liliaceae; 8 species) and Eragrostis (Poaceae; 5 species). A full species list is shown in Appendix D.

(ii) Species composition data

The MDS for all species (Figure 2.7a) revealed thicket vegetation as having the most distinct assemblage of species. Although more similar to communal vegetation, it had very little overlap on the ordination plot with savanna or acacia vegetation. This was verified with the cluster analysis dendrogram (Figure 2.7b).

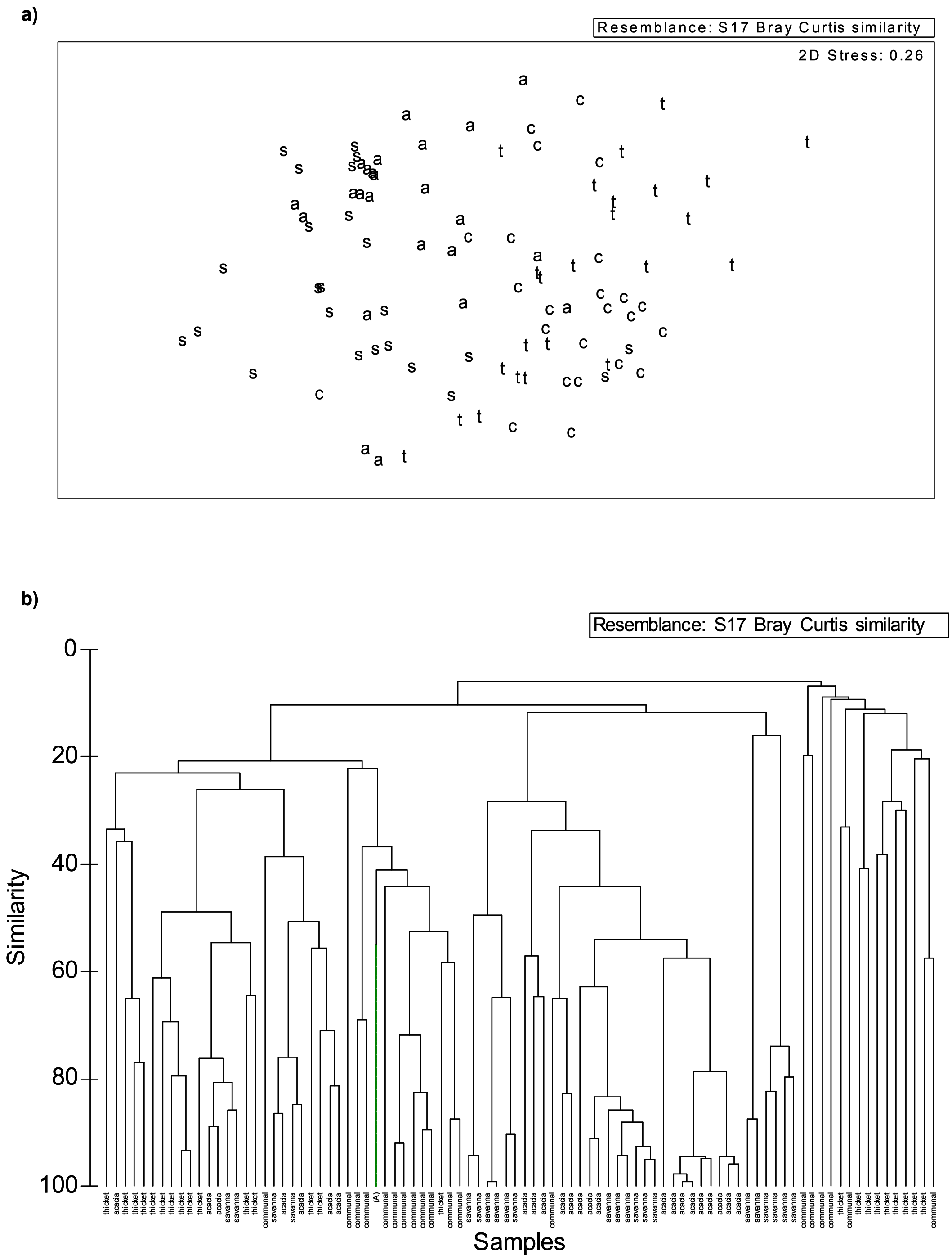

Figure 2.7. MDS ordination plot (a) and a cluster analysis dendrogram (b) to show the similarities between species assemblages found in the different vegetation states (thicket =t, communal =c, savanna =s, acacia =a).

ANOSIM showed an overall significant effect of vegetation state on species composition (Global R = 0.383; p = 0.001). Pairwise tests indicated significant differences between all vegetation states (Table 2.8).

Table 2.8. Pairwise Monte Carlo analysis to test for differences in species composition between the four vegetation states. Probability values (p) are given and significant results (α = 0.05) are highlighted in bold.

	Thicket	Communal	Savanna	Acacia
Thicket	xxx			
Communal	**0.001**	xxx		
Savanna	**0.001**	**0.001**	xxx	
Acacia	**0.001**	**0.001**	**0.002**	xxx

Table 2.9 summarises the key species that characterise the different vegetation states. Grass species were major key species in all four vegetation states. Thicket sites were mainly characterised by *Digitaria eriantha* and *Cymbopogon pospischilii*, communal sites by a combination of *Digitaria eriantha*, *Eragrostis chloromelas* and *Eragrostis obtusa*, savanna sites by *Themeda triandra* and *Eragrostis curvula* and acacia sites by *Themeda triandra* and *Acacia karroo*.

Table 2.9. The top five species that most contribute to the similarity within states.

Vegetation state	Average similarity	Species	Average abundance Score (0-80)	Percentage contribution	Ratio similarity/ contribution
Thicket	21.27	*Digitaria eriantha*	4.40	24.46	0.51
		Cymbopogon pospischilii	4.18	24.37	0.42
		Sporobolus fimbriatus	2.04	6.20	0.38
		Acacia karroo	1.97	4.53	0.30
		Eragrostis obtusa	0.93	4.15	0.65
Communal	27.56	*Digitaria eriantha*	7.22	63.72	1.02
		Eragrostis chloromelas	2.68	9.57	0.30
		Eragrostis obtusa	3.00	8.47	0.33
		Acacia karroo	1.33	4.53	0.64
		Themeda triandra	0.69	1.32	0.39
Savanna	24.61	*Themeda triandra*	4.31	41.11	0.45
		Eragrostis curvula	3.57	20.28	0.42
		Heteropogon contortus	2.52	9.57	0.23
		Cymbopogon pospischilii	2.65	9.17	0.28
		Digitaria eriantha	1.74	7.99	0.58
Acacia	36.95	*Themeda triandra*	6.68	41.82	0.81
		Acacia karroo	6.83	36.11	0.91
		Eragrostis curvula	2.69	4.96	0.32
		Cymbopogon pospischilii	2.59	4.94	0.24
		Digitaria eriantha	2.61	4.21	0.27

(iii) ***Species richness, Shannon index and Simpson's index of diversity***

(a) Large scale (800m²)

Thicket had significantly higher total species richness at this scale, compared with all the other vegetation states ($F = 9.54$; $df = 3$; $p<0.01$; Figure 2.8a). No significant differences were found between the vegetation states for the modified Shannon index or the modified Simpson's index of diversity.

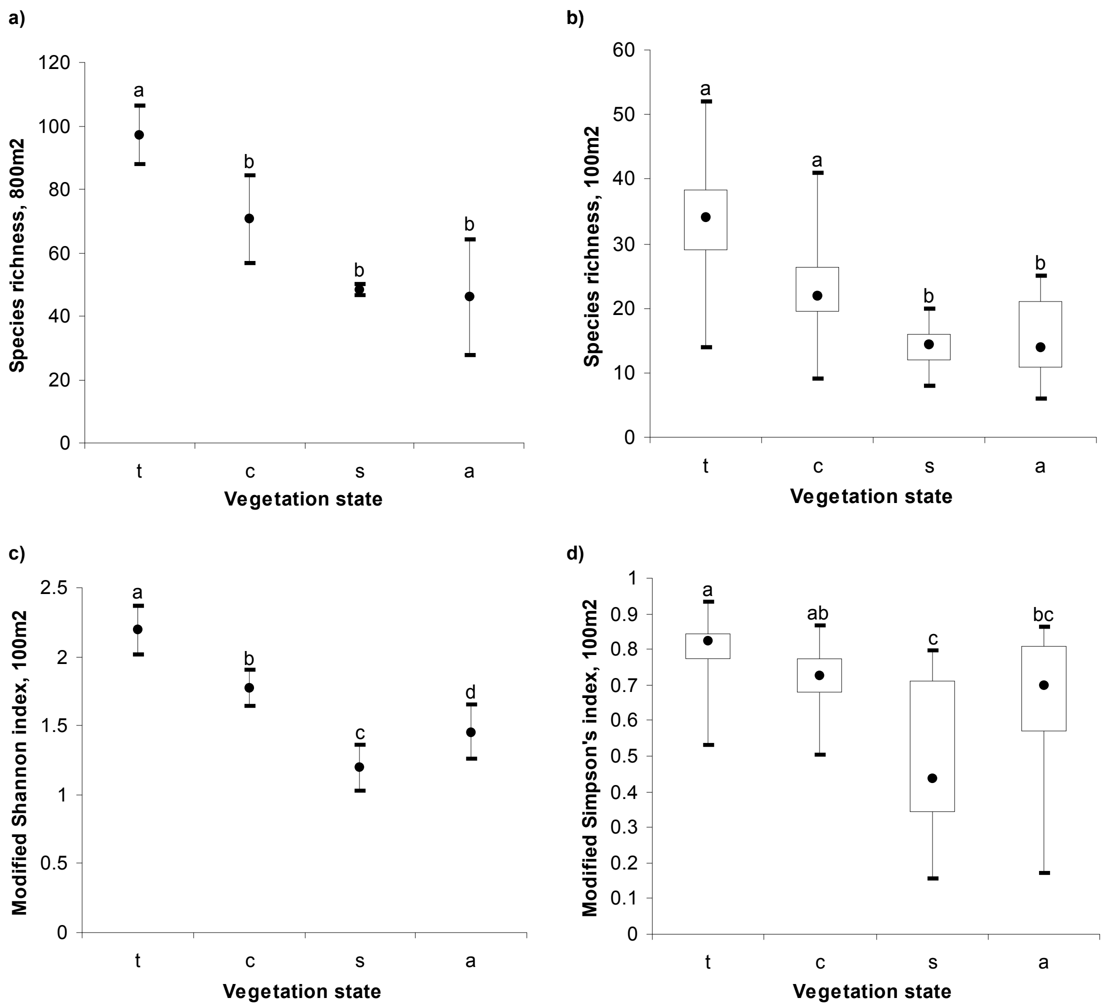

Figure 2.8. Means and 95%confidence limits for species richness 800m² and the modified Shannon index 100m² and the medians, first and third quartiles and ranges for the species richness 100m² and modified Simpson's index 100m² shown for the four vegetation states. Results of *post hoc* tests indicated with a,b,c and d; t=thicket, c=communal, s=savanna, a=acacia.

(b) Small scale (100m²)

Species richness was significantly greater in the thicket and communal states, compared with the savanna and acacia vegetation states, ($H = 45.07$; $df = 3$; $p<0.01$ Figure 2.8b). The modified Shannon index was significantly different for all four vegetation states, ($F = 24.47$; $df = 3$; $p<0.01$; Figure 2.8c). Significantly higher values for the modified Simpson's index of diversity were found in thicket compared with the savanna and acacia vegetation states and significantly lower values for the index were found in the savanna state compared with both thicket and communal states, ($H = 30.98$, $df = 3$; $p<0.01$; Figure2.8d).

(iv) Conservation value, Usefulness value, and Genus richness

(a) Large scale (800m²)

No significant difference was found between the four vegetation states for the conservation index (Figure 2.9a). Thicket had a significantly higher usefulness index compared with the other vegetation states ($F = 12.64$, $df = 3$, $p < 0.01$; Figure 2.9c) and greater genus richness compared with the savanna and acacia states ($F = 7.86$, $df = 3$, $p < 0.01$; Figure 2.9e).

(b) Small scale (100m²)

A Kruskal-Wallis analysis revealed significant differences between vegetation states for the conservation index ($H = 9.30$, $df = 3$, $p < 0.05$; Figure 2.9c), however pairwise tests failed to reveal significant differences between the treatments. The thicket state scored higher in terms of usefulness index compared with the savanna and acacia states and savanna had a significantly lower usefulness index compared with all the other states ($H = 45.07$; $df = 3$; $p < 0.01$; Figure 2.9d). Thicket and communal vegetation had greater genus richness than the savanna and acacia vegetation states ($H = 47.01$; $df = 3$; $p < 0.01$; Figure 2.9f).

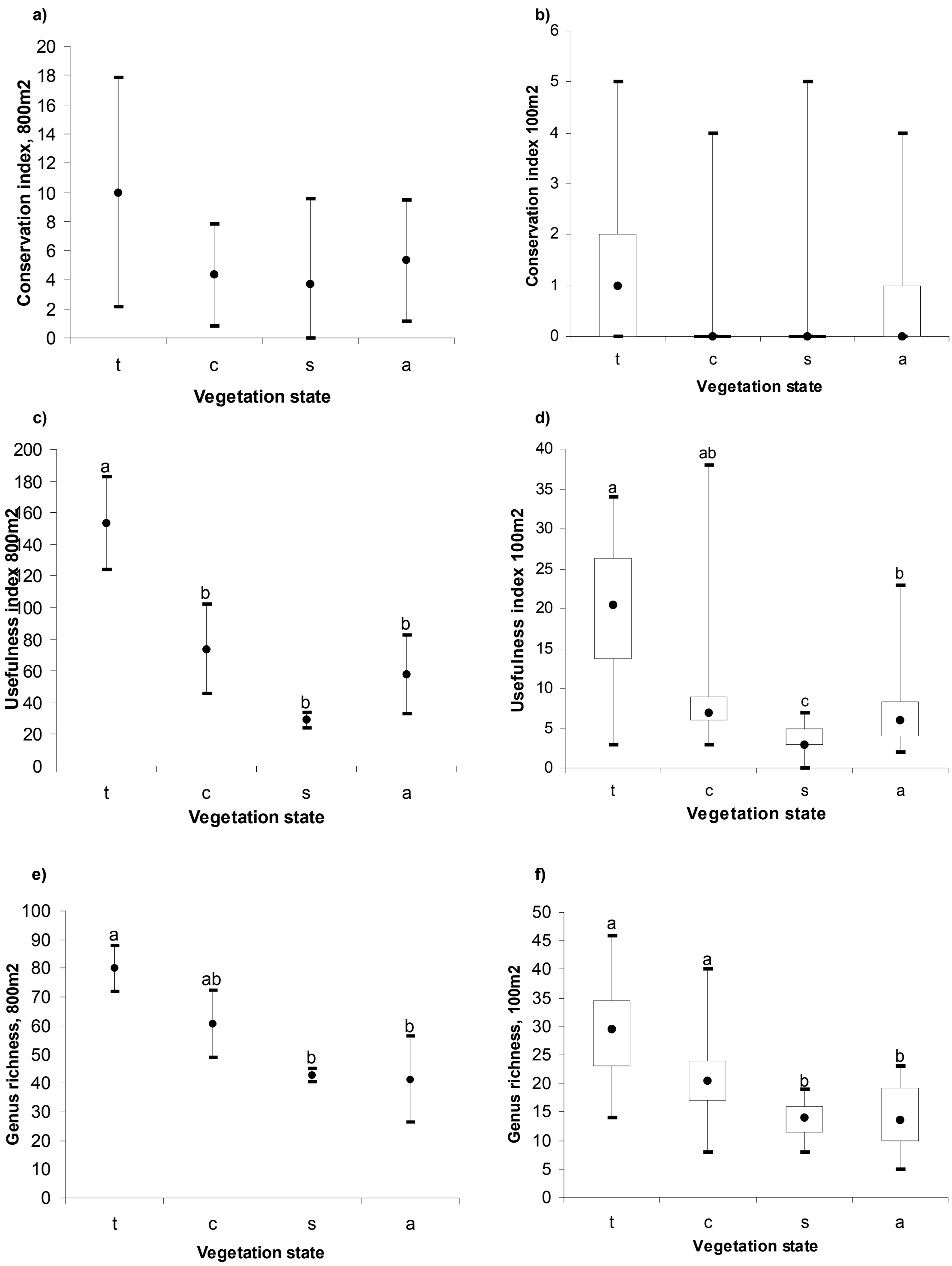

Figure 2.9. Means and 95% confidence limits for the conservation index, usefulness index and genus richness 800m². Medians, first, third quartiles and ranges shown for the conservation index and usefulness index and genus richness 100m². Results of *post hoc* tests indicated using a, b and c; t=thicket, c=communal, s=savanna, a=acacia vegetation states.

