THE IMPACT OF DIFFERENT LAND USES ON THE PHYTODIVERSITY OF THE WEST COAST STRANDVELD IN AND AROUND ROCHERPAN NATURE RESERVE

BY

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A THESIS SUBMITED IN FULFILMENT OF THE REQUIREMENT FOR THE MASTERS DEGREE IN TECHNOLOGY (FACULTY OF APPLIED SCIENCES) AT THE CAPE PENINSULA UNIVERSITY OF TECHNOLOGY

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Declaration

I hereby declare that the work reported in this Thesis is my own. It has not been submitted to any other University of Technology or University.

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N.W. Hanekom

February 2007

Dedication

I dedicate this thesis to my parents, Koos and Jeanette, my wife, Natalie and children, Cornel and Martinette who sent me to school, supported and encouraged me to aim at higher education.

Abstract

Changes in plant species richness and diversity were investigated in Rocherpan Nature Reserve across a fence (or old fence line) separating 34 years of conservation management, conservation management for 11 years south and north, natural veld grazed by cattle and goats, natural veld grazed by sheep, and strip-ploughed veld grazed by sheep. Vegetation surveys were conducted in September 2001. The modified 20 m x 50 m Whittaker plot design with its attractive features of long-thin plots and the original Whittaker plot design were used. Number of species (as richness data) and the numbers of individual recordings per species per land use (as abundance data) were used in calculations in the 20 m x 50 m (1000 m^2) plots.

The species richness index showed significantly smaller numbers of species in the conservation management 11 years south land. The results also showed an increase in species numbers under the grazing land use systems. The data from the comparative study of the five different species diversity indices showed no significant differences. As a result, the Shannon-Wiener index was selected for further assessing the species diversity index and the species diversity significance of different land uses in the West Coast Strandveld. In this particular study, the species that showed an increase in vegetation cover in response to grazing land use regimes were *Hemimeris racemosa* (annual herb) and *Ehrharta brevifolia* (annual grass). The only large shrub species that showed a significant increase in estimated canopy cover was *Tetragonia fruticosa* in the 11 years of conservation management north regime.

The number of annual species and the numbers of individuals recorded for the grazing land use regimes differed from those under the conservation land use systems, in that, the numbers were higher in the former. Interestingly, *Nemesia strumosa*, a rare endangered species, was found on plots grazed by cattle and goats, but not in the other land use systems. Higher numbers of spinescent species were found under the strip-ploughed and grazed by sheep land use regime as a result of *Emex australis,* a pioneer species dominant on these land uses but not palatable to livestock.

The assumption that species use the spinescent mechanism to protect themselves from grazing pressure was not proven in absolute terms from the data obtained in this study of the West Coast Strandveld. The results also showed that the geophyte species exhibited no significant differences with different land use systems. It was assumed at the onset that deciduous and stems-shedding species would be more susceptible to grazing. However, the results obtained here do not support this hypothesis. If anything, the study showed significantly increased number and abundance of prostrate plants species with grazing by cattle and goats. High species numbers were also found under the other two grazing land use regimes, namely, grazed by sheep, and strip-ploughed and grazed by sheep in comparison with the conservation land use regimes.

Analysis of soils collected from the different land use systems, revealed significant differences in nutrient concentrations. For example, the concentrations of K, S, Na, Cu, and Fe were significantly greater in the strip-ploughed and grazed by sheep land use regime, while C, P, Mg and Ca showed significantly increased levels in the conservation management 11 years north. Analyses of soil collected from different sites within a land use system (i.e. open space, in-between plants, and under bush clumps) revealed a gradient in plant available nutrient concentrations, with levels increasing from open spaces to under bush clumps. The higher nutrient levels in soil from under bush clumps should be expected as organic matter accumulate from above- and below-ground parts. In addition to the role of soil organic matter in altering nutrient levels under bush clumps, soil pH was also modified. Sampling soils during winter and summer revealed seasonal variation in soil nutrient concentrations. Soil chemical properties, including nutrient concentrations, were altered under the different land use regimes. But whether the observed differences in the concentrations of extractable soil nutrients in this study were due to the effect of the land use system, or caused by phytodiversity within the land use regimes, remains to be properly assessed.

TABLE OF CONTENTS

Acknowledgements

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CHAPTER 1

General Introduction and literature review

1.1. Introduction

Studies on mediterranean-type shrublands have been well documented by Di Castri, *et al.,* (1981). A broad research program initiated in the 1970's in the winter-rainfall region of the Cape, was exclusively concerned with fynbos vegetation types, which are heathlands (Moll & Jarman, 1984). It is generally recognized that the Cape's non-heath shrublands are the true mediterranean shrublands of the region which includes Mountain and Coastal Renosterveld and Strandveld (Boucher & Moll, 1981). It is these shrublands that should be studied and compared with other mediterranean-type shrublands. South Africa's mediterranean-type shrublands form the smallest proportion of these shrublands in the world (Di Castri *et al.*, 1981), and Strandveld covers only a relatively small area; about 2072 km^2 (Bossi, 1984). So far, however, little coordinated research has been conducted on Strandveld. The strandveld can be differentiated into South Coast and West Coast forms (Moll, Hilton-Taylor & Jarman., 1984), and it is the latter which is the focus of this study.

A survey of the conservation of various vegetation types showed that only 1 to 5 % of Strandveld was conserved (Edwards, 1974). Of the four conservation areas existing in this veld type at the time, only Rocherpan was guaranteed permanence, being administered by the Province (Boucher & Jarman, 1977). Data show that about 192 000 ha of Strandveld have remained untouched by agricultural production and grazing on the West Coast. Protected areas (including dune areas administered by South African National Parks) comprise 12.5% (approximately 24 000 ha) of this area. The new vegetation map of South Africa classified the West Coast Strandveld as Langebaan Dune Strandveld (Mucina & Rutherford, 2003) and listed it as a vulnerable vegetation type in the South African National Spatial Biodiversity Assessment (Rouget *et al.*, 2004). Of the original 43 768 ha, only 28 607 ha have remained untouched (i.e. about 65 % of the original vegetation type coverage). Twenty seven percent of this vegetation type is now under some form of conservation protection with a conservation target of 24 % being set by the National Spatial Biodiversity Assessment, which has resulted in this vegetation type being classified as "well protected" (Rouget *et al.*, 2004).

Agriculture occupies 86 % of the land that is in the Western Cape in an attempt to feed an ever-increasing human population, thus implying the likelihood of negative impacts on the environment from agricultural activities. Detrimental impacts can include soil degradation, water pollution, loss of biodiversity, and deterioration of vegetation (Opperman, 2001).