2.3.4 Primary production and biomass

The duration of high NDVI in the thicket state was significantly higher than in the other vegetation states ($F = 4.18$; $df = 3$; $p<0.05$; Figure 2.10a). However, no significant differences were found for the mean, neither maximum nor temporal CV of NDVI, or the MSDI. Thicket and savanna states had the lowest MSDI values and the communal state had the highest, which suggests that with a greater number of samples a significant difference might have been found, (Figure 2.10b).

The same general trend was seen in the LAI data for all four vegetation states, with maximum values being reached from November to January and minimum values from June to September. The savanna state had the lowest LAI values throughout the year, followed by thicket, then communal, then the acacia vegetation state (Figure 2.10c-g). The greatest range of values and larger standard deviations for each month were seen for acacia. The smallest range of values and standard deviations were seen in the savanna state.

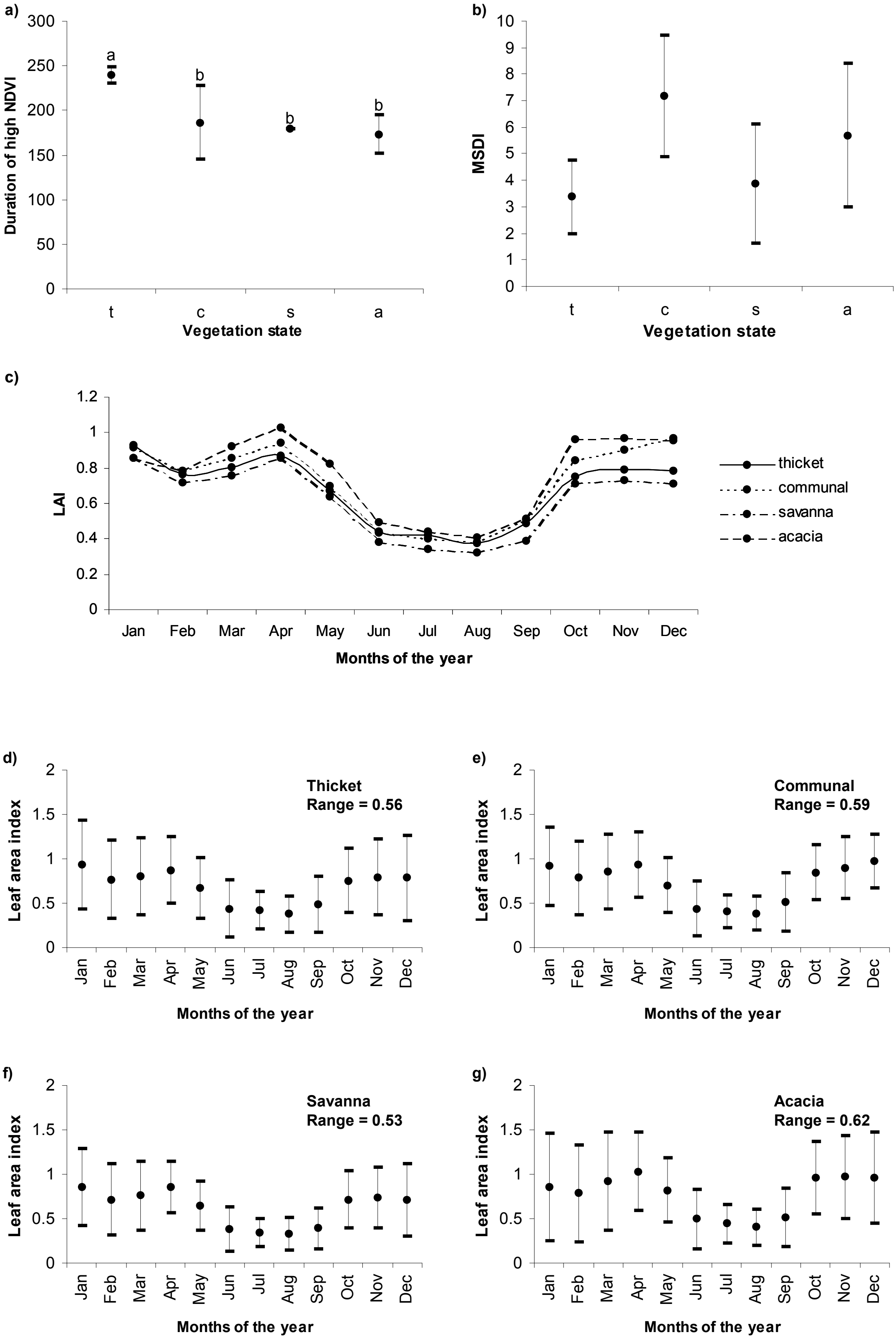

Figure 2.10. Means and 95% confidence limits shown for the duration of high NDVI and the MSDI for the four vegetation states and the monthly mean LAI for all four states from 2000-2008. Results of *post hoc* tests indicated using a and b. (t=thicket, c=communal, s=savanna, a=acacia).

2.3.5 Correlations between the different attributes

A correlation matrix showing how the selected indices correlated with each other is shown in Table 2.10. Indices derived from the same field data were all significantly positively correlated. Graphs of the significant correlations are shown in Figure 2.11a-h, and Figure 2.12a-f. Excluded are those graphs showing significant correlations between indices derived from the same data set.

Landscape function and biodiversity indices

The mean inter-patch range (the average distance between patches) correlated positively with species richness, the usefulness index and genus richness. The patch area index (total patch area/maximum area (transect length x10)), correlated negatively with the usefulness index. The stability index was negatively correlated with the conservation index.

Landscape function and primary production

The mean NDVI correlated positively with the nutrient cycling, stability and infiltration indices. No other relationship was found between primary production, grazing, browsing and biodiversity indices or rainfall.

Grazing and browsing potential

Rainfall was found to correlated negatively with forage potential (%) and positively with the mean grazing capacity (ha/AU). The grazing and browsing potential of the land did not correlate with any of the other indices, nor did the rainfall data.

Biodiversity indices

Genus richness correlated positively with species richness and thus with the other measures of diversity. A strong positive correlation existed between the usefulness index and the other biodiversity indices. The strongest correlation was with species and genus richness, followed by the modified Simpson's index of diversity and the modified Shannon's index, but none was found for the conservation index. The biodiversity indices did not show any relationship to grazing or browsing potential, nor to primary production or rainfall.

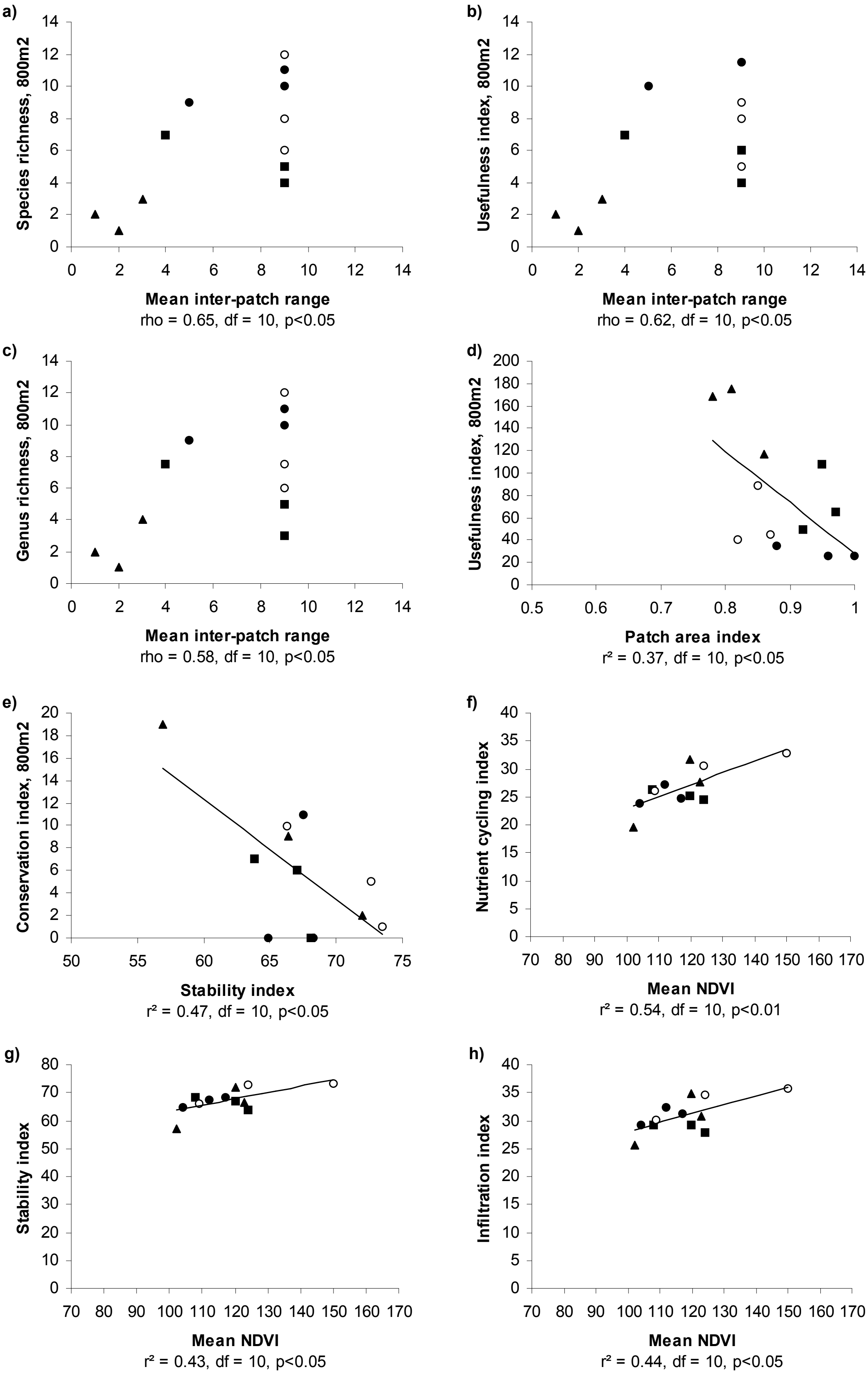

Figure 2.11. Significant correlations between the indices using Spearman's rank correlation, graphs a) b) and c) and Pearsons product-moment correlation coefficient, regression lines drawn in, graphs d)-h).

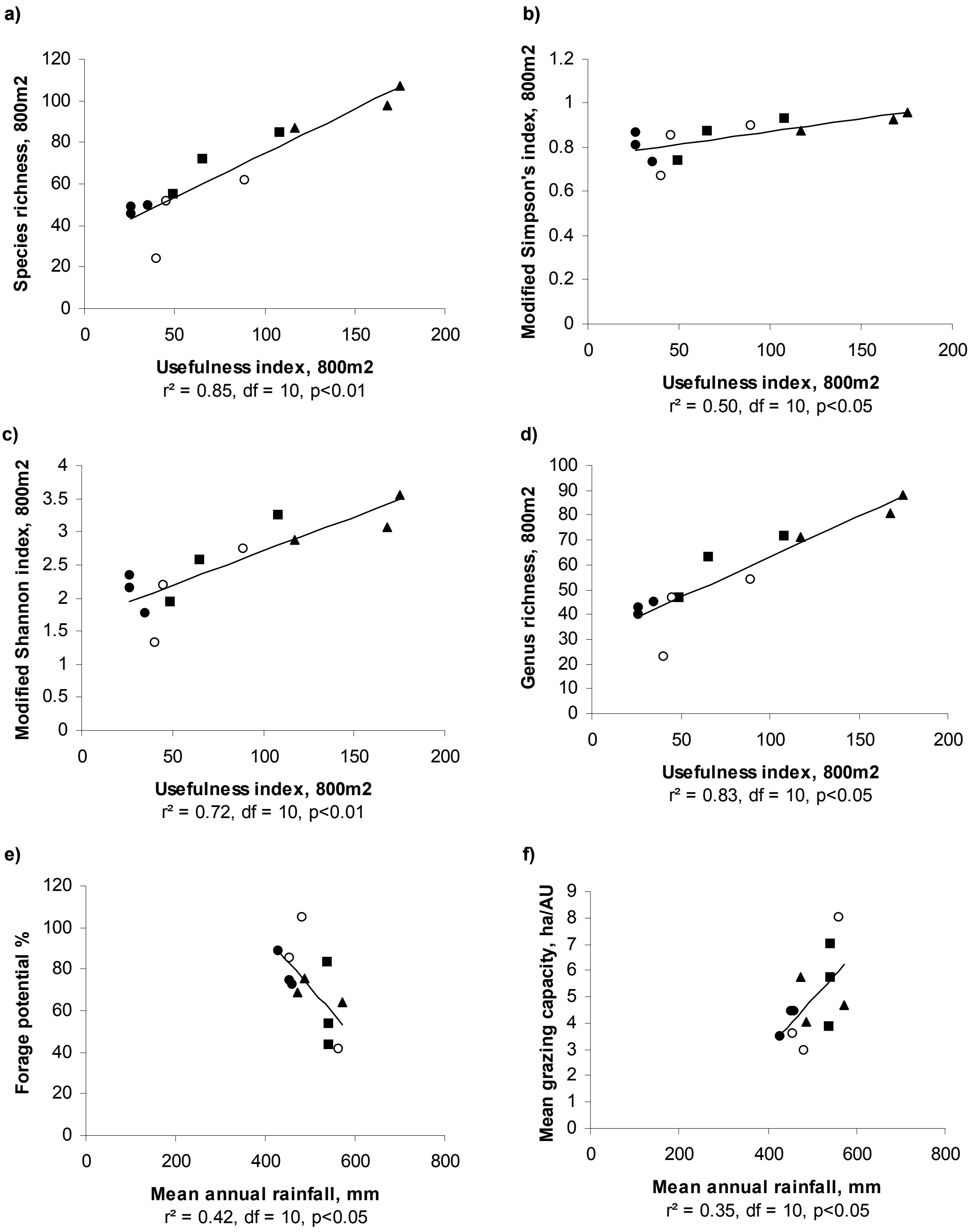

Figure 2.12. Significant correlations between the indices Pearsons product-moment correlation coeffiecient.

Table 2.10. Table to show the r/rho values for correlations between the most representative ecosystem quality indices

	Landscape organisation index (rho)	Mean inter-patch range (rho)	Number of patches per 10m	Patch area index	Nutrient cycling	Stability	Infiltration	Total tree equivalents per hectare	Browsing units <2m per hectare	Forage potential %	grazing capacity ha/au	Species richness (800m²) (S)	Modified Simpson's index (1-λ)	Shannon index H' (loge)	Conservation index	Usefulness index	Genus richness (800m²)	MSDI	18yr mean NDVI
Landscape organisation index (rho)																			
Mean inter-patch range (rho)	*-0.888																		
Number of patches per 10m	*-0.652	0.469																	
Patch area index	*0.649	-0.585	*-0.915																
Nutrient cycling	-0.305	0.086	0.475	-0.422															
Stability	-0.337	-0.023	0.349	-0.271	*0.932														
Infiltration	-0.194	-0.031	0.442	-0.382	*0.947	*0.933													
Total tree equivalents per hectare	-0.169	0.296	0.003	-0.285	0.091	-0.034	-0.087												
Browsing units <2m per hectare	-0.093	0.226	-0.001	-0.295	0.070	-0.076	-0.038	*0.877											
Forage potential %	0.014	-0.148	0.137	-0.132	-0.105	0.025	0.058	-0.354	-0.106										
Mean grazing capacity ha/AU	-0.032	0.187	-0.038	0.079	0.114	-0.001	-0.015	0.289	0.050	*-0.940									
Species richness (800m²) (s)	-0.534	*0.647	0.168	-0.317	-0.066	-0.288	-0.213	0.406	0.472	-0.413	0.225								
Modified Simpson's index (1-λ)	-0.151	0.265	-0.026	-0.042	0.062	-0.199	-0.066	0.298	0.472	-0.452	0.272	*0.818							
Modified Shannon index H' (loge)	-0.179	0.359	0.041	-0.158	0.046	-0.215	-0.100	0.334	0.452	-0.516	0.331	*0.933	*0.947						
Conservation index	0.220	0.016	-0.046	-0.032	-0.483	*-0.688	-0.488	0.105	0.285	0.173	-0.132	0.252	0.314	0.259					
Usefulness index	-0.557	*0.617	0.483	*-0.611	0.196	-0.071	0.043	0.373	0.423	-0.318	0.187	*0.920	*0.705	*0.846	0.224				
Genus richness (800m²)	-0.472	*0.582	0.162	-0.306	-0.059	-0.274	-0.210	0.406	0.482	-0.405	0.214	*0.998	*0.828	*0.934	0.234	*0.911			
MSDI	0.283	-0.522	-0.122	0.305	0.109	0.147	0.065	-0.228	-0.129	-0.190	0.325	-0.077	0.063	0.039	0.040	-0.111	-0.056		
18yr mean NDVI	-0.088	-0.200	0.527	-0.320	*0.737	*0.658	*0.669	-0.181	-0.116	-0.267	0.344	0.076	0.235	0.213	-0.340	0.264	0.096	0.553	
18 yr mean annual precipitation (mm)	-0.269	0.187	0.065	-0.112	0.492	0.365	0.270	0.433	0.327	*-0.647	*0.594	0.492	0.442	0.561	-0.274	0.525	0.498	0.427	0.532

Significant correlations are shown as follows: * $p<0.05$

2.4 Discussion

2.4.1 Landscape function and ecosystem health

Thicket vegetation is known to be patchy (Lechmere-Oertel et al. 2005; Cowling et al. 2005; Mucina 2006). Resource regulation in the thicket state varied from small-scale regulation by individual grass plants to large-scale regulation by bush clumps. The spatial heterogeneity shown by this state is expected in more functional landscapes by the Landscape Function Analysis model (Ludwig & Tongway 1995). However, large inter-patches allow more resource run-off and erosion to occur, resulting in less functional landscapes. This was also seen in the thicket state where erosion in the form of gullies was observed (*pers. obsv.*).

From the Landscape Function Analysis model one would expect the thicket vegetation state to be the more functional, with nutrients being collected and retained in the bush-clump patches and what seems like a lack of defined patches in the other states to add to their "leakiness". However, in the other three vegetation states the existence of a grass sward prevented mobility and loss of resources on a large scale, including in the so-called degraded communal lands. As a result the landscape organisation indices showed that the thicket state had more potential for loss of resources, regardless of the differences in carrying capacity.

Unlike the suggestions of Wessels (2004) and Charney (1977) the results suggest that the change in vegetation cover in the Smaldeel does not necessarily correspond to land degradation or reduced ecosystem services in terms of resource retention as proposed by the LFA model.

The soil surface assessment indices were more variable for the thicket state. The larger bush clump patches had higher nutrient cycling indices than patches in the other vegetation states due to the build up of leaf litter, often in a state of decomposition, under the bush-clumps. The nutrient index, which relies heavily on the litter assessment indicator, scored highest in thicket patch types, however the lack of a thick grass sward resulted in an overall loss of resources and the removal of local litter that lowered the nutrient cycling index for the whole site. Bush clumps were more protected from erosion and acted as major resource regulating features in the landscape as predicted and keeping in line with suggestions made by Teague et al. (1994) that bush clump areas i.e. more biodiverse areas are more functional.

Average site values from the SSA for the savanna vegetation, the most homogenous in terms of habitat complexity and landscape features, better represented the underlying ecosystem functions as shown by the small variation between sites.

The communal land did not show the expected signs of dysfunction. The constant grazing pressure resulted in the formation of a dense and closely cropped grass sward, which in many places acted as one large patch regulating the loss of resources from the land. In addition, the contribution of the remnant bush-clumps that acted as resource retaining patches resulted in indices for this vegetation state being higher than expected.

Acacia sites varied from having large open spaces that could account for up to half of the site, to very closed, dense patches of *Acacia karroo*, very often in valleys or near water sources, which would account for the variation seen in results for the SSA in this state.

The scale of the sites created a problem in terms of data collection as the indices varied between the different features of the landscape, such as the crest or upper-slope regions or the flat areas and closed depressions. Such features alter soil surface processes (Tongway & Hindley 2004) and the sites varied greatly in terms of the features they contained. It is perhaps not realistic to try and sum up the more structurally and functionally complex habitats with the average of the indices across sites; further LFA would be needed to more accurately gauge them.

From the positive correlation found between the SSA data and the mean NDVI it can be postulated that greener, more productive areas are better able to cycle nutrients, have better soil stability and have higher infiltration rates than less productive areas.

Landscape Function Analysis, which focuses on soil surface processes, can be extended to incorporate an element of habitat complexity. Vegetation has a functional role, increasing wind and water drag and therefore affects mobilisation and transfer of resources, so increased habitat complexity creates a more functional landscape (Tongway & Hindley 2004). The increase in the number of tree equivalents in the thicket vegetation for all height classes suggests that this vegetation state is more structurally complex, increasing the functionality of the landscape. This aspect needs to be taken into consideration when assessing overall landscape quality. The habitat complexity of the thicket state and to a lesser extent the communal state are linked to their increased biodiversity. The in playing a structural role the vegetation affords more opportunities for shelter, food and resources required by the local fauna and creates protected microclimates able to support additional species.

2.4.2 Range condition

As opposed to other studies on the degradation of the range in communal areas as compared with commercial areas, or more pristine areas (Evans et al. 2007; Vetter et al. 2006) no significant difference was found in terms of grass species composition and abundance between the communal areas and the other states. As all small shrubs including karroids, were included in the browse assessment, they were not recorded in the range assessment. However, the presence of karroids in the range assessment may have aided with the identification of over-grazed areas.

Although no significant differences were found between vegetation states for the grazing capacity many of the best results were in the savanna state, where the land was moderately grazed. The savanna state at the University

Farm had twice the abundance of *Themeda triandra*. This may be due to the high control exerted over a small area in the research plot (0.6Ha) and suggests that the larger camps on the commercial farms were still far from their supposed optimum state. However, a 96% *Themeda triandra* grassland may not be desirable as work by O'Connor et al. (2001) showed that stable production in the face of unpredictable rainfall events was more likely to be achieved with a variety of grass species being present. Species such as *Setaria sphalcelata, Eragrostis chloromelas* and *Digitaria eriantha* were shown to provide increased biomass on good or medium condition grasslands during dryer years, whereas *Themeda triandra* provided increased biomass during wetter years (O'Connor et al. 2001). Diversity in grass species composition is an important factor to take into consideration in areas of variable rainfall such as the Smaldeel. It would seem that grass species diversity provides stability in terms of forage production and so provides stability in livestock numbers. Key species for all the states included *Themeda triandra* and *Digitaria eriantha*, suggesting that all the states would be equally stable in biomass production in response to variable rainfall.

The condition of the range was most variable in the acacia state. High-density bush is known to reduce the quality of the range (Teague et al. 1994). The distribution of *Acacia karroo* throughout the 1km² site was not even, closed acacia thicket being found in clumps. This made the landscape very heterogeneous at the transect scale, with open grassy areas being in good condition and grass under the acacia thicket being of poorer quality.

Increaser II species, which replace decreaser species when the range is over-grazed were more prevalent on the communal land. Two of the most abundant increaser II species on communal land, namely *Digitaria eriantha* and *Sporobolus fimbriatus*, were the two with the highest forage factors (Trollope 1999), adding to the forage potential and the grazing capacity of the land, even though it was heavily utilised.

The presence of increaser I and II species in the thicket vegetation state, suggests that it was selectively grazed. The areas chosen to represent the thicket state were lightly grazed by cattle or not at all, with small and large game present in varying amounts. The range did not form a densely packed grass sward as in the other states, although this difference didn't show up as significant with the point-to-tuft distance method of basal cover estimation. As opposed to the LFA method the point-to-tuft distance does not allow for the existence of litter-bridges, which help indicate the presence of a grass sward. Whereas the LFA method classified the status of the sites differently in terms of their susceptibility to erosion and mobility of resources, the point-to-tuft distance method did not detect any significant differences. The methods differ in their ability to distinguish the effects of litter bridges on soil surface processes within grassy landscapes. Litter bridges affect soil surface run-off helping to conserve resources and the LFA method will recognise non-living elements as counting towards overall patch structure. In contrast, the point-to-tuft distance method considers the living plant material only and side steps the effect of litter bridges within the landscape.

Removal of browse species deemed less useful for cattle production by management practices such as browsing/grazing by goats and sheep, and the use of fire, is carried out to increase the grass forage potential of the land. Ergo, removing the "biodiversity" supposedly increases the potential of the land and creates the optimum vegetation state for agriculture as suggested by rangeland scientists (Teague et al. 1994). However, no significant differences were found between states, the more biodiverse thicket state and the acacia state, with its closed acacia thicket stands, having the same grass forage potential as the other states. The communal state that ranked behind the thicket state in terms of biodiversity and is generally regarded as being in poor condition, also maintained its agricultural potential with few signs of selective removal of *Themeda triandra* (Teague et al. 1994; Owen-Smith & Danckwerts 1997) or reduced competitivity of *Themeda triandra* following heavy grazing (Danckwerts 1993). The results suggest that all four states can be considered equal in terms of the agricultural potential of the rangeland.

Areas of high rainfall had lower grass forage potential (%) and higher mean grazing capacity (ha/AU). The results are unexpected, as it is known that there is a direct link between the available soil moisture and the carrying capacity of the land in sweet veld. The relationship is probably a result of a combination of factors. Higher rainfall areas were found to the east where sites had more browse vegetation, reducing the area available to grasses and therefore the forage potential. However, the eastern sites, especially the communal areas had a greater amount of *Themeda triandra* than expected, which could be a response to higher rainfall levels (O'Connor et al. 2001), so maintaining the agricultural potential of the land above that expected. If one considers forage production per unit rainfall (Abel 1997) the results follow the expected pattern, with highest production levels found in the savanna and lowest production levels in more degraded areas i.e. the communal state.

The woody plants differed between states in terms of both quantity and species composition. Having selected the states according to visual criteria, the majority of which centred on the type and quantity of woody species present, the results verified to some extent the premise that these were different states. That acacia and thicket states had more large (>2m) woody species than the other states, but not significantly more palatable species in the larger height class indicating that the other trees observed in the thicket state were not all palatable. A distinctive species assemblage was found in the more biodiverse thicket state, which was most similar to the communal state in terms of composition. That the communal state did not have much browse in the greater height class was probably a result of continuous browsing or due to the removal of larger specimens for building wood and fuel (Shackleton et al. 2001; Shackleton et al. 2007). The acacia state and savanna state were selected for the majority of large trees in the states being *Acacia karroo* and this was verified by the results, these two states overlapping in the ordination plot and both scoring lowest regarding most of the biodiversity measures.

All small shrubs were included in the browse assessment as many of them are palatable to some degree (Appendix B). As the original method distinguished between two height classes, it was thought that this would not cause an underestimate of available browse by favouring the smaller shrubs.

Although it appears that there is little or no small browse in the savanna state, these camps were often stocked with large numbers of browsers keeping the potential trees and shrubs small, resulting in significantly fewer browsing units under 2m being found in the savanna vegetation. Similarly the high stocking numbers on the communal land would account for there being less small browse on these rangelands.

In recent years, due to stock theft, less small stock has been run on both the communal and commercial rangelands, and both are now suffering in some areas from bush encroachment by *Acacia karroo* (*pers. obs*). According to the owners all the acacia state sites previously contained small stock. The availability of *Acacia karroo* makes all of the sites desirable in terms of providing a high quantity of food for browsers. Neither Boer goats nor Nguni goats show dietary preference for thicket species such as *Grewia occidentalis, Scutia myrtina, Diospyros lycioides, Rhus longispina*, and *Ehretia rigida* over *Acacia karroo* (Dziba et al. 2003), suggesting that the *Acacia karroo* infested areas are just as desirable for goat farming as the thicket areas. However, the added biodiversity of woody shrubs in the thicket state results in many of the perennial species remaining available as forage during the times when the *Acacia karroo* has lost its leaves and during times of drought. Stability in terms of forage availability for domestic livestock is essential for avoiding population crashes in times of drought. In that respect, both the thicket and communal state vegetation, being the most diverse in terms of browse species composition, offer the most economic stability to farmers.

2.4.3 Species richness and diversity

The assemblage of species in the thicket state was different from the savanna and acacia state and overall it scored highest for all the diversity indices. The communal state was generally the next species rich and on the whole can be considered a highly utilised version of the thicket state vegetation.

Species richness positively correlated with both the modified Shannon's index and the modified Simpson's index of diversity. These measures are all in fact functions of the number of species in a statistical population (Brewer & Williamson 1994). In addition, genus richness correlated with other measures of diversity as would be expected from studies showing higher taxon richness can be used as a surrogate for species richness (Gaston & Williams 1993).

The thicket state was expected to be the most diverse due to the presence of bush-clumps containing typical Thicket species that were notably diminished or absent in the other vegetation states. Thicket biome vegetation is known for its high plant taxon diversity (Cowling et al. 2005). Phylogenetic diversity was found to be greatest in the thicket state using genus richness as a surrogate measure. Bush-clumps had the highest scores for the SSA indices as well as being the areas of highest genus richness in line with other studies that have shown phylogenetic diversity to be linked to the functional diversity of the ecosystem and maintenance of ecosystem health and stability (Lechmere-Oertel et al. 2005a; Lechmere-Oertel et al. 2005b). Genus richness correlated in this study with the mean inter-patch range that was found to be greater in the thicket state, due to its patchy nature.

Increase in species richness with area has been well documented (MacArthur & Wilson 1967) and more recently (Palmer & White 1994). In this study richness was greater for the larger area as would be expected. Crawley and Harral (2001) list several reasons as to why "species accumulate as the sample area is increased namely, a sampling effect; a spatial clumping effect; a spatial segregation effect; and a habitat effect. Due to the more heterogeneous nature of the thicket state and to a lesser extent the communal state at the transect scale, species tended to be spatially aggregated or clumped together, an effect that was not observed within the acacia and savanna states.