There is thus an increasing need to develop new strategies for dealing with these environmental changes caused by agriculture in an attempt to feed human population ever increasing. Adequate protection and management of biodiversity in any environment should be key to such strategies.

Defining species diversity

Species richness and diversity and the methods for measuring diversity have remained problematic. In particular, the relationship between diversity and stability of ecosystems has attracted much debate (May, 1973; Goodman, 1975; Margalef, 1975; Pielou, 1975; van der Maarel, 1988). Margurran (1988) has provided a valuable review on diversity, but stressed that the word was hard to define. Species richness, or a count of the number of plant species in a quadrat, defined area or community, is often equated with diversity. When ecologists refer to high diversity, they often mean a community containing a large number of different species. However, as Margurran (1988) has indicated, the components of diversity include species richness and species abundance (evenness or unevenness) within a sample or community. Perfect evenness of five species in a quadrat of 20 % would mean that for 100% cover, they were distributed five times 20 %. Diversity is thus measured by recording the number of species and their relative abundance. The two components of species richness and evenness may then be examined separately or combined into some form of index.

Species diversity includes the number of species, the abundance of the species and the apportioning of abundance among the species (Green, 1979; Magurran, 1988; Smith, 1990). Fischer *et al* (1943) first introduced the concept of species diversity in connection with log-series distribution (Pielou, 1969; Green, 1979). The work of Margalef (1958) popularized this concept among ecologists (Green, 1979) and created strong interest in diversity indices as a means of simplifying and explaining communities. Species diversity measures have therefore been divided into three main categories (Magurran, 1988), namely species richness indices, species abundance models that describe the distribution of species abundances, and indices that are based on the proportional abundances of species.

Biological Indices for Measuring biodiversity

Biodiversity indices are attractive because they can reduce the information of large amounts of data to single numbers (Kent & Coker, 1994). But the application of single-figure diversity indices to characterize complex community structure have been criticised, because much of the original species information has been lost (Green, 1979).

A widely used method (Clarke & Warwick, 1994; Kent & Coker, 1994) for measuring species diversity is the Shannon-Wiener diversity index (Shannon & Wiener, 1963), a concept based on the proportional abundance of species. Here a single index value can be used to express the species diversity of a large sample area (Kent & Coker, 1994). The formula is sensitive to changes in the number of species and to the distribution of individuals among the species. As a result, it is sometimes referred to as the heterogeneity index because it is based on the proportional abundance of species, taking into account both equitability and species richness (Magurran, 1988).

The Shannon-Wiener formula requires species richness data and the relative abundance of each species for the comparison of diversity in sample areas of equal size (Green, 1979; Magurran, 1988; Smith, 1990; Kent & Coker, 1994). This method is therefore considered useful for comparing diversity where a number of replicate samples are involved, and the indices are suitable for the use of parametric statistics such as analysis of variance. When a measure of species diversity is required for comparative purposes, simple, meaningful indices, such as species richness (S) and the Margalef (1975) species richness index (Dmg) are less ambiguous, but equally informative as the more complex indices such as the Shannon-Wiener diversity index (Green, 1979).

In a simulation study, Green (1979) found that species richness was a better indicator of biological change than the Shannon-Wiener index (H'). However Kempton (1979) observed that the distribution of species abundance is often a more sensitive measure of environmental disturbance than species richness alone. Also, although as a heterogeneity measure, the Shannon-Wiener index takes into account the evenness of species abundance (Peet, 1975), a separate, additional measure of evenness, the Pielou evenness index (E) (Pielou, 1969), can be calculated. High evenness, which occurs when species are equal or close to equal in abundance, is conventionally equated with high diversity (Magurran, 1988).

The major threats to phytodiversity in the Strandveld are agriculture and aliens in the south, and overgrazing in the drier north (Liengme, 1987). Although studies have been conducted on the utilization and management of the West Coast Strandveld, little has been done on the impacts of different management activities on phytodiversity.

The West Coast Strandveld has been, and still is, primarily a stock-farming area, as the vegetation contains many palatable species that serve as natural pasture (Liengme, 1987). It has undoubtedly suffered as a result of stock grazing. Experiments conducted by Terblanche (1966) at Nortier Experimental Farm, Lamberts Bay, showed that a judicious use of the veld can potentially result in the maintenance of good natural pasture with a high cover of grasses and palatable species. However, incorrect use of the veld and overstocking can lead to decreased cover and increased succulence.

Description of the different land uses

Grazed by a combination of cattle and goats.

This treatment consisted of a section of a farm called Bokkeram (not part of the Reserve) that was used for grazing by both cattle and goats since 1988. Although the total carrying capacity for the West Coast Strandveld is 25 ha per large stock unit, the study was conducted on a 440 ha camp with a total of 20 cattle and 50 goats resulting in a actual stocking rate of 15.5 ha/LSU for the area or an overstocking of 11.75 %.

Thirty four years of conservation management (Proclaimed as Provincial Nature Reserve).

Efforts to formally conserve the seasonal wetland, now known as Rocherpan, were initiated in 1965 and it was expropriated on 14 July 1967. The main farming activity on this land has been cattle farming. However no grazing has occurred in this part of the nature reserve since 1967.

Eleven years of conservation management (north and south);(Proclaimed as Provincial Nature Reserve).

The remainder of the farm, approximately 520 ha, was expropriated on 23 March 1990. The farming activity on this land was cattle and horses before the establishment of the Nature Reserve, so no grazing has occurred in this part of the nature reserve since 1990.

Natural veld grazed by sheep.

A section of the farm called Modderfontein (not part of the reserve) was used for grazing by sheep since 1985. The recommended carrying capacity for the West Coast Strandveld is 25 ha per large stock unit. The study was conducted on a 200 ha camp with a total of 200 sheep and a stocking rate of 33.3 large stock units. Six sheep is equal to one large stock unit. The recommended carrying capacity for the area according to the South African Department of Agriculture is eight large stock units for the 200 hectares.

Strip-ploughed and grazed by sheep.