That the modified Simpson's index of diversity did not detect any significant differences between vegetation states at the large scale, but did at the smaller scale, was probably due to the insensitivity of the index to the presence of rarer species in the sample (Magurran 2003). A curvilinear relationship exists between the number of species and the index, such that the addition of more species beyond the first 10 to 12 has little change on the value of the index (DeJong 1975).

More useful plants were found in areas of greater diversity as would be expected, however the same did not hold true for the conservation index. It may be that these species were removed from the sites found more centrally in the study area, or they are unevenly distributed throughout the Smaldeel area. As a result the conservation index, unexpectedly, did not correlated with the other biodiversity indices.

The plant surveys were carried out during the same season, with the same amount of time (sampling effort) applied to each site (Gotelli & Colwell 2001b) and are therefore comparable. Some ephemeral species may have been missed, as the sites were not repeatedly sampled at different times of year however, on the whole the data are thought to be accurate.

2.4.4 Primary production and biomass

Rainfall has been found to be a major determining factor regarding NDVI and LAI values. (Du Plessis 1999), however in this study there was no correlation found between rainfall and the mean NDVI values for the four vegetation states. Overall the sites were surprisingly similar in terms of primary productivity considering the difference in the abundance of trees and shrubs between states. As predicted primary productivity was greater in more functional landscapes, with a positive correlation being found between the nutrient, stability and infiltration indices and the 18yr mean NDVI for the sites, in keeping with similar studies done in nearby areas (Palmer et al. 2001).

As satellite data represents productivity in terms of the “greenness” of an area it does not detect changes in species composition from palatable to unpalatable species and therefore cannot be used to directly represent farming value. The savanna state in particular had the lowest LAI values, and yet had some of the best grazing capacity scores. The communal land had the second highest LAI values and yet some of the lowest forage potential scores.

The NDVI values for the communal state suggest the vegetation is more resilient to subsistence farming compared with vegetation types that support subsistence farming in other areas. The communal sites on average received greater annual precipitation than the savanna sites that tended to receive more variable rainfall (Appendix A). The LFA data indicates that the communal lands in the area are not as degraded as commonly perceived, which may be due to the small rainfall gradient found across the study area. Other studies comparing states have tended to focus on fence-line comparisons, where the states are in close proximity and the influence of rainfall would be the same on both states (Palmer et al. 2001; Lechmere-Oertel et al. 2005a).

The LAI time-series data gave an indication of the variability of the different states. Ecological stability, measured by the percentage departures from the long term mean of each pixel (Noy-Meir & Walker 1986) suggest that acacia is the least stable state, undergoing larger changes in leaf area than the other states, probably due to changes in leaf cover in *Acacia karroo* and a lack of diversity regarding tree and shrub species. However, overall the LAI values were highest for the acacia state throughout the year, as were the 18 yr mean NDVI values.

The mean NDVI values and the LAI values for the four vegetation states followed the same pattern, however the duration of high NDVI was significantly greater for thicket vegetation, showing that the thicket vegetation state had a longer growing period than the other vegetation states, which may be due to its more evergreen nature.

2.5 Conclusions

Biodiversity measures scored highest in the thicket vegetation state with the exception of the conservation index. Protecting plants of conservation interest would not necessarily protect the diversity of plant species in the area. Species designated conservation status were found in the most western sites in the acacia vegetation state and in the more eastern, less utilised sites i.e. thicket vegetation state.

Given that the functionality as defined by the LFA method did not differ largely between states, it would seem that the ecosystem processes are not seriously affected by a change in structure and composition of the vegetation. The states could be considered equally as valid in terms of maintaining ecological processes. The resulting level of functionality in the savanna state may be acceptable in terms of forage production, but not other uses such as the maintenance of habitat complexity for sheltering livestock, or the provision of additional "useful" resources. The additional habitat complexity and spatial heterogeneity resulting from the increased biodiversity of the thicket state add to its functionality and capacity to retain resources.

There was no clear relationship between biodiversity and agricultural potential in terms of grass and browse availability. In the thicket state, the higher biodiversity did not necessarily indicate a greater number of palatable species and conversely in the savanna state the high grazing potential resulting from large amounts of *Themeda triandra* did not contribute to measures of diversity. The diversity of grasses found in most sites added to their stability in terms of response to rainfall. The increased biodiversity of the communal and thicket states added to their stability in terms of forage production, due to the presence of a higher number of perennial shrubs and trees, likely to maintain livestock through periods of drought.

Although the values for the grazing capacity of the savanna state were better overall than the other states, the difference was not significant. The abundance of the more nutritious increaser II species in the communal state and the slight rainfall gradient kept the grazing capacity higher than expected when compared with other studies. The creation of the savanna state reduces biodiversity at a local scale and increases the dependence on supplementary feed by limiting the presence of perennial trees and shrubs likely to maintain livestock through periods of drought. However, in terms of forage production per unit rainfall the savanna state was the more productive.

Productivity and range management on the communal lands are not viewed in the same way as on the commercial land. Although cattle are considered important (Chapter 3), goats are kept primarily for cultural reasons such as slaughter during traditional ceremonies (Mahanjana & Cronje 2000; Shackleton et al. 2001; Cocks et al. 2003). A more inclusive view is taken of the landscape, with main concerns being water availability and the resilience of the vegetation during drought (see Chapter 3). The more biodiverse sites are more likely to meet the needs of the farmers, with the additional habitat complexity providing shelter, as well as the perennials providing forage for livestock in times of drought.

The productivity as measured by the NDVI and LAI showed little change between the states. Productivity is thought to be highest and least stable in the acacia vegetation state and more stable and with a longer growth period in the more biodiverse states due to an increase in the number of perennial species.

Range condition, functional changes in the landscape and plant productivity at this scale were of great interest to both the commercial and communal farmers. Overall the vegetation states seem to be resilient to the different management regimes, maintaining their functional integrity and agricultural productivity. The significantly higher levels of biodiversity in the thicket state added to its usefulness, conservation value, functional diversity, structural diversity and stability in terms of forage production, without detracting from its agricultural potential.

CHAPER 3

How does farmers' preference for landscapes relate to measures of forage production and plant diversity?

3.1 Introduction

In South Africa landholders and rural communities, through their land use practices and different management techniques, shape the landscape around them. The preservation of biodiversity largely depends on those people that use the land, however little information exists that demonstrates how different user groups, including both commercial and communal farmers, value landscapes and how these values relate to more conventional measures of ecosystem quality.

3.1.1 Protecting biodiversity

Concern for loss of the Earth's diversity is apparent at a global level (International Convention on Biological Diversity, 1992) and within South Africa itself, where the issue is addressed by the Biodiversity Act (2004). The Act aims defines biodiversity as "the variability among living organisms from all sources including, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part and also includes diversity within species, between species, and of ecosystems". One of its objectives is to protect species and ecosystems that "warrant national protection", but how do communities and different land-use groups such as communal and commercial farmers value landscapes on a local level? And do these values relate to the preservation of South Africa's biodiversity?

Given that in much of South Africa's biodiversity is known to exist on farmland, it is the farm owners and their particular sets of values that govern the fate of much of South Africa's biodiversity. Little research has been done into the preferences for different vegetation states among those dependent on the land for their livelihoods, although recent attempts in South Africa have been made to collect landowners' viewpoints regarding biodiversity and its preservation (Knight & Cowling 2003).

3.1.2 Land tenure

That humans influence landscape ecology is well understood (Naveh 2000). In the Eastern Cape, both commercial and subsistence farmers use land for raw materials (wood), to produce food for consumption and sale, as well as for housing and recreation. In the Eastern Cape 66% of land is owned privately, the majority of which is in the hands of (mainly white) commercial farmers that aim to maintain the veld in an optimum state for commercial beef production (Teague et al. 1994). Thirty percent exists as communal tenure with much of the land considered marginal. Cultural differences between the commercial and communal areas lead to different management practices. Poor land management can result in land degradation in both areas, but due to the heavy stocking rates and the high reliance on the land of the rural farmers, land under communal tenure is often in a degraded state (Palmer et al. 2001; Fabricius et al. 2002).

3.1.3 Visual preferences

Research into visual preference has tended to focus on landscape features in natural settings and wilderness areas in natural parks (Arthur et al. 1977; Steinitz 1990; Van den Berg et al. 1998; Daniel 2001). Some studies within natural parks have shown that people having higher levels of environmental concern are less tolerant of environmental impacts (Floyd et al. 1997).

Gobster (1994; 1995) has shown a preference for modified savanna environments, which Orians (1980) related to an inherited disposition that gave early hunters an evolutionary advantage. Modified savanna environments provide long unimpeded views and frequent changes in elevation, with trees for refuge and shade and resources for grazing and browsing animals within 2m of the ground. Human preferences may be related to the evolution of our ability to organise and categorise visual information; crucial to survival in such environments (Kaplan 1987; Kaplan & Kaplan 1989a; Kaplan & Kaplan 1989b).

In contrast to the perspective outlined above, which seeks an evolutionary explanation for preferences, the concept of a sense of belonging can influence preference for landscapes. Belonging has been defined as the sense of feeling at home and/or having a close relationship and affinity for a place (Seamon 1979). These affinities are thought to result from social experiences that occur throughout one's lifetime. Thus social experiences within a particular type of landscape result in the landscape holding a particular emotional significance. Differing cultures and individuals relate to and value biodiversity in different ways as each experiences landscape in their own way (Posey 2002).

Nassauer (1995) suggests that habitats of high ecological quality have a messy appearance and that picturesque conventions are so intrinsic to nature that they are commonly mistaken for ecological quality. A cultural preference for the picturesque, which is often akin to the cultural idea of good stewardship, may not be consistent with the preservation of biodiversity as neater landscapes, such as the idea of traditional parkland, are often highly managed and maintained and hence usually less biodiverse. If our underlying psychology and cultural experiences determine our preferences, they may inadvertently deter efforts to preserve biodiversity.

In another study, a positive relationship between biodiversity and beauty ratings was found for a variety of different user groups, but not for farmers (Van den Berg et al. 1998). The study, which took place in the Netherlands, investigated preferences between current landscape scenes and computer generated images of potential landscapes should the area be converted to a nature reserve. It was found that the majority of different societal groups preferred the more "natural" scenes, but the preferences of farmers were biased by economic criteria and feelings of familiarity towards the current landscapes.

The experience people have of landscapes can shape their preferences, in particular feelings of nostalgia and familiarity (Posey 2002). The commercial farmers from the study area were mainly cattle farmers and therefore familiar with landscapes having high grazing potential. This is expected to be a major influencing factor in determining the preferences of commercial farmers. In addition, many commercial farmers had some small stock, such as sheep that are grazers and goats that are browsers, and were game farmers, such that the presence or absence of appropriate habitat within in a landscape able to support other farming activities aside from raising cattle is likely to influence their preferences. Women living on commercial farms, being generally less involved in the farming would be expected to view the land in a different way, although aware of the type of landscapes that offer an ideal farming opportunity, they probably view the land from a more aesthetic, less utilitarian standing.

The customs of the rural communities shape their dependence on the landscape. Men and women in the communal areas have different roles, and as a result, different landscape needs (Mayer et al. 1992). Men in communal settings herd cattle and sheep, as well as goats. Goats are mainly kept for slaughter during traditional ceremonies (Mahanjana & Cronje 2000). Men also require wood for kraals, Ubuhlanti, described as the man's domain (Cocks et al. 2003), and the site for many cultural ceremonies. As a result one would expect the communal men to show a preference for the more biodiverse lands, showing a habitat able to meet the needs of their domestic livestock including wood for the construction of kraals. For communal women the collection of fuel wood is equally significant, for the igoqo (woodpile) represents their social status and is the woman's equivalent of the kraal (Cocks et al. 2003). Women's responsibilities also include the planting of vegetable gardens and the collection of food, materials for household articles, tools and construction, medicinal plants and plants for rituals (Shackleton et al. 2001; Cocks & Dold 2004; Shackleton et al. 2007). These requirements suggest that the women will prefer diverse landscapes, with a high woody component, but at the same time space for planting. Belief that the ancestors are part of the land means both men and women are greatly attached to the landscape. Wiersum and Shackleton (2005) describe how migrant families in South Africa return to their ancestral lands to partake in cultural festivities and ceremonies featuring wild plants. Given the feelings of familiarity (Posey 2002) and the attachment of cultural importance to communal landscapes, it is expected that men and women from the communal areas will show a higher preference for the communal vegetation state than their commercial counterparts.

3.1.4 Study area

The sample area selected for the study was the Smaldeel area of the Eastern Cape, lying between the towns of Bedford and Middledrift. Throughout the area the vegetation exists in several states as a result of different management practices (Chapter 1). Four states were identified for the study: (1) a bush-clump grassland mosaic, (2) large (>1.5m) *Acacia karroo* scattered amongst *Themeda triandra* grassland, (3) *Acacia karroo* encroached grassland and (4) communal land characterised by low, woody and herbaceous vegetation (hereafter referred to as thicket, savanna, acacia and communal states, respectively).

3.1.5 Measures of ecological quality

Most groups interested in biodiversity or ecosystem health will assess the landscape using the criteria that most relate to their particular set of values, the results of which may or may not correlate to other measures of ecosystem quality (Chapter 2). On a global scale species richness is the most widely used and intuitive measure of biodiversity (Magurran 2003), but measures of species richness do not necessarily correlate to use value e.g. forage production for livestock.

A summary of how the states ranked using a number of measures of ecological quality (Chapter 2) can be seen in Table 3.1. The thicket state was the most species rich of the states and had the highest browse potential, thus being capable of supporting a large number of game animals. The thicket state also had the greatest abundance of useful plant species. The savanna state is considered to confer optimum veld condition for agricultural production by academic pastoral scientists (Trollope & Tainton 1986; Trollope 1999), but was not found in this study to have significantly higher grazing capacity than the other states (Chapter 2). The savanna state was also found to have the lowest plant diversity and abundance of useful plants among the four states. The acacia state was variable in terms of forage potential, and although not highly biodiverse was found to contain species of conservation importance. The communal sites were heavily stocked and thus over-grazed and browsed and yet the state remained fairly biodiverse and the grazing capacity was not significantly lower than that of the other states.

Table 3.1. Table to show the ranking of the four vegetation states by several ecological quality measurements.

	Palatable tree equivalents per hectare	Density of woody plants >2m	Total species (s)	Shannon index H'(loge)	Conservation index	Usefulness index
Thicket	1	1	1	1	1	1
Communal	2	2	2	2	1	2
Savanna	3	3	2	4	1	4
Acacia	2	1	2	3	1	3

3.1.6 Study aims and predictions

The aim of this study was twofold. Firstly, to find out how four different user groups (men and women in the commercial and communal farming areas of the Smaldeel) rank the same vegetation type, maintained in four different states, both from a utilitarian point of view and a recreational point of view.

Secondly to find out how these preferences compared with a selection of measures of ecological quality, listed in Table 3.1.

From a utilitarian point of view the commercial men would be expected to opt for states that represent agricultural potential i.e., the savanna state for its grazing potential and/or the thicket state for hunting and browse availability. The commercial women on the other hand, may not be so influenced by agricultural potential and may opt for more aesthetically pleasing landscapes. The communal men are more likely to opt for the thicket state for the quantity of browse and useful plants it contains, followed by the acacia state for browse or the communal state for useful plant species and so show preferences that correspond to measures of such ecological attributes. The communal women, needing useful plants for a wide variety of reasons are expected to opt for the thicket state, followed by the communal state, their choices corresponding with high usefulness value.

Regarding aesthetic preference, if subsistence and commercial farmers respond to biodiversity then the thicket state, scoring highest for nearly all the diversity indices, is most likely to be selected by all groups. Otherwise the savanna and possibly thicket state will be selected by the commercial men and women due to feelings of familiarity (Posey 2002) and sense of place, or alternatively, the savanna state in line with Gobster's (1994) theory of preference towards modified savannas. The communal men and women, being familiar and culturally attached to the communal and the thicket states, are likely to express a preference towards them (Posey 2002). Any preference for the savanna state, once again falling in line with Gobster's (1994) theory.

3.2 Methods

Two methods were used for the study, namely semi-structured interviews and preference ranking of photos, to gauge people's perceptions and the value they place on the landscape.

3.2.1 Participants

Four different land use groups were selected, namely men and women from the communal areas and commercial farms within the Smaldeel area. Due to time constraints, the need for a translator and the dispersed nature of the rural villages, men and women from the communal areas were interviewed in groups. Commercial farmers were interviewed individually as it was more difficult to get them together due to the nature of their work and farm responsibilities. In total one group of 5 rural men, two groups of communal women, 5 and 17 participants, each group from neighbouring settlements and 6 men and 4 women from the commercial farm area were interviewed. One of the women was an active farmer and the other three were wives or mothers of commercial farmers some of whom took part in the interview process, though participants were interviewed individually.

3.2.2 Data collection

The study used a qualitative research process in order to access people's perceptions of landscapes and the values they use in defining the importance of the landscapes to their livelihoods. Semi-structured interviews were used with four different groups of participants. In the communal areas, men and women were interviewed separately as this is thought to increase women's participation in discussions (Mayer et al. 1992).

Preference ranking of the four vegetation states was carried out during the interviews. Colour photographs have been found to adequately represent landscapes when compared with preference rankings made in the field (Trent et al. 1987; Wherrett 2000). Four A3 size colour photos were prepared, each representing one of the four different vegetation states, Figure 3.1, within the Smaldeel area. As far as possible, artificial features were excluded from the photographs. The four photographs were presented at the same time to avoid effects associated with order of presentation. The most preferred state was given a score of 1 and the least preferred 4. In the communal areas this was done by the placement of stones on the photos. The photo preferred by the majority was then removed and participants had to then select a new preferred state, and so forth until the states had been ranked by general consensus. At each point the frequency of each preference was recorded. For all the communal areas, interviews were conducted with the aid of a translator. At each stage people were asked to give reasons for their preference rankings. All interviews were recorded and later transcribed (in English). Within each group the number of participants choosing a particular state was divided by the total number of participants in the group to calculate the frequency by which each state was preferred and this was used to derive the overall ranking of the four states by each user group.

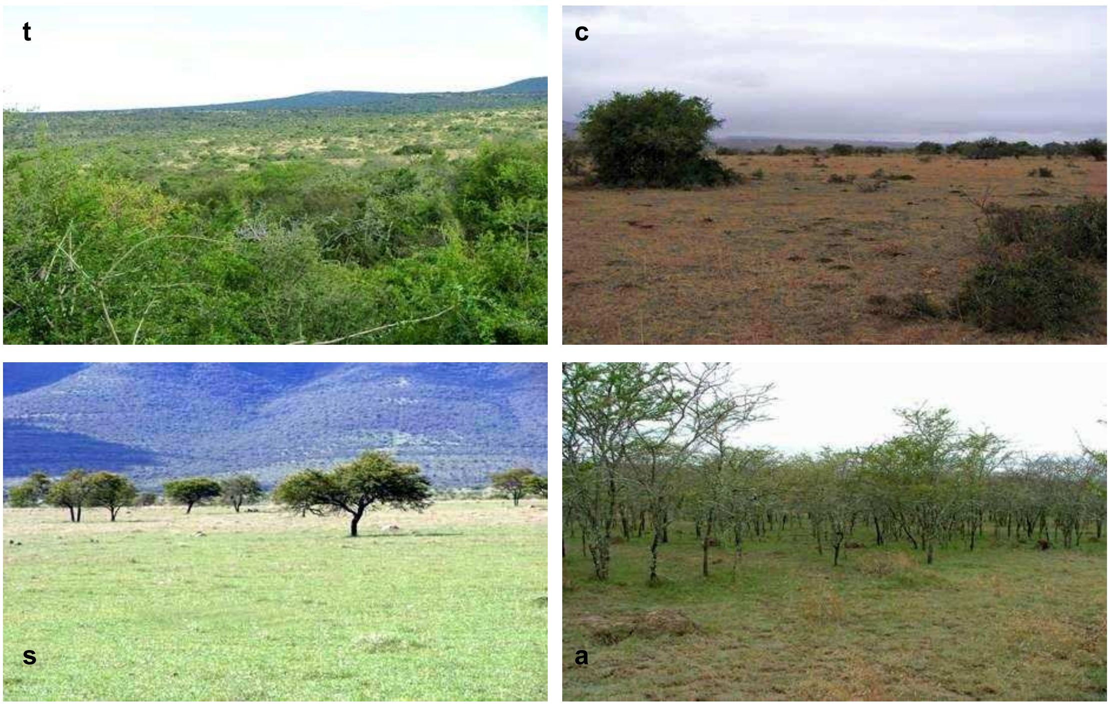

Figure 3.1 Photographs used to represent the four vegetation states (t=thicket, c=communal, s=savanna, a=acacia).

User groups were then asked to picture themselves far from their farming activities and current lifestyle and imagine that they lived in a town, worked in an office and that their everyday existence had nothing to do with farming. Then participants were asked to indicate which landscape they would to look for if they were visiting the countryside for recreational reasons, to relax and enjoy themselves. The percentage of respondents per user group that preferred each state was noted and respondents were again asked to justify their choice.

The different user groups' ranking of preferred landscapes were then compared to the ranking of the states according to their ecological attributes (Table 3.1). Because of the small sample sizes and the different sample sizes and methods employed when interviewing different user groups, statistical analyses were deemed inappropriate.

3.3 Results

3.3.1 Utilitarian preferences

Communal men

Thicket was the preferred vegetation state among communal men (Table 3.2). Sixty percent of the communal men classed thicket as their first choice, the other 40% opting for the communal vegetation state. When the thicket vegetation was removed from the picture all the men present opted for the communal vegetation state as their first choice, followed unanimously by the savanna state, leaving the acacia state last.

Thicket vegetation was seen to provide many palatable species for a combination of cattle, sheep and goats, throughout the seasons and in times of drought, as well as providing medicines for animals, shelter, and water (springs), and thicket was highly valued by both communal men and women for those reasons. The communal men did not view the savanna state as good for cattle farming. Although they recognised that there was a considerable amount of grass, they were not happy with the lack of browse, shelter and water. Regarding the acacia state the communal men were of opinion that the high density would mean that the browse would be of poor quality for grazers. The communal men saw the amount of browse as being a potential difficulty as they would require a permit to remove the *Acacia karroo* trees manually. As well as livestock production, plant material was discussed in terms of fuel, building material, food supplements, and medicinal and veterinary plants, all more prevalent in the thicket state.

Communal women

Of the communal women, great interest was shown in the savanna state as they deemed it “beautiful”. However, thicket vegetation was chosen unanimously by one group as the preferred vegetation state and by 53% of a second group. Of the second group 35% opted for acacia as their preferred vegetation state, whilst the remaining 12% preferred savanna. With the thicket photo removed, one group unanimously opted for the acacia state, followed by the savanna. The other group unanimously ranked acacia and savanna the other way round. In contrast with the men, none of the women from either rural group considered the communal land to be a desirable vegetation state.

The communal women were particularly concerned about the lack of water in the savanna state and the inability of the landscape to meet all the needs of the cattle. Both communal men and women acknowledged that cattle were very important to their livelihoods and the needs of the cattle would be most easily met in the thicket vegetation state.

Communal women were not sure what such high density of acacia would mean for the cattle, but liked the acacia state for the availability of other resources such as wood, medicine and honey.

Table 3.2. Table to show the ranking of the different vegetation states by the four participant groups and the perceived benefits and problems associated with each state.

Group	State	Rank	Perceived benefits/problems
Communal Men	Thicket	1	High food availability for livestock (cattle), even in times of drought; sheep and goats can survive too; plenty of shelter for the animals from cold prevailing winds; river or water source near by for animals; will contain medicines for people and animals because of the diversity and dry fuel wood and honey.
	Communal	2	Good for ploughing. Soil is good because of the presence of termites; the trees are green so livestock can survive.
	Savanna	3	Trees are high and cattle cannot eat the acacia in times of drought; no shelter and no water for the animals, only sheep and goats can survive.
	Acacia	4	Acacia is damaging the grass so the state is not good for cattle; would need a permit to remove the acacia so management would be difficult; termite mounds show that the soil is good; honey, medicines and wet fuel wood to be found.
Communal Women	Thicket	1	Green, so its good for livestock as during drought they eat trees; wind protection and shelter for animals; diversity means there are medicines, medicines for livestock, and its healthy; there will be water (springs), for livestock and vegetable gardens; cattle are important so its good there is less acacia.
	Acacia	2	Protection by trees, but not good for grazing or still good for cattle (opinion varied); smaller medicinal plants (as opposed to larger specimens found in thicket), but good for a special medicine from the acacia; flowers for honey (from acacia); fuel wood (coal from the acacia); wood for rituals (from the acacia); less water (than thicket); monkeys and baboons (neither a good nor bad thing).
	Savanna	2	Too dry for cattle as there is less water, plus there is no shelter for cattle (cold) and no trees for cattle during times of drought; small medicines because of the lack of water.
	Communal	3	Too dry, less water (than thicket) means medicine plants will be less plentiful and smaller; good for goats and sheep; open for vegetable gardens.
Commercial Men	Savanna	1	Good grass cover with no moribund grasses. Grazing cycle and small stock farming with browse line created by goats apparent. Managed by continuous pressure. More exposed, occasional trees give protection, shade, and soil nitrogen. Highest weaning weights for cattle and higher carrying capacity, but animals may need supplementing in winter as there is less variety (plant species), looks sterile. Best for cattle and sheep, more grass than other states. Easier farming and stock collection (small and large), less ticks. Canned hunting, but good for hunting springbok.
	Thicket	2	Most balanced veld type, best for goats (more edible species), better in times of drought, better winter veld (sheltered), most diversity (variety of species) provides well for the animals, best for farming, best for game hunting and conservation, all the life and health is here, better for overall land use and pleasing to the eye, preferred by tourists, but difficult for cattle and stock collection, more ticks, more disease (Heartwater).
	Acacia	3	Has suffered soil disturbance, which causes acacias to appear. Good if acacias can be controlled, basal grass cover not so good due to too much shading, needs goats. Lower carrying capacity for cattle, but good for goats (more browse for small stock). Legumes pump nitrogen into the soil so should give better grass cover with proper management.
	Communal	4	Needs serious management (recovery time), but has good grass cover and healthy soil, drier, overused, good for hunting, lowest carrying capacity for cattle.
Commercial Women	Savanna	1	Nicest place to live. Good for a picnic, aesthetically pleasing, beautiful. Safer than thicket.
	Thicket	2	Contains more nature, whole landscape more appealing, more plants and animals, relaxing. More biodiverse, healthier, more browsers so better hunting Too bushy, more diversity, more exciting for children.
	Communal	3	Looks like drought and overgrazed. Too bare.
	Acacia	4	Nice to have thorn trees. Can't use it. Too bushy.

Commercial men

The preferred vegetation state for 67% of the commercial men was the savanna state, the remaining men opting for thicket. With the savanna state removed from the options, 67% of the commercial men opted for thicket. The remaining 33% of men selected acacia state as their second preference. When presented with a choice between communal and acacia states, the majority of men opted for the acacia state leaving the communal state last.
The commercial men valued the savanna for its potential regarding commercial beef production. It was thought to have the highest grazing capacity as it had good grass cover and no moribund grasses. They recognised that this state was maintained by a tight management regime. Although excellent for farming cattle they did recognise that it looked sterile compared with the other states and that the lack of plant variety and palatable bush could mean that stock would need supplementing in winter. However, this state was still preferred as stock management and collection in open land was considered easier and the tick load and the risk of associated diseases, such as Heartwater (a disease of ruminants), lower.

When the acacia state was viewed the men admitted that they were generally reluctant to take on a farm having such vegetation and they recognised that it posed several problems in terms of land management. With the number of small stock (goats as potential browsers) being kept by commercial farms on the decrease due to the difficulties experienced with stock theft, they felt that few options remained to tackle the apparent problem of acacia encroachment presented in the photo. Any preference of this state by the commercial men was based on the belief that *Acacia karroo*, being a legume, would pump nitrogen into the soil. This was thought to make the grass good quality for grazers. Some farmers (those that kept goats) viewed acacias as being a large quantity of browse available for goats. It was suggested that management of the state would include the use of goats to “get the acacias under control” and so improve the condition of the range, whilst earning a profit by changing the potential browse into saleable stock.

The views of the commercial men were particularly profit based, with the thicket state being regarded as an opportunity for the diversification of farming activities and opportunities for income via eco-tourism and game farming.

Commercial women

The preferred vegetation for 75% women living on the commercial farms was also the savanna state, the remaining women opting for thicket. With savanna state removed 75% of women ranked thicket as their most preferred landscape and made reference to the diversity and "healthiness" of the landscape. Only one woman opted for the acacia state as their second most preferred state. When presented with a choice between communal and acacia states, unlike commercial men, the women opted for the communal vegetation state, although they recognised that it was over-utilised and in need of resting. Generally the commercial women suggested more aesthetic and recreational reasons for their preferences and had a much less utilitarian view of the landscape.

3.3.2 Recreation and aesthetics

Thicket and savanna were the preferred states for the majority of communal men (40%: 40%), with the remaining 20 % preferring the communal state (Table 3.3). The potential the landscape offered for viewing wildlife and the space available for children to play, were the most commonly cited reasons for the choice in each case Thirty six percent of women regarded the thicket state as best for recreational purposes. Much interest was shown in the savanna vegetation and 32% of women preferred this state. The rest of the women preferred the communal state. Like the men, the opportunity the landscape afforded for viewing wildlife and educating children were the most cited reasons for the choice. Both commercial men and women were divided 50:50 between the savanna and thicket states when selecting a preferred state for recreational reasons. Aesthetics was thought to enhance the value of the land for other farming activities with the thicket being regarded as a more enjoyable state for eco-tourism and hunting game. The commercial groups never suggested the communal state for recreational use and none of the four groups selected the acacia state for recreational use.

Table 3.3. Table to show the preferred vegetation states of the four participant groups for recreational purposes.

Group	Preferred state, percentage of respondents that preferred it	Reasons given
Communal men	Thicket 40%	There will be a stream and shade, kids can watch the wildlife as there are more animals and birds in the thicket.
	Savanna 40%	This one is good for having a braai and letting the kids run around and play football. It is safer. You can walk around and see far.
	Communal 20%	It is like the thicket but not so dense so you can see the wildlife and play the children can play there.
Communal women	Thicket 36%	There are more plants and animals to look at so it is good to take the children there to learn about the wildlife.
	Savanna 32%	It's beautiful and restful so you can relax and let the kids play.
	Communal 32%	This reminds them of other nice places to visit.
Commercial men	Thicket 50%	There is more nature and one would be able to see more birds and animals so it is more exciting. Grown up in this landscape so feel attached to it.
	Savanna 50%	Its more open, and if one lived in a town it would be nice to come into a wide open space, really in open spaces there is more chance of seeing wildlife.
Commercial women	Thicket 50%	One is closer to nature in the thicket vegetation, there is more wildlife to look at, a greater diversity of animals and plants.
	Savanna 50%	The trees dotted through the savanna is lovely to look at, it's beautiful and gives a restful feeling. It is safer than thicket.