A section of the same vegetation type on the farm St Helenafontein (not part of the Reserve) was ploughed into strips and planted with pasture to increase the carrying capacity of the veld in 1985. Forty meters was ploughed and 40 m natural vegetation was maintained to prevent wind erosion. The plots selected for data collection were laid out in the natural veld strips, as far away as possible from the edge of the natural veld in order to minimize the effect of imported planted pastures on plant diversity. The veld was used for sheep grazing. The total carrying capacity for the West Coast Strandveld is 25 ha per large stock unit. The study was conducted on a 200 ha camp with a total of 200 sheep and a stocking rate of 33.3 large stock units, more than four times (417%) the recommended stocking rate. In this case six sheep were equal to one large stock unit. The carrying capacity for the area, according to the South African Department of Agriculture, is eight large stock units for the 200 ha.

Vegetation Analysis

The approach was largely descriptive, using a variety of contrasting agricultural practices in the landscape mosaic as the main units of comparison. Although there is no problem in this approach *per se* unavoidable design limitations associated with this approach occurs (e.g.

pseudo-replication). Pseudoreplication is defined as the use of inferential statistics to test for treatment effects with data from experiments where either treatments are not replicated (though samples may be) or replicates are not statistically independent (Hurlbert, 1984). In ANOVA terminology, it is the testing for treatment effects with an error term inappropriate to the hypothesis being considered. Scrutiny of 176 experimental studies published between 1960 and the present revealed that pseudoreplication occurred in 27% of them, or 48% of all such studies that applied inferential statistics (Hurlbert, 1984). One way to undertake vegetation analysis of an ecosystem is to consider the structure (i.e. the growth forms, layering, and arrangement) of vegetation stands. This is not only a way around the complexities of taxonomy, but an indication of adaptation as the structure of any vegetation tends to reflect limiting factors in the environment irrespective of the plant species involved. Raunkiaer's (1937) life form classification system was the first attempt at a general description of vegetation based on structural characters. It was devised in 1905 and has been extensively modified over the decades. Although seemingly obsolete, many of the terminologies coined for the system have remained current. The Raunkiaer's system has tended to emphasize the mechanisms employed by plants to survive unfavourable seasonal conditions, particularly the position of perennating buds with respect to the ground surface (Raunkiaer, 1937).

This study uses a fence-line contrast between natural vegetation under 34 years of conservation management, natural veld under conservation for 11 years, grazing by a combination of cattle and goats, strip-ploughed vegetation grazed by sheep, and natural veld grazed by sheep to study the phytodiversity of the West Coast Strandveld.

The parts to this study include:

i) Assessing the effectiveness of five different biological indices for measuring the phytodiversity of native plant species in the West Coast Strandveld, ii) an evaluation of the impact of different land uses on phytodiversity in the West Coast Strandveld of Rocherpan Nature Reserve iii) an evaluation of the impact of different land uses on the phytodiversity in different functional groupings of the West Coast Strandveld in and around Rocherpan Nature Reserve and, iv) the effect of land use regimes on mineral nutrient concentrations in soils of the Rocherpan Nature Reserve.

CHAPTER 2

Assessing the effectiveness of five different biological indices for measuring the phytodiversity of native plant species in the West Coast Strandveld

2.1. Introduction

The concept of species richness and diversity is problematic and often misunderstood. There is confusion over the meaning of diversity, the methods for measuring and assessing diversity, as well as the ecological interpretation of different levels of diversity. In particular, the relationship between diversity and stability in ecosystems has attracted considerable research (Goodman, 1975; Margalef, 1975; 1975; Pielou, 1975). Species richness, meaning a count of the number of plant species in a quadrat or community, is often equated with diversity. When ecologists talk of high diversity, they often mean a community containing a large number of different species. However, as Magurran (1988) has argued most methods for measuring diversity actually consist of two components, namely species richness, and the relative abundance (evenness or unevenness) of species within the sample or community. Perfect evenness of five species in a quadrat of 20 % would mean that for 100 % cover, they were distributed five times 20 %. Diversity is thus measured by recording the number of species and their relative abundance. The two components of species richness (i.e. the number of species) and evenness (i.e. the number of individuals per species recorded) may then be examined separately or combined into some form of index.

Fence-line contrasts, which are usually indicative of heavy grazing, can be viewed as natural experiments (Todd & Hoffman, 1994) that provide a unique opportunity for testing the long-term consequences of heavy grazing.

This study uses a fence-line contrast between five different land uses, namely 34 years of conservation management, 11 years of conservation management, natural veld grazed by sheep, natural veld grazed by a combination of cattle and goats, and strip-ploughed natural vegetation grazed by sheep.

The aim of this study was to determine the impact of these land uses on plant species diversity using different indicators such as species richness, Margalef index, Shannon-Wiener diversity index, Pielou evenness index, and the Simpson index. It was hoped that the results of this study would provide some indication on the suitability of using the Shannon-Wiener diversity index for further studies on diversity in the five land use regimes.

2.2. Materials and methods

2.2.1. Study site

The study was conducted in the Rocherpan Nature Reserve (18° 18' E 32° 36' S) 24 km north of the town Velddrif, South Africa, during September 2001. The site lies in the winter rainfall region of South Africa at an elevation 0 to 8 meter above sea level. The mean rainfall for the five year period from 1997 to 2001 is 236.78 mm. The year 2001 was a very wet year with a total of 160.22 mm more than the mean rainfall of 236.78 mm for the past five years

Data were collected in and around Rocherpan Nature Reserve as close as possible to the fence line. This was done in order to minimize the possible effect of topography and environmental heterogeneity on phytodiversity. Data were collected over a single period in order to maintain consistency and the fieldwork was conducted in September 2001, as that is the time when most plant species flower in the veld.

Rainfall During Experimental period

The wettest year was in 2001 with a total rainfall of 397 mm followed by 1997 with a total rainfall of 224.5 mm. With a mean rainfall for the five year period of 236.78 mm, 2001 was a very wet year with 160.22 mm more than the mean rainfall of 236.78 mm for the five year period (see Figure 1).