3.3.3 Relationships between measurements and landscape value

The preferences of communal men correlated positively with the majority of the biodiversity measures. The thicket state, which was ranked highest for all measures except the conservation index, was by far the preferred state. The preferences shown by the commercial men correlated negatively with the amount of available forage for browsers and thus anecdotally positively correlated with the perceived grazing capacity of the land. Their preferences correlated negatively with the biodiversity measures. The utilitarian preferences for landscapes shown by the communal women tended to correlate with higher measures of biodiversity, with the issue of water and the communal state appearing drier complicating the relationship between biodiversity and usefulness. The commercial women preferred the thicket or savanna states that most of the time had contrasting values for all the ecological indices.

Aesthetic preference was expressed by the communal men and women for all the states except for the acacia state. Thicket, the more biodiverse state, was preferred by the majority, closely followed by the least biodiverse state, the savanna state, indicating that the relationship between preference and biodiversity is not straightforward. Similarly the commercial men and women preferred these two contrasting states.

3.4 Discussion

3.4.1 Landscape preferences and biodiversity

As the study attempted to determine preference for landscapes by commercial farm owners and communal farmers, who all derive their livelihoods from the land in different ways, initial viewpoints expressed in the interviews were unsurprisingly biased towards a utilitarian view of the landscape and aesthetics did not determine preference.

Communal areas

The communal farmers were more reliant on the landscape to meet all the needs of their livestock and unlike commercial farmers did not artificially provide food, shelter or water. As a result the photos were studied carefully with the men trying to ascertain if all the requirements of the livestock could be met within the landscape shown. “Greenness” was thought to measure of the health of the landscape as it indicated the presence of water. The higher species and structural diversity of the thicket state was perceived as a very positive thing, presenting many opportunities. The land was considered to be in a very healthy state. The picturesque conventions that Nassauer (1995) suggests are often mistaken for ecological quality do not appear to be conventions that exist within the Xhosa culture and the “messy” appearance and habitat complexity apparent in the thicket state was viewed as having high value.

Conversely, due to the reliance of the rural farmers on the landscape the savanna state was considered poor grazing country as the landscape offered good grass but little else for the cattle, so the difference in the farming systems of communal and commercial areas was a major influencing factor determining preference. The communal men, experienced with their own land regarded the communal state as good grazing country. Thicket and communal state vegetation were viewed as similar and the preferences expressed for both could be a result of feelings of familiarity (Posey 2002). This agrees with the analysis of plant composition shown in Chapter 2, which revealed the thicket and communal states to be similar in composition if not structure.

From a recreational viewpoint men ordered sites were in terms of visual preference, with preference defined as the degree to which an individual likes the specific scenery being viewed (Kaplan 1987) in terms of the landscape elements it contains. The men opted for the landscape that they were familiar with i.e., the thicket state (Posey 2002) or the preferred modified savanna environment of Gobster (1994; 1995).

Communal women

The difference in preference shown by the men and women has to do with the separate roles and responsibilities they have within the community. As with communal men, water was a main concern of the communal women and “greenness” was thought to indicate a very healthy landscape and in particular was thought to affect the size and availability of the medicinal plants. The communal state, although fairly biodiverse, was perceived as being heavily utilised and gave the impression that the bigger and better specimens of medicinal plants would have been removed, hence this state was not always ranked highly. Great interest was shown in what the different areas would provide along the lines of medicine, food, space for gardens, the availability of wood for rituals and fuel, compared with the men whose main concerns were their cattle and wood.

The cultural diversity of the Xhosa people of the Eastern Cape is known to be dependent on the biodiversity of the area and it is estimated that one third of all the plant resources collected are destined for cultural related uses (Cocks et al. 2003). Many plant species are directly used to enhance a sense of well-being (Cocks & Møller 2002). Another study by Grierson and Afolayan (1999) revealed that 38 plant species belonging to 26 families were frequently used for the treatment of wounds in the Eastern Cape, indicating that the high phylogenetic diversity is of cultural value.

From an aesthetic point of view, the women like the communal men either opted for the open savanna state in line with preference theories put forward by Gobster (1994; 1995), or for the thicket state for the enjoyment of being close to nature and the importance of education for the children regarding nature. Interestingly, although the communal women ranked the communal state last in their initial ranking, a third of them rated it as their most preferred state in terms of recreation and beauty. This supports Posey's (2002) theory that familiarity and a sense of attachment strongly influences people's perceptions of landscapes.

Commercial men

The preferences of commercial men, geared towards cattle farming for profit and educated in the theory of veld condition and the nutritional value of grasses, correlated with the most profitable landscapes, ordering the states in terms of the generally perceived grazing capacity of the land (though this was not necessarily supported by data in Chapter 2). The farming practices of the commercial men (feed supplementation, provision of shelter) means that they are not as dependent on the land to meet the needs of all their livestock as the communal men. Due to the difference in culture, the men did not express preference for landscapes where there was wood, honey or natural medicines, but rather preferred landscape that were open for ease of farming and reduced risk of disease. The commercial men were more willing to transform the landscape as demonstrated by discussions over the fate of the acacia state vegetation. This probably results from the interpretation of veld condition along a grazing gradient and the understanding that management can be used to change between states.

As well as an aesthetic preference for open savanna landscapes based on a combination of farming preference and in agreement with Gobsters' (1994;

1995) theory of preference for these landscapes, several commercial men expressed having a sense of belonging to the thicket landscape when asked to choose a photo based on aesthetics or recreational purposes, suggesting that landscapes are not valued solely for utilitarian purposes or visual experience as suggested by Seamon (1979).

Commercial women

Women on the commercial farms mentioned a restful feeling that one gets from a safe environment with a open panoramic scene, whereby one gets a sense of perspective on the landscape, in line with the preference for modified savanna environments put forward by Gobster (1994; 1995). A striking contrast could be seen between commercial and communal women's roles, as commercial women are not directly reliant on the landscape to meet any of their basic needs. The savanna state was viewed as the most aesthetically pleasing, or the most beautiful and safer than the thicket, but thicket was appreciated for the biodiversity it contained. Even with prompting the women, with the exception of one active farmer, could not come up with any use for the landscape.

3.4.2 Limitations

The importance of photograph colour and scale to represent the landscapes became obvious during the course of the interviews. Colour was a major influencing factor when it came to selection, and although the photographs had been adapted so that they represented similar "greenness", it became clear that the amount of green in the minds of the farmers determined the amount of water present in the landscape. Another problem was that of scale. The perspective of the land and the number of landscape features that the photo captures in the back- and foreground may well have influenced peoples' decisions, particularly regarding recreational use or aesthetics. A selection of photos showing each vegetation type from a series of perspectives may better represent each state.

3.5 Conclusions

The biodiverse thicket was ranked highly by communal and commercial farmers based on both their farming objectives and aesthetic considerations.

The commercial farmers viewed the savanna state as a desirable state, for easy and productive cattle rearing. This contrasted with the views of communal men and women, who recognised that their needs and the needs of their livestock could not be met in this state.

For the commercial farmers there was some conflict between cattle grazing, which is better done in the savanna state, and maintaining large expanses of thicket. However, many farmers recognised that a wide variety of farming activities could be supported by the thicket state. Commercial farmers that wish to preserve the thicket state vegetation to maintain activities such as hunting, eco-tourism, or the aesthetic enjoyment of wildlife in a natural setting are obliged to preserve biodiversity.

The thicket state was viewed by men and women from the rural areas as offering the best conditions in times of drought and was therefore considered the more stable state. A continued production of forage for livestock represents stability in terms of maintaining livestock numbers and the vegetation was viewed as providing a type of insurance for future droughts. The high usefulness value of the thicket state (Chapter 2) also made it the preferred state for communal men and women, with their dependence on the land to meet many needs (Cocks et al. 2003; Cocks & Dold 2004; Shackleton et al. 2007)

The thicket state was repeatedly described as the "healthiest" or "most balanced" state indicating that farmers, both communal and commercial, intuitively gauge the resilience of the land and of ecosystem services such as water quality and nutrient cycling (higher values in bush-clumps, see Chapter 2). Nausser (1995) claims that ecological function is not visible to people who are not trained to look for it, but farmers, although not trained to measure ecological function *per se*, have enough experience of the landscapes on which to base their judgements.

Ecosystem functions such as climate regulation, water cycling and purification are difficult to study, but are recognized to have economic value (Costanza et al. 1997) and concern regarding these ecosystem services was shown by a few of the commercial farmers. Commercial farmers were aware that a change in vegetation state could indicate a change elsewhere, and that a change in species composition, although indicative of veld condition, was not indicative of overall ecosystem quality. Grass species composition and the presence of *Acacia karroo* were their main concerns. Communal farmers considered aspects of the ecology of the landscape such as stability, presence of water, soil quality in their visual assessment when comparing photos of the vegetation states and focus centred on the health of the thicket vegetation state in that respect.

The acacia and communal state seem to result not of choice for a preferred state, but are rather an unintended result of farming practices, which are not easy to reverse. Farmers perceptions suggest that they would be open to preserving at least some thicket state and therefore biodiversity on their land, but whatever constraints caused it to be lost (e.g. communal tenure with very high population density and lack of control over management in communal areas) would need to be addressed rather than people's attitudes.

The innate preference for savanna environments proposed by Gobster (1995) or rather preference in terms of the "space" one is viewing was apparent amongst all four groups. Savanna was recognised as an aesthetically pleasing place to be and all groups pictured themselves within the landscape enjoying recreational pastimes. However, there was an obvious attachment to the landscape from personal experience or through cultural experience, or preference shown in terms of the "place" one is viewing and the sense one has of belonging to it (Seamon 1979). With this sense of place came a preference for the thicket vegetation, the communal men and women recognising it as their own land or similar, and all groups referring to the enjoyable experience of wildlife and diversity to be had within the landscape.

Although other studies have shown a positive relationship between biodiversity and beauty ratings (Van den Berg et al. 1998), this study shows that biodiversity does not have to be beautiful, in the conventional parkland sense, to be preferred. Other criteria such as the opportunity the landscape affords for education, a sense of place or attachment, and personal as well as cultural experience are strong motivating factors.

CHAPTER 4

IMPLICATIONS FOR BIODIVERSITY

The underlying biodiversity provides the basis for the vegetation states studied. Hence, it is recommendable to preserve the floristic quality in part of the area, whilst using suitable farmland to its best production potential. The perspectives of the landholders need to be taken into consideration and integrated into biodiversity conservation efforts and management practices if biodiversity is to be preserved on both the commercial and communal land.

The thicket vegetation state, which had significantly higher species richness at both spatial scales and in general was a less utilised vegetation state appeared to be the least functional landscape, having the greatest inter-patch range. However, the added influence of habitat complexity indicates that the vegetation in this state is the more functional, habitat structure adding to control over resources. The other vegetation states tended to have a more complete grass sward, with fewer, smaller inter-patches, due to the influence of grazing. These states were all more heavily utilised areas, more homogenous in terms of habitat complexity and less species rich.

The higher biodiversity shown in the thicket state was linked to more stable forage productivity due to the presence of more perennial species, higher nutrient retention in bush-clumps and a more functional ecosystem, as with other studies on similar relationships (Tilman & Downing 1996; Tilman 1996; Tilman et al. 1998; Hector et al. 1999; Gotelli & Colwell 2001a).

Although the productivity as shown by the LAI and NDVI was not found to be significantly different between states, a correlation was observed between the capture and use of resources and higher productivity in keeping with observations made in other studies (Tilman & Downing 1996; Hector & Schmid 1999; Fridley 2001).

Thicket state was most similar to the communal state in terms of browse composition. The way that the land was managed seemed to determine browse structure. Removal of larger specimens for building wood and fuel in the communal areas, combined with high stocking rates kept the woody shrubs small, but no action was taken to remove shrubs for the purpose of improving the condition of the grass. Utilisation of the land rather than manipulation of the land was the preferred management practice and one that tended to preserve the more biodiverse bush-clumps albeit in a heavily utilised state.

The thicket state and thus areas of higher biodiversity were not distributed evenly throughout the Smaldeel. Fire regimes determined by seasonal precipitation are thought to be the selective force for the pattern of Thicket, which is known to be found as outliers in places of fire refuge (Mucina 2006) and soil type is not a restricting factor in its distribution (Cowling et al. 2005). Fires have been shown to completely remove bush-clumps (Trollope & Tainton 1986) and it could be that topography of the area, with the steeper valleys in the east and the open, rolling, more fire-prone hills in the west, has been an influencing factor in the distribution of bush-clump mosaic state throughout the Smaldeel. However not all the biodiversity was contained in the thicket state, with species of conservation importance being found in the acacia state vegetation, further to the west. The implications of this are twofold. Firstly, the protection of species of conservation interest will not necessarily protect the majority of biodiversity in the area and secondly, protecting the areas of high biodiversity value will not always protect species of importance to conservation.

Monitoring efforts made over a larger temporal scale are recommended for the application of policies within the area, in order to ascertain whether or not the states are still in a state of transition, with particular reference to the problem of *Acacia karroo* encroachment. *Acacia karroo* encroachment in the area has been related the reduction of goats being kept as livestock. Local farmers had several viewpoints on this, either that the browse needed to be cleared by fire so the cattle were better off; that the browse would be better converted to profit by letting goats eat it, these farmers viewed encroachment as an opportunity; others thought that the acacias were better left alone, that they would compete and die back. All farmers agreed that attempting to remove acacias mechanically caused more to appear. The widespread idea that the *Acacia karroo* encroachment is bad for the quality of the grass did not hold true in this study (Chapter 2). Although useful for browsers the landholders all recognised that this state was not desirable, as it did not represent land at its optimum potential for either farming or conservation.

The communal state, which was heavily stocked, often had a thick grass sward making it stable, but it was heavily utilised with plants being removed for fuel, food and medicinal purposes. The vegetation types found within the study area all seemed to be particularly resilient to heavy utilisation, which contrasts with findings by other studies (Vetter 2007; Desmet 2007). Vetter et al. (Vetter et al. 2006) found that the relative importance of "bottom-up" factors such as rainfall, soil type, slope position and geology, and "top down" controls such as grazing and fire, in determining vegetation structure and composition differed between environments and with the nature, frequency and intensity of grazing and fire. In some areas heavy communal grazing has been found to have severe effects on biodiversity and/or forage potential, soil erosion and stability (Lechmere-Oertel et al. 2005a; Lechmere-Oertel et al. 2005b). The resilience of the vegetation may be due to the grazers switching to browse during the dry season. The communal state was also heterogeneous and complex, enhancing the resilience of the state. The communal subsistence farmers, with their more inclusive viewpoint, valued the land for different reasons (Chapter 3), appreciating the potential usefulness of the biodiversity.

The over-harvesting of *Pelargonium sidoides* for sale to international pharmaceutical producers is an example where removal of a species outstrips potential for natural regeneration reducing biodiversity in an area, but also demonstrates how economic incentives affect landscapes. Managing for sustainability, biodiversity in these overcrowded, poverty stricken areas where individuals have few resources and little control over management is fraught with difficulties. Agricultural stability for better nutrition and improved livelihoods is a much sought after political goal in many poor areas of the world. Preservation of the cultural diversity, which relies on biodiversity, would preserve the majority of species (Cocks & Dold, 2003). Cocks and Dold (2004) demonstrate that the cultural values of the people affect the landscape around them, by the removal of species, and thus to the detriment of biodiversity, but argue for the preservation of biodiversity from a cultural perspective as the cultural practices of the Xhosa people are dependent on the biodiversity of the landscape that they live on. The recognition of the role of indigenous value systems has greatly contributed to the development of community-based natural resource management schemes (Fabricius 2004).