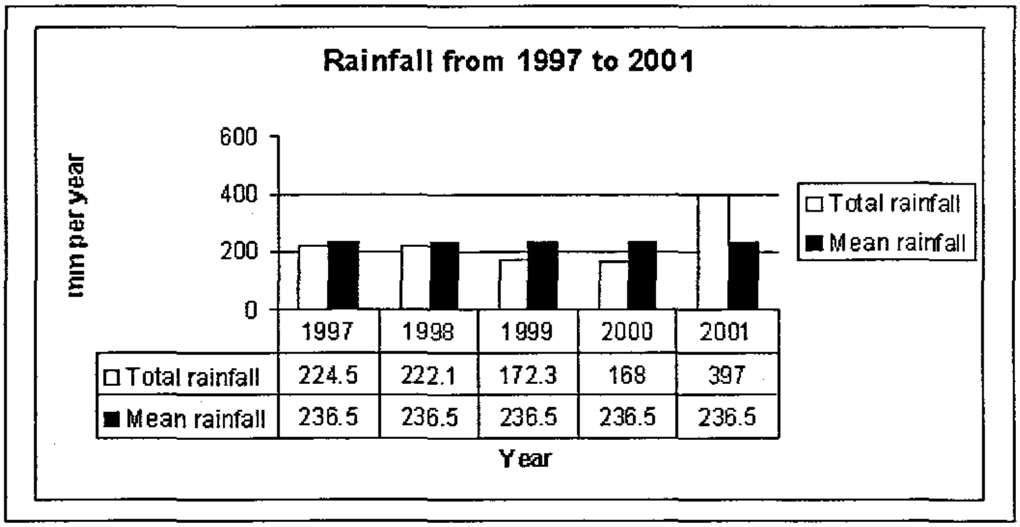


Figure 1. Total and mean yearly rainfall measured at Rocherpan Nature Reserve for the period 1997 to 2001.

However, the mean maximum temperature in summer (November, December, January) is 36,9 ^{0}C, while the mean minimum temperature in winter (June, July, August) is 3,3 ^{0}C (extrapolated from the data for Cape Columbine weather station). The warmest month on average is February, and the coldest, August. The dominant winds in summer are southerly and south-easterly winds, while in winter it is north-westerly, which generally brings rain. Dry, desiccating east winds can occur through out the year.

2.2.2. Different land uses

The five land uses employed in the testing of the different diversity indices were:

i) 34 years of conservation management,

ii) 11 years of conservation management,

iii) natural veld grazed by sheep,

iv) natural veld grazed by a combination of cattle and goats, and

v) strip-ploughed natural vegetation grazed by sheep.

The 11 years of conservation management land use was divided into northern and southern sections. Plots were laid out close to the fence line to minimize possible effects of topography and environmental heterogeneity on phytodiversity. The 34 years conservation management land use and the one grazed by a combination of cattle and goats were close to the south of the reserve. But the natural veld grazed by sheep land use was close to the northern section of the reserve, hence the necessity to split the 11 years conservation management land use into a northern and southern section (Appendix A). Detailed description of these land uses is provided in Chapter 3.

2.2.3. Sampling procedures

2.2.3.1. Plot Layout

Three replicate samples were collected randomly from a 20 m x 50 m area per land use so that they were representative of the different topographic units of the landscape. In each instance, the sample was situated well within a homogenous stand. A modified 20 m x 50 m Whittaker plot design with long-thin plot design was used. The modified Whittaker plot design minimizes the problems in the original design by using consistent rectangle proportions in the subplots to remove the plot size-shape interactions (Stohlgren *et al.*, 1995). Like the original Whittaker plot design, the modified Whittaker plot is 20 m x 50 m. However, the 0.20 m x 0.50 m, 1 m x 1 m, 2 m x 5 m and 10 m x 10 m subplots were arranged systematically inside the perimeter of the 20 m x 50 m plot (See Appendix B).

The 20 m x 50 m plot was laid out starting from the centre of the plot. The centre point was marked with a pole and the GPS reading recorded. The plot was orientated with the 50 m border in an east/west and the 20 m border in a north/south direction. The plot was laid out and marked using a rope starting 25 m from the marked centre to both sides in an east/west direction and 20 m to the north. Ten 0.20 m x 0.50 m, ten 1 m x 1 m, two 2 m x 5 m and two 10 m x 10 m subplots were laid out in the 20 m x 50 m plot (See Appendix B).

2.2.3.2. Data collection

The subplots and the 20 m x 50 m plot were scanned for species starting from the 0.20 m x 0.50 m, 1 m x 1 m, 2 m x 5 m, 10 m x 10 m and finally the 20 m x 50 m plot. All species present in these plots were recorded and marked with a star on the design vegetation data sheets (Appendix C). All subplots were handled separately. If a species was recorded in a subplot which was laid out inside another subplot the species was recorded as present for all the subplots. For instance, if species one was recorded in subplot 1, which was laid out in subplot 10 and in turn was laid out in the

20 m x 50 m plot, then that species was recorded as present in the three different subplots. Species that did not root in the subplot but spread their branches/leaves hung over the line were noted separately and marked by a plus sign. For instance, if a species was not rooted in the plot 0.20 m x 0.50 m (subplot 1), but the branches/leaves hanged over the line and the species rooted in subplot 10, then the species was recorded by a plus sign in subplot 1 and marked with a star as present in the subplot 10 and inside 20 m x 50 m plot. Two photographs were taken at each 20 m x 50 m plot and 10 m x 10 m subplot to document the landscape as well as the structure of the vegetation. The monitoring included the identification of all plant species in the plot, as well as the recording of all species present in the plot. Species that did not root in the plot but spread their branches/leaves over it were noted separately.

2.2.3.3. Information gathered at each sampling site

A special set of field data sheets was designed for this purpose (See Appendix C). A GPS reading was taken at the centre of the southern 50 m border. The GPS was set to the WGS 84 map datum. Additional location information included the Region, District, farm or name of area, and a short description of the locality. Habitat information included the slope, the terrain type, aspect, stone cover estimation, lithology (parent material), erosion severity, surface sealing/crusting and disturbances.

2.2.4. Database

Excel for Windows was used for analysing the data collected from field plots. The database contained information on the list of species known to occur in southern Africa, as prepared and updated by the National Botanical Institute in Pretoria, RSA (Arnold & de Wet, 1993).

2.2.5. Species diversity indices

Using data from this study, five of the most commonly used methods of expressing diversity (Clarke & Warwick, 1994) in terms of species richness, equitability, or both, were compared across the three grazing and three conservation treatments. These methods of expressing diversity include species richness (S) (Magurran, 1988), Margalef's index (Dmg) (Margalef, 1958), the Shannon-Wiener diversity index (H') (Shannon & Wiener, 1963), Pielou's evenness index (E) (Pielou, 1969) and Simpson (1949) diversity index.

Species richness (S) provides an instantly comprehensible expression of diversity (Magurran, 1988) and comprises the number of species recorded in any given sample area.

In general, the Margalef diversity index formula is expressed as:

$Dmg = (S - 1) / \log N$ (Margalef, 1958).

Where the Margalef diversity index (Dmg) incorporates both species richness and evenness and is a measure of the number of species present (S) for a given number of individuals (N).