The best way to measure and preserve biodiversity in the commercial areas would be to appeal to the economic motivations of the farmers on the one hand and their aesthetic sensibilities on the other, given that both were strong determining factors in determining their preferences. Diverse farming activities provide a wider source of income, and require diverse landscapes. The most ideal landscape from a biodiversity and farmers point of view combined is probably a heterogeneous landscape including savanna states for beef production and more biodiverse thicket states for eco-tourism and game farming. The LFA results indicate that a combination of bush-clumps with a grass sward as produced by light grazing would be beneficial in terms of resource regulation allowing for grazing in the bush-clump areas. The acacia state is not desirable from an aesthetic or farming point of view and as such the land is not being utilised to its optimum potential. In areas of *Acacia karroo* encroachment, appropriate management actions would be the removal of small shrubs by either fire or goats or a combination of both (Trollope & Tainton 1986).

If commercial farmers are required to preserve biodiversity an appropriate method would be needed so that the various vegetation states on the farm could be quickly and easily assessed. Richness would work as an umbrella strategy for monitoring biodiversity, allowing farmers to assess different camps on the farm quickly and easily, not requiring the identification of the entire subset of “forbs”. Because of the multifaceted nature of biodiversity, no single measure is able to capture its essence and assessment procedures need to be tailored to suit the purpose of the investigation. A more straightforward strategy would be to maintain areas of Thicket bush-clumps within the savanna matrix, as these were the areas found to have the greatest species richness.

Given that many commercial farmers are familiar with the NPK analysis system for referring to fertilizers, it may be possible to develop a similar sounding system to cover the three concepts of forage potential, browse condition, and biodiversity. Just as forage potential is related to a benchmark site, so biodiversity could be related to a benchmark, in this case the floristic potential of the area. On the whole species richness was the best umbrella measure for biodiversity in the area, with the exception of species of conservation interest, and it has the added advantage to farmers of not requiring the identification of all the species. A quick count of species within of the quadrants while carrying out the veld/browse condition survey (Teague et al. 1994) would gather all the extra information required. A camp could then be summed up, for example, as a 7:3:2, indicating forage potential at 70%, 30% browse cover and 20% of the biodiversity represented, or something similar. Species designated conservation status did not correlate with the other biodiversity indices and may not be preserved by such a method as noted earlier.

Given that the commercial and communal landholders found the biodiverse areas aesthetically pleasing, felt that they belonged to the environment and valued it highly for its agricultural potential, it would appear that they are prepared to and would benefit from the conservation of biodiversity on their land, so ensuring the continued maintenance of the underlying ecosystem processes as well as the continued enjoyment of the areas diversity in all its forms.

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Appendix A. Satellite data showing how environmental variables change across the sites. Means and standard deviations of the four vegetation states for altitude (m), annual precipitation (mm), rainfall concentration (%) and heat units; NOAA satellite; 18 years of data.

	Altitude (m)	Annual precipitation (mm)	Rainfall concentration (%)	Heat units
Thicket	443.3 +/- 31.1	510.7 +/- 54.4	28.3 +/- 2.5	234.7 +/- 3.5
Communal	517.0 +/- 36.5	539.7 +/- 3.2	29.3 +/- 1.2	222.7 +/- 6.7
Savanna	665.3 +/- 8.1	446.7 +/- 16.4	30.7 +/- 0.6	216.7 +/- 1.5
Acacia	708.7 +/- 84.4	499.0 +/- 55.5	30.7 +/- 0.6	209.3 +/- 10.7

Appendix B. Browse species ranking by the original method (1=palatable, 0=unpalatable), expert opinion (2=most desirable, 1=less desirable, 0=eaten in times of stress) and final rank (0=unpalatable, 1= palatable)

Species	Rank by method	Rank by expert	Final Rank
Acacia karroo Hayne	1	2	1
Allophylus decipiens (Sond.) Radlk.	1	0	1
Aloe ferox Mill.	0	0	0
Asparagus africanus Lam.	0	1	1
Asparagus striatus (L.f.) Thunb.		1	1
Asparagus suaveolens Burch.		1	1
Atriplex semibaccata R.Br.		2	1
Azima tetracantha Lam.	0	2	0
Blepharis integrifolia (L.f.) E.Mey. ex Schinz		1	1
Brachylaena elliptica (Thunb.) DC	1	1	1
Buddleja saligna Willd.	1	1	1
Carissa bispinosa (L.) Desf. ex Brenan	0	2	0
Chascanum cuneifolium (L.f.) E.Mey.		0	0
Chrysocoma ciliata L.		0	0
Clausena anisata (Willd.) Hook.f. ex Benth. var. *anisata*	1	0	1
Coddia rudis (E.Mey. ex Harv.) Verdc.	1	0	1
Conyza scabrida DC.		0	0
Crassula muscosa L.		1	1
Cussonia spicata Thunb.	1	1	1
Cyphostemma cirrhosum (Thunb.)		?	0
Delosperma ecklonis (Salm-Dyck) Schwantes		1	1
Delosperma sp.		1	1
Delosperma sp. (2)		1	1
Diospyros dichrophylla (Gand.) De Winter	0	0	0
Diospyros lycioides Desf. subsp. *lycioides*	0	2	1
Drosanthemum sp.		2	1
Ehretia rigida (Thunb.) Druce	1	2	1
Euclea undulata Thunb.	0	1	0
Felicia filifolia (Vent.) Burtt Davy		0	0
Felicia muricata (Thunb.) Nees subsp. *muricata*		0	0
Flueggea verrucosa (Thunb.) G.L.Webster	1	?	1
Gnidia cuneata Meisn.		1	1
Grewia occidentalis L. var. occidentalis	1	2	1
Grewia robusta Burch.	1	2	1
Gymnosporia heterophylla (Eckl. & Zeyh.) Loes.	1	0	1
Helichrysum rosum (P.J.Bergius) Less. var. *arcuatum* Hilliard	0	1	0
Hermannia althaeoides Link	1	1	1
Hermannia coccocarpa (Eckl. & Zeyh.) Kuntze		1	1
Hibiscus pusillus Thunb.		1	1
Hibiscus trionum L.			1
Hippobromus pauciflorus (L.f.) Radlk.	1	1	1
Indigofera sessilifolia DC.		2	1
Jamesbrittenia microphylla (L.f.) Hilliard		0	0
Jamesbrittenia pinnatifida (L.f.) Hilliard		0	0
Jasminum angulare Vahl	0	2	0

Lepidium ecklonii		1	1
Leucas capensis (Benth.) Engl.	0	1	0
Lippia javanica (Burm.f.) Spreng.	1	?	1
Lycium ferocissimum Miers	1	1	1
Melolobium candicans (E.Mey.) Eckl. & Zeyh.		2	1
Mystroxylon aethiopicum (Thunb.) Loes. subsp. *aethiopicum*	0	0	0
Olea europaea L. subsp. *africana* (Mill.) P.S.Green	1	1	1
Opuntia sp.	0	0	0
Ozoroa mucronata (Bernh.) R.Fern. & A.Fern.	0	1	0
Pappea capensis Eckl. & Zeyh.		0	1
Pentzia incana (Thunb.) Kuntze		2	1
Plumbago auriculata Lam.	0	2	0
Portulacaria afra Jacq.	1	2	1
Ptaeroxylon obliquum (Thunb.) Radlk.	0	1	0
Pteronia incana (Burm.) DC.		2	1
Putterlickia pyracantha (L.) Szyszyl.	1	0	1
Rhus crenata Thunb.	1	0	1
Rhus longispina Eckl. & Zeyh.	1	0	1
Rhus lucida L.	1	0	1
Schotia afra (L.) Thunb.	1	2	1
Scutia myrtina (Burm.f.) Kurz	1	0	1
Selago corymbosa L.		1	1
Selago geniculata L.f.		1	1
Senecio inaequidens DC.	0	1	0
Senecio pterophorus DC.		1	0
Solanum linnaeanum Hepper & Jaeger		1	1
Solanum tomentosum L.		1	1
Teucrium trifidum Retz.		1	1
Wahlenbergia sp.			0

Appendix C. Table to show 'useful' species and corresponding rank (Very Important = 3; Important =2; Least Important = 1; Not Used = 0).

Family	Species	Rank
ACANTHACEAE	*Thunbergia capensis* Retz	1
AIZOACEAE	*Aizoon glinoides* L.f.	1
AIZOACEAE	*Delosperma ecklonis* (Salm-Dyck) Schwantes	1
AIZOACEAE	*Drosanthemum sp.*	1
AIZOACEAE	*Trichodiadema intonsum* (Haw.) Schwantes	2
ALLIACEAE	*Tulbaghia alliacea* L.f.	3
ALOEACEAE	*Aloe ferox* Mill.	2
ALOEACEAE	*Gasteria bicolor* Haw.	3
AMARYLLIDACEAE	*Bulbine abyssinica* A.Rich.	2
AMARYLLIDACEAE	*Bulbine frutescens* (L.) Willd.	2
AMARYLLIDACEAE	*Scadoxus puniceus* (L.) Friis & Nordal	3
AMPELIDACEAE	*Rhoicissus digitata* (L.f.) Gilg & M.Brandt	3
AMPELIDACEAE	*Rhoicissus rhomboidea* (E.Mey. ex Harv.) Planch.	3
ANACARDIACEAE	*Ozoroa mucronata* (Bernh.) R.Fern. & A.Fern.	1
APIACEAE	*Ledebouria ovalifolia* (Schrad.) Jessop	2
APIACEAE	*Ledebouria undulata* (Jacq.) Jessop	2
APIACEAE	*Pappea capensis* Eckl. & Zeyh.	1
APOCYNACEAE	*Carissa bispinosa* (L.) Desf. ex Brenan	1
ARALIACEAE	*Cussonia spicata* Thunb.	1
ASCLEPIADACEAE	*Sarcostemma viminale* (L.) R.Br	1
ASTERACEAE	*Arctotis arctotoides* (L.f.) O.Hoffm.	1
ASTERACEAE	*Brachylaena elliptica* (Thunb.) DC	1
ASTERACEAE	*Cirsium vulgare* (Savi) Ten.	1
ASTERACEAE	*Gerbera piloselloides* (L.) Cass.	3
ASTERACEAE	*Taraxacum officinale* Weber, aggregate species	1
BORAGINACEAE	*Ehretia rigida* (Thunb.) Druce	1
CAMPANULACEAE	*Cyphia sp.*	1
CELASTRACEAE	*Mystroxylon aethiopicum* (Thunb.) Loes. subsp. *aethiopicum*	3
COMMELINACEAE	*Commelina africana* L.	1
CRASSULACEAE	*Cotyledon orbiculata* L.	1
CRASSULACEAE	*Crassula arborescens* (Mill.) Willd. subsp. *undulatifolia* Tölken	1
CUCURBITACEAE	*Kedrostis foetidissima* (Jacq.) Cogn.	3
EUPHORBIACEAE	*Clutia pulchella* L.	2
EUPHORBIACEAE	*Euphorbia triangularis* Desf.	1
FABACEAE	*Acacia karroo* Hayne	1
FABACEAE	*Dolichos falciformis* E.Mey.	1
FABACEAE	*Indigofera sessilifolia* DC.	1
FABACEAE	*Schotia afra* (L.) Thunb.	2
FLACOURTIACEAE	*Dovyalis rotundifolia* (Thunb.) Thunb. & Harv.	1
FLACOURTIACEAE	*Scolopia zeyheri* (Nees) Harv.	1
HYACINTHACEAE	*Drimia anomala* (Baker) Baker	2
HYACINTHACEAE	*Eucomis autumnalis* (Mill.) Chitt.	2
IRIDACEAE	*Moraea polystachya* (Thunb.) Ker Gawl.	1
LAMIACEAE	*Becium burchellianum* (Benth.) N.E.Br.	1
LAMIACEAE	*Leucas capensis* (Benth.) Engl.	1
LAMIACEAE	*Teucrium trifidum* Retz.	1

LILIACEAE	*Asparagus setaceus* (Kunth) Jessop	1
LILIACEAE	*Asparagus suaveolens* Burch.	1
LILIACEAE	*Ornithogalum longibracteatum* Jacq.	1
LILIACEAE	*Sansevieria hyacinthoides* (L.) Druce	1
OLEACEAE	*Olea europaea* L. subsp. *africana* (Mill.) P.S.Green	3
PLUMBAGINACEAE	*Plumbago auriculata* Lam.	3
POACEAE	*Cymbopogon pospischilii* (K.Schum.) C.E. Hubb	1
POLYGALACEAE	*Polygala illepida* E.Mey. ex Harv.	2
PORTULACACEAE	*Talinum caffrum* (Thunb.) Eckl. & Zeyh.	2
PTERIDACEAE	*Cheilanthes hirta* Sw.	1
RHAMNACEAE	*Scutia myrtina* (Burm.f.) Kurz	1
RHODOMELACEAE	*Pteronia incana* (Burm.) DC.	1
RUTACEAE	*Clausena anisata* (Willd.) Hook.f. ex Benth. var. *anisata*	2
RUTACEAE	*Zanthoxylum capense* (Thunb.) Harv.	1
SALVADORACEAE	*Azima tetracantha* Lam.	1
SAPINDACEAE	*Hippobromus pauciflorus* (L.f.) Radlk.	2
SAPINDACEAE	*Ptaeroxylon obliquum* (Thunb.) Radlk.	3
SCROPHULARIACEAE	*Ipomoea crassipes* Hook.	1
SOLANACEAE	*Solanum *nigrum* L.	1
STERCULIACEAE	*Hermannia coccocarpa* (Eckl. & Zeyh.) Kuntze	1
TILIACEAE	*Grewia occidentalis* L. var. *occidentalis*	1
VERBENACEAE	*Lippia javanica* (Burm.f.) Spreng.	1

Appendix D. List of Species found in the Smaldeel using the method by Proches and Cowling (Ş Procheş & R. M Cowling 2006).

Family AZ	(Genus) Species
ACANTHACEAE	*Barleria obtusa* Nees
ACANTHACEAE	*Blepharis integrifolia* (L.f.) E.Mey. ex Schinz
ACANTHACEAE	*Chaetacanthus setiger* (Pers.) Lindl.
ACANTHACEAE	*Hypoestes forskaolii* (Vahl) R.Br.
ACANTHACEAE	*Thunbergia capensis* Retz
AIZOACEAE	*Aizoon glinoides* L.f.
AIZOACEAE	*Delosperma ecklonis* (Salm-Dyck) Schwantes
AIZOACEAE	*Delosperma sp*.
AIZOACEAE	*Delosperma sp*. (2)
AIZOACEAE	*Drosanthemum sp*.
AIZOACEAE	*Galenia sarcophylla* Fenzl
AIZOACEAE	*Galenia secunda* (L.f.) Sond
AIZOACEAE	*Rhombophyllum albanense* (L.Bolus) H.E.K.Hartmann
AIZOACEAE	*Mestoklema sp*.
AIZOACEAE	*Trichodiadema intonsum* (Haw.) Schwantes
ALLIACEAE	*Tulbaghia alliacea* L.f.
ALOEACEAE	*Aloe ferox* Mill.
ALOEACEAE	*Gasteria bicolor* Haw.
AMARANTHACEAE	*Achyropsis leptostachya* (E.Mey. ex Meisn.) Baker & C.B.Clarke
AMARANTHACEAE	*Pupalia lappacea* (L.) A.Juss. var. *lappacea*
AMARYLLIDACEAE	*Bulbine abyssinica* A.Rich.
AMARYLLIDACEAE	*Bulbine frutescens* (L.) Willd.
AMARYLLIDACEAE	*Bulbine narcissifolia* Salm-Dyck
AMARYLLIDACEAE	*Scadoxus puniceus* (L.) Friis & Nordal
AMPELIDACEAE	*Rhoicissus digitata* (L.f.) Gilg & M.Brandt
AMPELIDACEAE	*Rhoicissus rhomboidea* (E.Mey. ex Harv.) Planch.
ANACARDIACEAE	*Ozoroa mucronata* (Bernh.) R.Fern. & A.Fern.
ANACARDIACEAE	*Rhus crenata* Thunb.
ANACARDIACEAE	*Rhus longispina* Eckl. & Zeyh.
ANACARDIACEAE	*Rhus lucida* L.
APIACEAE	*Ledebouria ovalifolia* (Schrad.) Jessop
APIACEAE	*Ledebouria undulata* (Jacq.) Jessop
APIACEAE	*Pappea capensis* Eckl. & Zeyh.
APOCYNACEAE	*Carissa bispinosa* (L.) Desf. ex Brenan
APOCYNACEAE	*Pachypodium succulentum* (L.f.) Sweet
ARALIACEAE	*Cussonia spicata* Thunb.
ASCLEPIADACEAE	*Raphionacme hirsuta* (E.Mey.) R.A.Dyer ex E.Phillips
ASCLEPIADACEAE	*Sarcostemma viminale* (L.) R.Br
ASCLEPIADACEAE	*Secamone alpini* Schult.
ASPHODELACEAE	*Trachyandra affinis* (Compton) Oberm.
ASTERACEAE	*Arctotis arctotoides* (L.f.) O.Hoffm.
ASTERACEAE	*Berkheya decurrens* (Thunb.) Willd
ASTERACEAE	*Berkheya heterophylla* (Thunb.) O.Hoffm.
ASTERACEAE	*Brachylaena discolor* DC.
ASTERACEAE	*Brachylaena elliptica* (Thunb.) DC
ASTERACEAE	*Chrysocoma ciliata* L.