The Shannon-Wiener diversity index (H') is based on the proportional abundance of species, taking into account both equitability and richness. The index value usually falls between 1.5 and 3.5.

The Shannon-Wiener formula is expressed as:

$H' = -\sum pi \log pi$ (Shannon & Wiener, 1963).

where pi is the proportion of the total abundance arising from the ith species. The Pielou evenness index (E) gives a value of the ratio of observed diversity to maximum diversity. Maximum diversity would be found where all species are equally abundant. This index is constrained between 0 and 1, with 1 representing all species being equally abundant.

The Pielou evenness index (E) is expressed as:

$E = H' / \log S$ (Pielou, 1969).

where H' is the diversity value calculated using the Shannon-Wiener formula.

D is a diversity index proposed by Simpson (1949) to describe the probability that a second individual drawn from a population should be of the same species as the first.

The statistic, C, is given by:

$$C = \sum_{i}^{S_{obs}} p_I^2$$ (Simpson, 1949)

but, for a finite population

$$p_I^2 = \frac{N_i (N_i - 1)}{N_i (N_t - 1)},$$

where Ni is the number of individuals in the ith species and NT the total individuals in the sample.

The index calculated here is:

$$D = \frac{1}{C}$$

so the larger its value the greater the diversity. The statistic 1 - C gives a measure of the probability of the next encounter (by the collector or any animal moving at random) being from another species (Hurlbert, 1971).

These five methods were used to study diversity in the West Coast Strandveld, and they took into account species richness (number of species per land use) and species abundance (number recordings per species per land use) in the 20 m x 50 m plot (1000 m^2).

2.3. Statistical analysis

The data obtained was analyzed using Species Diversity and Richness - PISCES Conservation Ltd (version 2.65) and Microsoft Excel. The mean was used as the measure of central tendency with standard deviation as the measure of variability. Parametric one-way analysis of variance (ANOVA), was used to test for statistically significant differences between the means of measured vegetation parameters across the five land uses.

2.4. Results

Mean species richness (number of species recorded per land use) and species abundance (number of individual recordings per species per land use) over the increasing sample plot area in each treatment was calculated using the five different diversity indices and the data recorded in the 0.1 m^2, 1 m^2, 10 m^2, 100 m^2 and 1000 m^2 subplots of each land use.

The data in Table 2.1 represents the number of species with their individual number of recordings per land use that were employed in determining the significance of the different diversity indices in the different land uses.

Species richness in the 20 m x 50 m plots was significantly reduced in the 11 years conservation north and south when compared to the other land uses (Table 2.1). Similarly the Margalef, Shannon-Wiener and Simpson's indices were all significantly smaller under conservation 11 years north (Table 2.1). There were however no differences between the other land uses in respect of the various indices used in this study (Table 2.1).

2.5. Discussion

Results of five different species diversity indices were evaluated and compared in order to determine their effectiveness in assessing species diversity in the West Coast Strandveld. Interestingly significant differences were found between the five diversity indices for various land uses such as that grazed by cattle and goats, 34 years of conservation management, natural veld grazed by sheep, and strip-ploughed and grazed by sheep (Table 2.1). Interestingly, significant differences were found under the conservation management 11 years south land use under the species richness index, were significant smaller number of species were recorded. The other diversity indices under conservation management 11 years south land use did not showed significant differences. Species richness, Margalef diversity index, the Shannon-Weiner index and the Simpson's diversity index all showed significantly lower numbers under the conservation management 11 years north land use and showed no comparison towards the other land use regimes where higher number of species were recorded. The results from this study showed a increase in numbers under the grazing land uses, with no significant differences between the grazing land use systems and the conservation management 34 years and conservation management 11 years south land use systems and does not compare with results found by Roux and Vorster (1983), where long term grazing experiments have shown that plant diversity is influenced by grazing pressure and the overuse of rangelands by domestic herbivores can result in the loss of plant diversity (Milton *et al.,* 1994). It however, compare with the results from a study by Todd and Hoffman (1999), where despite maintaining a stocking rate approximately twice that of the local commercial farmers, there has not been a significant reduction in within plot species richness on the communal rangelands.

Significant differences were also found under the species richness, Margalef, Shannon-Wiener and Simpson's diversity indices under the conservation management for 11 years north land use, but not with the Pielou diversity index. In all instances, the mean and standard deviation values were lower than the other land uses, suggesting that lower numbers of species with lower individual counts per species was recorded within this land use. Although the results from the comparative study of the five different species diversity indices showed no differences, a pattern could be discerned. In all the land uses, the Shannon-Wiener index was comparable to the Margalef, Simpson's and Species Richness indices in describing species diversity in the West Coast Strandveld (Tables 2.1). This compare well with the results from Wheeler (2003) study on impacts of grazing systems on Nama karoo phytodiversity, where the same diversity indices showed the same results for a comparative study on impacts on grazing systems on the Nama Karoo's phytodiversity. It can therefore be concluded that the Shannon-Wiener index can be used in further assessing the species diversity index and the species diversity significance of different land uses in the West Coast Strandveld.

Table 2.1. Species richness (SR); Margalef species richness indices (M); Shannon-Wiener diversity indices (H'), Pielou evenness indices (E) and Simpson's diversity indices (SIM) with number of species and species density per land use as the measures of abundance showing means and standard deviations for each land use. ANOVA test results of analysis of variance denote significant differences between land uses types at the $p<0.05$ level are indicated in the (Sig) column. NS = not significant. S = significant (Land use treatments CG = grazed by cattle and goats, C34 = conservation 34 years, C11s = eleven years of conservation management south, C11n = eleven years of conservation management north, S = Natural veld grazed by sheep and SS = Strip-ploughed Natural veld grazed by sheep.

Diversity indices for 1000 m^2 (20 m x 50 m)																								
	CG				C34				C11 s				C11n				S				SS			
Index	Mean	±	SD	Sig	Mean	±	SD	Sig	Mean	±	SD	Sig	Mean	±	SD	Sig	Mean	±	SD	Sig	Mean	±	SD	Sig
SR	102	±	27.47	ns	74	±	40.86	ns	63	±	29.57	s	64	±	23.39	s	91	±	44.12	ns	86	±	26.15	ns
M	10.07	±	0.42	ns	9.98	±	1.10	ns	9.12	±	0.68	ns	9.06	±	0.67	s	11.03	±	0.75	ns	10.98	±	0.90	ns
H' density	3.78	±	0.06	ns	3.81	±	0.15	ns	3.67	±	0.10	ns	3.61	±	0.03	s	3.92	±	0.05	ns	3.85	±	0.13	ns
E density	0.83	±	0.01	ns	0.85	±	0.03	ns	0.84	±	0.02	ns	0.84	±	0.01	ns	0.87	±	0.01	ns	0.86	±	0.03	ns
SIM density	39.51	±	2.89	ns	47.49	±	7.66	ns	39.87	±	5.10	ns	35.33	±	1.08	s	50.40	±	4.29	ns	44.71	±	7.32	ns

CHAPTER 3

An evaluation of the impact of different land uses on phytodiversity in the West Coast Strandveld of Rocherpan Nature Reserve

3.1. Introduction

Agriculture occupies about 86 % of the land in the Western Cape. This implies that agricultural activities are likely to have some impact on the environment from the practices associated with crop production (Opperman, 2001). Biodiversity is one natural resource that is easily altered by agricultural practises.

A 1974 survey of the conservation of various vegetation types in South Africa showed that only 1 to 5 % of Strandveld was conserved (Edwards, 1974). It has been documented (Jarman, 1986) that the West Coast Strandveld vegetation covers about 192 000 ha, of which West Coast National Park and Rocherpan Nature Reserve comprise 12.5% (approximately 24 000 ha). The major threats to plant diversity in the Strandveld include agriculture, aliens in the south, and overgrazing in the drier north (Liengme, 1987). Although research has been carried out on the utilization and management of West Coast Strandveld (Liengme, 1987), studies on the impact of different management activities and utilization on plant diversity for West Coast Strandveld are non-existent.

Species diversity technically includes the number of species, the abundance of the species and the apportioning of abundance among the species (Green, 1979; Magurran, 1988; Smith, 1990). Species diversity measures have therefore been divided into three main categories (Magurran, 1988): species richness indices, species abundance models that describe the distribution of species abundances, and indices based on the proportional abundances of species.

Diversity indices are attractive as they appear to reduce the information of large amounts of data to single numbers (Kent & Coker, 1994), but the application of single-figure diversity indices to characterize complex community structure is easily criticised, as much of the original species information is lost (Green, 1979).

A widely used approach (Clarke & Warwick, 1994; Kent & Coker, 1994) to measuring species diversity is the Shannon-Wiener diversity index method (Shannon & Wiener, 1963), which is based on the proportional abundances of species. Here, a single index value is used to express the species diversity of a sample area (Kent & Coker, 1994). The formula is sensitive to changes in the number of species and to the distribution of individuals among the species, and is sometimes referred to as a heterogeneity index, as it is based on the proportional abundance of species taking into account both equitability and species richness (Magurran, 1988).

For a comparison of diversity in sampled areas of equal size, the Shannon-Wiener index requires species richness data as well as the relative abundance of each species (Green, 1979; Magurran, 1988; Smith, 1990; Kent & Coker, 1994). This method is considered useful for comparing diversity when using a number of replicate samples, and the index is suitable for the use of parametric statistics such as analysis of variance.

Fence-line contrasts, which are usually indicative of different grazing treatments, can be viewed as natural experiments (Todd & Hoffman, 1999) that provide a unique opportunity for testing the long-term consequences of heavy grazing. This study uses a fence-line contrast between 34 years of conservation management, conservation management for 11 years, natural veld grazed by sheep, grazing by a combination of cattle, and goats and strip-ploughed natural vegetation grazed by sheep to assess the effect of different land uses on phytodiversity in the West Coast Strandveld.

3.2. Materials and methods

3.2.1. Study site

Field experiments were conducted at Rocherpan Nature Reserve (18° 18' E 32° 36' S) 24 km north of the town Velddrif, South Africa, during September 2001. The site lies in the winter rainfall region of South Africa at an elevation 0 to 8 meter above sea level. The mean rainfall for the five year period from 1997 to 2001 is 236.78 mm. The year 2001 was a very wet year with a total of 160.22 mm more than the mean rainfall of 236.78 mm for the five years

Scattered, low shrubs and small trees such as *Salvia lanceolata* and *Nylandtia spinosa* dominate West Coast Strandveld, with succulent shrubs such as *Zygophyllum morgsana, Euphorbia mauritanica* and *Euphorbia burmannii* as common species. Geophytes, annuals and species of the Cape Reed Family (Restionaceae) become more dominant where this vegetation type is associated with Sand Plain Fynbos (Low & Rebelo, 1996).

Data were collected in and around Rocherpan Nature Reserve as close as possible to the fence line to minimize the possible effect of topography and soil differences on plant diversity.

3.2.2. Description of the different land uses

Grazed by a combination of cattle and goats.

This treatment consisted of a section of a farm called Bokkeram (not part of the Reserve) that was used for grazing by both cattle and goats since 1988. Although the total carrying capacity for the West Coast Strandveld is 25 ha per large stock unit, the study was conducted on a 440 ha camp with a total of 20 cattle and 50 goats resulting in a actual stocking rate of 15.5 ha/LSU for the area or an overstocking of 11.75 %.

Thirty four years of conservation management.

Efforts to formally conserve the seasonal wetland, now known as Rocherpan, were initiated in 1965 and it was expropriated on 14 July 1967. The main farming activity on this land has been cattle farming. However no grazing has occurred in this part of the nature reserve since 1967.

Eleven years of conservation management (north and south).

The remainder of the farm, approximately 520 ha, was expropriated on 23 March 1990. The farming activity on this land was cattle and horses before the establishment of the Nature Reserve, so no grazing has occurred in this part of the nature reserve since 1990.

Natural veld grazed by sheep.

A section of the farm called Modderfontein (not part of the reserve) was used for grazing by sheep since 1985. The recommended carrying capacity for the West Coast Strandveld is 25 ha per large stock unit. The study was conducted on a 200 ha camp with a total of 200 sheep and a stocking rate of 33.3 large stock units. Six sheep is equal to one large stock unit. The recommended carrying capacity for the area according to the South African Department of Agriculture is eight large stock units for the 200 hectares.

Strip-ploughed and grazed by sheep.