ASTERACEAE	*Cirsium vulgare* (Savi) Ten.
ASTERACEAE	*Conyza scabrida* DC.
ASTERACEAE	*Cotula sericea* L.f.
ASTERACEAE	*Cuspidia cernua* (L.f.) B.L.Burtt
ASTERACEAE	*Felicia filifolia* (Vent.) Burtt Davy
ASTERACEAE	*Felicia muricata* (Thunb.) Nees subsp. *muricata*
ASTERACEAE	*Gazania linearis* (Thunb.) Druce
ASTERACEAE	*Gerbera piloselloides* (L.) Cass.
ASTERACEAE	*Gnaphalium declinatum* L.f.
ASTERACEAE	*Helichrysum rosum* (P.J.Bergius) Less. var. *arcuatum* Hilliard
ASTERACEAE	*Osteospermum grandidentatum* DC.
ASTERACEAE	*Pentzia globosa* Less.
ASTERACEAE	*Pentzia incana* (Thunb.) Kuntze
ASTERACEAE	*Pseudognaphalium luteo-album* (L.) Hilliard & B.L.Burtt
ASTERACEAE	*Senecio angulatus* L.f.
ASTERACEAE	*Senecio inaequidens* DC.
ASTERACEAE	*Senecio pterophorus* DC.
ASTERACEAE	*Taraxacum officinale* Weber, aggregate species
ASTERACEAE	*Trichogyne verticillata* (L.f.) Less.
BORAGINACEAE	*Cynoglossum hispidum* Thunb.
BORAGINACEAE	*Ehretia rigida* (Thunb.) Druce
BRASSICACEAE	*Lepidium ecklonii*
BUDDLEJACEAE	*Buddleja saligna* Willd.
CACTACEAE	*Opuntia sp*.
CAMPANULACEAE	*Cyphia sp*.
CAMPANULACEAE	*Lobelia anceps* L.f.
CAMPANULACEAE	*Lobelia flaccida* (C.Presl) A.DC. subsp. *flaccida*
CAMPANULACEAE	*Wahlenbergia sp*.
CELASTRACEAE	*Gymnosporia capitata* (E.Mey. ex Sond.) Loes.
CELASTRACEAE	*Gymnosporia heterophylla* (Eckl. & Zeyh.) Loes.
CELASTRACEAE	*Mystroxylon aethiopicum* (Thunb.) Loes. subsp. *aethiopicum*
CELASTRACEAE	*Putterlickia pyracantha* (L.) Szyszyl.
CHENOPODIACEAE	*Atriplex semibaccata* R.Br.
CHENOPODIACEAE	*Salsola aphylla* L.f.
CHENOPODIACEAE	*Selago corymbosa* L.
CHENOPODIACEAE	*Selago geniculata* L.f.
COMMELINACEAE	*Commelina africana* L.
COMMELINACEAE	*Commelina speciosa*
COMMELINACEAE	*Cyanotis speciosa* (L.f.) Hassk.
CONVOLVULACEAE	*Convolvulus farinosus* L.
CONVOLVULACEAE	*Falkia repens* Thunb.
CRASSULACEAE	*Cotyledon orbiculata* L.
CRASSULACEAE	*Crassula arborescens* (Mill.) Willd. subsp. *undulatifolia* Tölken
CRASSULACEAE	*Crassula capitella* Thunb.
CRASSULACEAE	*Crassula ericoides* Haw.
CRASSULACEAE	*Crassula inanis* Thunb.
CRASSULACEAE	*Crassula mesembryanthemoides* (Haw.) D.Dietr.
CRASSULACEAE	*Crassula muscosa* L.
CRASSULACEAE	*Crassula pellucida* L.
CRASSULACEAE	*Crassula perfoliata* L.
CRASSULACEAE	*Crassula perforata* Thunb.

CRASSULACEAE	*Crassula tetragona* L.
CRASSULACEAE	*Kalanchoe rotundifolia* (Haw.) Haw.
CUCURBITACEAE	*Kedrostis foetidissima* (Jacq.) Cogn.
CYPERACEAE	*Cyperus rubicundus* Vahl
CYPERACEAE	*Cyperus sp*. (2)
CYPERACEAE	*Ficinia sp*.
EBENACEAE	*Diospyros dichrophylla* (Gand.) De Winter
EBENACEAE	*Diospyros lycioides* Desf. subsp. *lycioides*
EBENACEAE	*Euclea undulata* Thunb.
ERIOSPERMACEAE	*Eriospermum porphyrium* Archibald
EUPHORBIACEAE	*Clutia pulchella* L.
EUPHORBIACEAE	*Croton sylvaticus* Hochst.
EUPHORBIACEAE	*Euphorbia globosa* (Haw.) Sims
EUPHORBIACEAE	*Euphorbia gorgonis* A.Berger
EUPHORBIACEAE	*Euphorbia mauritanica* L.
EUPHORBIACEAE	*Euphorbia triangularis* Desf.
EUPHORBIACEAE	*Flueggea verrucosa* (Thunb.) G.L.Webster
EUPHORBIACEAE	*Phyllanthus heterophyllus* E.Mey. ex Müll.Arg.
FABACEAE	*Acacia karroo* Hayne
FABACEAE	*Argyrolobium molle* Eckl. & Zeyh.
FABACEAE	*Dolichos falciformis* E.Mey.
FABACEAE	*Indigofera sessilifolia* DC.
FABACEAE	*Lotononis laxa* Eckl. & Zeyh.
FABACEAE	*Medicago laciniata* (L.) Mill. var. *laciniata*
FABACEAE	*Melilotus sp.*
FABACEAE	*Melolobium candicans* (E.Mey.) Eckl. & Zeyh.
FABACEAE	*Melolobium sp*.
FABACEAE	*Rhynchosia caribaea* (Jacq.) DC.
FABACEAE	*Rhynchosia totta* (Thunb.) DC. var. totta
FABACEAE	*Schotia afra* (L.) Thunb.
FACACEAE	*Tephrosia capensis* (Jacq.) Pers.
FLACOURTIACEAE	*Dovyalis rotundifolia* (Thunb.) Thunb. & Harv.
FLACOURTIACEAE	*Scolopia zeyheri* (Nees) Harv.
GENTIANACEAE	*Sebaea sp*.
GERANIACEAE	*Pelargonium alchemilloides* (L.) L'Hér.
GERANIACEAE	*Pelargonium aridum* R.A.Dyer
GERANIACEAE	*Sarcocaulon vanderietiae* L.Bolus
HYACINTHACEAE	*Albuca exuviata* Baker
HYACINTHACEAE	*Albuca setosa* Jacq.
HYACINTHACEAE	*Drimia anomala* (Baker) Baker
HYACINTHACEAE	*Drimia intricata* (Baker) J.C.Manning & Goldblatt
HYACINTHACEAE	*Eucomis autumnalis* (Mill.) Chitt.
HYPOXIDACEAE	*Hypoxis argentea* Harv. ex Baker
IRIDACEAE	*Moraea polystachya* (Thunb.) Ker Gawl.
LAMIACEAE	*Ajuga ophrydis* Burch. ex Benth.
LAMIACEAE	*Becium burchellianum* (Benth.) N.E.Br.
LAMIACEAE	*Leucas capensis* (Benth.) Engl.
LAMIACEAE	*Salvia stenophylla* Burch. ex Benth.
LAMIACEAE	*Stachys aethiopica* L.
LAMIACEAE	*Stachys scabrida* Skan
LAMIACEAE	*Teucrium trifidum* Retz.

LEGUMINOSAE	*Sutera campanulata* (Benth.) Kuntze
LILIACEAE	*Asparagus africanus* Lam.
LILIACEAE	*Asparagus crassicladus* Jessop
LILIACEAE	*Asparagus densiflorus* (Kunth) Jessop
LILIACEAE	*Asparagus macowanii* Baker
LILIACEAE	*Asparagus setaceus* (Kunth) Jessop
LILIACEAE	*Asparagus striatus* (L.f.) Thunb.
LILIACEAE	*Asparagus suaveolens* Burch.
LILIACEAE	*Asparagus subulatus* Thunb.
LILIACEAE	*Ornithogalum graminifolium* Thunb.
LILIACEAE	*Ornithogalum longibracteatum* Jacq.
LILIACEAE	*Sansevieria hyacinthoides* (L.) Druce
LINYPHIIDAE	*Lessertia sp.*
MALVACEAE	*Abutilon sonneratianum* (Cav.) Sweet
MALVACEAE	*Hibiscus aethiopicus* L.
MALVACEAE	*Hibiscus pusillus* Thunb.
MALVACEAE	*Hibiscus trionum* L.
MALVACEAE	*Sida ternata* L.f.
MOLLUGINACEAE	*Pharnaceum dichotomum* L.f.
OLEACEAE	*Jasminum angulare* Vahl
OLEACEAE	*Olea europaea* L. subsp. *africana* (Mill.) P.S.Green
OXALIDACEAE	*Oxalis smithiana* Eckl. & Zeyh.
OXALIDACEAE	*Oxalis sp.*(2)
PLANTAGINACEAE	*Plantago *rhodosperma* Decne.
PLUMBAGINACEAE	*Plumbago auriculata* Lam.
POACEAE	*Aristida congesta* Roem. & Schult. subsp. *barbicollis* (Trin. & Rupr.) De Winter
POACEAE	*Cymbopogon pospischilii* (K.Schum.) C.E. Hubb
POACEAE	*Cynodon dactylon* (L.) Pers
POACEAE	*Digitaria eriantha* Steud.
POACEAE	*Ehrharta villosa* var. *maxima*
POACEAE	*Eragrostis capensis* (Thunb.) Trin.
POACEAE	*Eragrostis chloromelas* Steud.
POACEAE	*Eragrostis curvula* (Schrad.) Nees
POACEAE	*Eragrostis lehmanniana* Nees
POACEAE	*Eragrostis obtusa* Munro ex Ficalho & Hiern
POACEAE	*Eustachys paspaloides* (Vahl) Lanza & Mattei
POACEAE	*Helictotrichon turgidulum* (Stapf) Schweick.
POACEAE	*Heteropogon contortus*
POACEAE	*Microchloa caffra* Nees
POACEAE	*Panicum deustum* Thunb.
POACEAE	*Panicum maximum* Jacq.
POACEAE	*Setaria sphacelata* (Schumach.) Moss var. *sphacelata*
POACEAE	*Sporobolus africanus* (Poir.) Robyns & Tournay
POACEAE	*Sporobolus fimbriatus* (Trin.) Nees
POACEAE	*Sporobolus nitens* Stent
POACEAE	*Themeda triandra* Forssk.
POACEAE	*Tragus berteronianus* Schult.
POLYGALACEAE	*Polygala illepida* E.Mey. ex Harv.
POLYGALACEAE	*Polygala leptophylla* Burch. var. *leptophylla*
POLYGALACEAE	*Polygala refracta* DC.
POLYGALACEAE	*Polygala uncinata* E.Mey. ex Meisn.

PORTULACACEAE	*Portulacaria afra* Jacq.
PORTULACACEAE	*Talinum caffrum* (Thunb.) Eckl. & Zeyh.
PTERIDACEAE	*Cheilanthes hirta* Sw.
RHAMNACEAE	*Scutia myrtina* (Burm.f.) Kurz
RHODOMELACEAE	*Pteronia incana* (Burm.) DC.
RUBIACEAE	*Coddia rudis* (E.Mey. ex Harv.) Verdc.
RUBIACEAE	**Richardia humistrata* (Cham. & Schltdl.) Steud.
RUBIACEAE	Rubiaceae
RUTACEAE	*Clausena anisata* (Willd.) Hook.f. ex Benth. var. *anisata*
RUTACEAE	*Zanthoxylum capense* (Thunb.) Harv.
SALVADORACEAE	*Azima tetracantha* Lam.
SANTALACEAE	*Thesium scandens* Sond.
SAPINDACEAE	*Allophylus decipiens* (Sond.) Radlk.
SAPINDACEAE	*Hippobromus pauciflorus* (L.f.) Radlk.
SAPINDACEAE	*Ptaeroxylon obliquum* (Thunb.) Radlk.
SCROPHULARIACEAE	*Jamesbrittenia microphylla* (L.f.) Hilliard
SCROPHULARIACEAE	*Jamesbrittenia pinnatifida* (L.f.) Hilliard
SCROPHULARIACEAE	*Ipomoea crassipes* Hook.
SCROPHULARIACEAE	*Nemesia denticulata* (Benth.) Grant ex Fourc.
SCROPHULARIACEAE	*Nemesia floribunda* Lehm.
SCROPHULARIACEAE	*Nemesia fruticans* (Thunb.) Benth.
SCROPHULARIACEAE	Scrophulariaceae
SCROPHULARIACEAE	*Zaluzianskya capensis* (L.) Walp.
SOLANACEAE	*Lycium ferocissimum* Miers
SOLANACEAE	*Solanum chrysotrichum* Schltdl.
SOLANACEAE	*Solanum linnaeanum* Hepper & Jaeger
SOLANACEAE	*Solanum *nigrum* L.
SOLANACEAE	*Solanum tomentosum* L.
STERCULIACEAE	*Hermannia althaeoides* Link
STERCULIACEAE	*Hermannia coccocarpa* (Eckl. & Zeyh.) Kuntze
TACHINIDAE	*Isoglossa ciliata* (Nees) Lindau
TACHINIDAE	*Isoglossa origanoides* (Nees) Lindau
THYMELAEACEAE	*Gnidia cuneata* Meisn.
TILIACEAE	*Grewia occidentalis* L. var. *occidentalis*
TILIACEAE	*Grewia robusta* Burch.
URTICACEAE	*Laportea peduncularis* (Wedd.) Chew
VERBENACEAE	*Chascanum cuneifolium* (L.f.) E.Mey.
VERBENACEAE	*Lippia javanica* (Burm.f.) Spreng.
VERBENACEAE	**Verbena pinnatifida*
VERBENACEAE	**Verbena sp*.
VISCACEAE	*Viscum rotundifolium* L.f.
VITACEAE	*Cyphostemma cirrhosum* (Thunb.)