A section of the same vegetation type on the farm St Helenafontein (not part of the Reserve) was ploughed into strips and planted with pasture to increase the carrying capacity of the veld in 1985. Forty meters was ploughed and 40 m natural vegetation was maintained to prevent wind erosion. The plots selected for data collection were laid out in the natural veld strips, as far away as possible from the edge of the natural veld in order to minimize the effect of imported planted pastures on plant diversity. The veld was used for sheep grazing. The total carrying capacity for the West Coast Strandveld is 25 ha per large stock unit. The study was conducted on a 200 ha camp with a total of 200 sheep and a stocking rate of 33.3 large stock units, more than four times (417%) the recommended stocking rate. In this case six sheep were equal to one large stock unit. The carrying capacity for the area, according to the South African Department of Agriculture, is eight large stock units for the 200 ha.

3.2.3. Sampling procedures

3.2.3.1. Plot Layout

Three replicate samples were collected randomly from 20 m x 50 m area per land use so that they were representative of the different topographic units of the landscape. In each instance, the sample was situated well within a homogenous stand. A modified 20 m x 50 m Whittaker plot design with long-thin plot was used. The modified Whittaker plot design minimizes the problems in the original design by using consistent rectangle proportions in the subplots to remove the plot size-shape interactions (Stohlgren *et al.*, 1995). Like the original Whittaker plot design, the modified Whittaker plot is 20 m x 50 m. However, the 0.20 m x 0.50 m, 1 m x 1 m, 2 m x 5 m and 10 m x 10 m subplots were arranged systematically inside the perimeter of the 20 m x 50 m plot (See Appendix B). Likewise the 10 m x 10 m subplots were centred in the plot.

The 20 m x 50 m plot was laid out starting from the centre of the plot. The centre point was marked with a pole and the GPS reading recorded. The plot was orientated with the 50 m border in an east/west and the 20 m border in a north/south direction. The plot was laid out and marked using a rope starting 25 m from the marked centre to both sides in an east/west direction and 20 m to the north. Ten 0.20 m x 0.50 m, ten 1 m x 1 m, two 2 m x 5 m and two 10 m x 10 m subplots were laid out in the 20 m x 50 m plot (See Appendix B).

3.2.3.2. Data collection

The subplots and the 20 m x 50 m plot were scanned for species starting from the 0.20 m x 0.50 m, 1 m x 1 m, 2 m x 5 m, 10 m x 10 m and finally the 20 m x 50 m plot. All species present in these plots were recorded and marked with a star on the design vegetation data sheets (Appendix C). All subplots were handled separately. If a species was recorded in a subplot which was laid out inside another subplot the species was recorded as present for all the subplots. For instance, if species one was recorded in subplot 1, which was laid out in subplot 10 and in turn was laid out in the 20 m x 50 m plot, then that species was recorded as present in the three different subplots. Species that did not root in the subplot but spread their branches/leaves hung over the line were noted separately and marked by a plus sign. For instance, if a species was not rooted in the plot 0.20 m x 0.50 m (subplot 1), but the branches/leaves hanged over the line and the species rooted in subplot 10, then the species was recorded by a plus sign in subplot 1 and marked with a star as present in the subplot 10 and inside 20 m x 50 m plot.

The vegetation information consisted of a full list of species found on the plot, which was collected following the standard Braun-Blanquet procedure in the subplot 23, which measured 10 m x 10 m (Mueller-Dombois & Ellenberg 1974). Plants that could not be identified in the veld were collected for later identification in the herbarium. A standard collection form accompanied each specimen. Two photographs were taken at each 20 m x 50 m plot and 10 m x 10 m subplot to document the landscape as well as the structure of the vegetation. The monitoring included the identification of all plant species in the plot, as well as the recording of all species present in the plot. Species that did not root in the plot but spread their branches/leaves over it were noted separately.

3.2.3.3. Information gathered at each sampling site

A special set of field data sheets was designed for this purpose (See Appendix C). A GPS reading was taken at the centre of the southern 50 m border. The GPS was set to the WGS 84 map datum. Additional location information included the Region, District, farm or name of area, and a short description of the locality. Habitat information included the slope, the terrain type, aspect, stone cover estimation, lithology (parent material), erosion severity, surface sealing/crusting and disturbances.

3.2.4. Database

Excel for Windows was used for analysing the data collected from field plots. The database contained information on the list of species known to occur in southern Africa, as prepared and updated by the National Botanical Institute in Pretoria, RSA (Arnold & de Wet 1993).

3.2.5. Species diversity indices

Using data from this study, one of the most commonly used methods of expressing diversity (Clarke & Warwick 1994) in terms of species richness, equitability, or both, were compared across the three grazing and three conservation treatments. This method of expressing diversity are the Shannon-Wiener diversity index (H') (Shannon & Wiener, 1963).

The Shannon-Wiener diversity index (H') is based on the proportional abundance of species, taking into account both equitability and richness. The index value usually falls between 1.5 and 3.5.

The Shannon-Wiener formula is expressed as:

$H' = -\sum p_i \log p_i$ (Shannon & Wiener, 1963).
where pi is the proportion of the total abundance arising from the ith species.

This method was used to assess species diversity in West Coast Strandveld, and took into account species richness (number of species per land use) and species abundance (number recordings per species per land use) in the 20 m x 50 m plot (1000 m^2).

3.3. Statistical analysis.

The data obtained was analyzed using Species Diversity and Richness - PISCES Conservation Ltd (version 2.65) and Microsoft Excel. The mean was used as the measure of central tendency with standard deviation as the measure of variability. Parametric one-way analysis of variance (ANOVA), was used to test for statistically significant differences between the means of measured vegetation parameters across the five land uses.

3.4. Results

Species richness over the increasing sample plot area in each treatment was calculated using the species richness recorded in the 0.1 m^2, 1 m^2, 10 m^2, 100 m^2 subplots and the 1000 m^2 area of each land use.

The total number of species types found in the land use regimes was greater with cattle and goat grazing, and lower in 11 years conservation management north and south (Table 3.2.1). The numbers of individuals counted in the grazed by cattle and goats land use regime was also much higher relative to the other land use regimes, and this was the result of an increased number of annuals (Table 3.2.1).

Some species were found in certain land use regimes, but not in others. For example, *Indigofera procumbens, Pelargonium triste, Nemesia strumosa, Cyanella sp, Babiana sp, Heliophila sp, Lessertia sp, Hordeum capense* were only found in grazed by cattle and goats plots, while *Pelargonium gibbosum, Moraea gawleri Pelargonium sp* and *Oxalis sp* were uniquely found in the 11 years conservation management south land use regime (Table 3.2.2). Similarly, *Ornithoglossum sp, Manochlamys albicans, Solanum guineense, Senecio scapiflorus* and *Viscum capensis* occurred in only the natural veld grazed by sheep land use regime, while *Aspalathus sp, Hermannia incana, Erucastrum sp, Grielum humifusum, Asparagus capensis, Arctopus echinatus, Senecio sp, Disparago sp, Lachenalia sp* and *Oncosiphon grandiflorum* were found in strip-ploughed natural veld grazed by sheep land use regime (Table 3.2.3). Thirty-two species were commonly found in all land use regimes. For example, *Rhus glauca, Zygophyllum morgsana, Othonna cylindrica, Asparagus, declinatus, Pteronia divaricata, Heliophila digitata, Pelargonium fulgidum, Asparagus fasciculatus, Droguetia iners, Babiana tubulosa, Ruschia subpaniculata, Eriocephalus kingesii, Silene undulate, Ehrharta villosa, Salvia lanceolata, Hermannia scordifolia, Cyphia crenata, Willdenowia incurvata, Tetragonia fruticosa, Melasphaerula ramose, Ehrharta brevifolia, Wahlenbergia cf. ramulosa, Wahlenbergia androsacea, and Hemimeris racemosa* were found in all land use regimes (Table 3.2).

When the Shannon-Wiener index was applied to species diversity in the five land use systems, only the conservation 11 years north regime was found to have a significantly lower species richness relative to the others (Fig. 3.1). Species diversity was unaltered in the remaining land use systems.

3.5. Discussion

The rainfall in 2001, the year of this study was exceptionally high. At Rocherpan the rainfall was 397 mm, which was 150 % above the 5-year mean. The second wettest year for the five-year period 1997 to 2001 was in 1997 with a total rainfall of 224.5 mm. Because of this high rainfall, seedling numbers were most likely not be representative of an average year as good wet soils tend to provide optimal conditions for seed germination and plant growth. The data collected in this study seem to provide a full description of diversity (Magurran, 1988) in terms of species richness and abundance (density and cover). The Shannon-Wiener index was tested against other indices in Chapter 2 and found to be suitable for assessing diversity as it takes into account species richness (number of species per land use) and species abundance (number of recordings per species per land use).

The Modified-Whittaker sampling method is designed for the recording of species richness per sample area, with an estimate of abundance. The sampling method used in the study further improved the Modified-Whittaker method (Stohlgren *et al.*, 1995) by increasing the area sampled for species richness and by using smaller areas, (e.g. 0.20 m x 0.50 m, up to 10 m x 10 m and 20 m x 50 m subplots) for recording various vegetation parameters. The increased study area, as expected, resulted in an increase in the number of species recorded per sample area (e.g. 136 in 1000 m^2 *versus* 109 in 100 m^2 area). This compare well with the study results from Wheeler (2003), where the numbers increase in species richness over the increasing sample plot area in each treatment for the species richness recorded in the $1m^2$, $10m^2$, $20m^2$, $100m^2$, $850m^2$, $1750m^2$ and $2500m^2$ subplots of each replicate.

As the emphasis of this study was on the effects of different land uses on plant diversity, the use of the small subplots allowed the recorder to scrutinize each subplot and obtain accurate measurements of vegetation changes. Focus on the small subplot area also ensured that the chances of not recording smaller and hidden species were minimized. The trade-off in obtaining these accurate species density is that it is more time-consuming and fewer plots can be sampled over the same time period.

The species richness results showed no significant differences between land uses, except for the land use 11 years of conservation management north. This was illustrated by the number of species and total number of recordings of individuals in this study in the 11 years of conservation management north regime. This does not compare with results found by Roux and Vorster (1983), where long term grazing experiments have shown that plant diversity is influenced by grazing pressure and the overuse of rangelands by domestic herbivores can result in the loss of plant diversity (Milton *et al.*, 1994). The species richness and abundances was lower than the other land uses. It however, compare with the results from a study by Todd and Hoffman (1999), where despite of maintaining a stocking rate approximately twice that of the local commercial farmers, there has not been a significant reduction in within plot species richness on the communal rangelands. Grazing on the natural vegetation resulted in a reduction in total vegetation cover and altered the dominance of perennials in favour of annuals. The findings of this study are consistent with those of other studies in arid and semi-arid Mediterranean regions, where heavy grazing also resulted in a shift from perennial to annual vegetation (Naveh & Whittaker 1979; Olsvig-Whittaker *et al.*, 1993). In this study, the species that showed an increase in cover in response to grazing land uses were *Hemimeris racemosa* (annual herb) and *Ehrharta brevifolia* (annual grass), which exhibited a significant difference in diversity in the land use regime grazed by cattle and goats. The only large shrub species that showed a significant increase in estimated canopy cover was *Tetragonia fruticòsa* in the 11 years of conservation management north regime.

The assumption before the study started was that strip-ploughing would result in a low plant species diversity in comparison to the other land use regimes as a result of species loss. However, the results of the strip-ploughed natural veld grazed by sheep have compared well with the other land uses, except for the 11 years of conservation management north land use. Of all the plant species collected from this land use regime, only one was an alien introduced into the site. This observation thus eliminated any possibility of a higher plant species diversity in this regime being attributed to introduced alien species.

The number of annual species and the number of individuals recorded for the grazing land use regimes grazed differed from those under the conservation land use regimes, in that the numbers were higher in the former. Interestingly, *Nemesia strumosa*, a rare endangered species, was found on plots grazed by cattle and goats, but not in the other land uses. Apparently its distribution next to Rocherpan Nature Reserve is the furthest north this species has occurred.

The data in Appendix D represents the number of species with their numbers of recordings per land use regime that were used to assess the significance of the various diversity indices on the different land uses. Further studies are needed to determine if it would be a good management practice to utilize vegetation in declared conservation areas for livestock grazing. Further studies should focus on the different functional groupings in the West Coast Strandveld and the effect of the different land use options on them. Further studies are also needed on soil structure and nutrient cycling to determine the effect of soil composition on plant species diversity and how it would differ between different land use options.

Table 3.1. Species numbers and number of annual and perennial species found in each land use regime (CG = grazed cattle and goats, C34 = conservation 34 years, C11s = eleven years of conservation management south, C11n = eleven years of conservation management north, S = Natural veld grazed by sheep and SS = Strip-ploughed Natural veld grazed by sheep).

Parameters	Land use						
	CG	C 34	C 11s	C 11n	S	SS	Total
Total number of different species recorded	93	85	76	70	89	88	136
Number of individuals counted	920	670	579	566	818	774	4327
Number of perennial species counted	374	489	452	339	448	376	2478
Number of annual species counted	549	181	127	227	372	393	1849

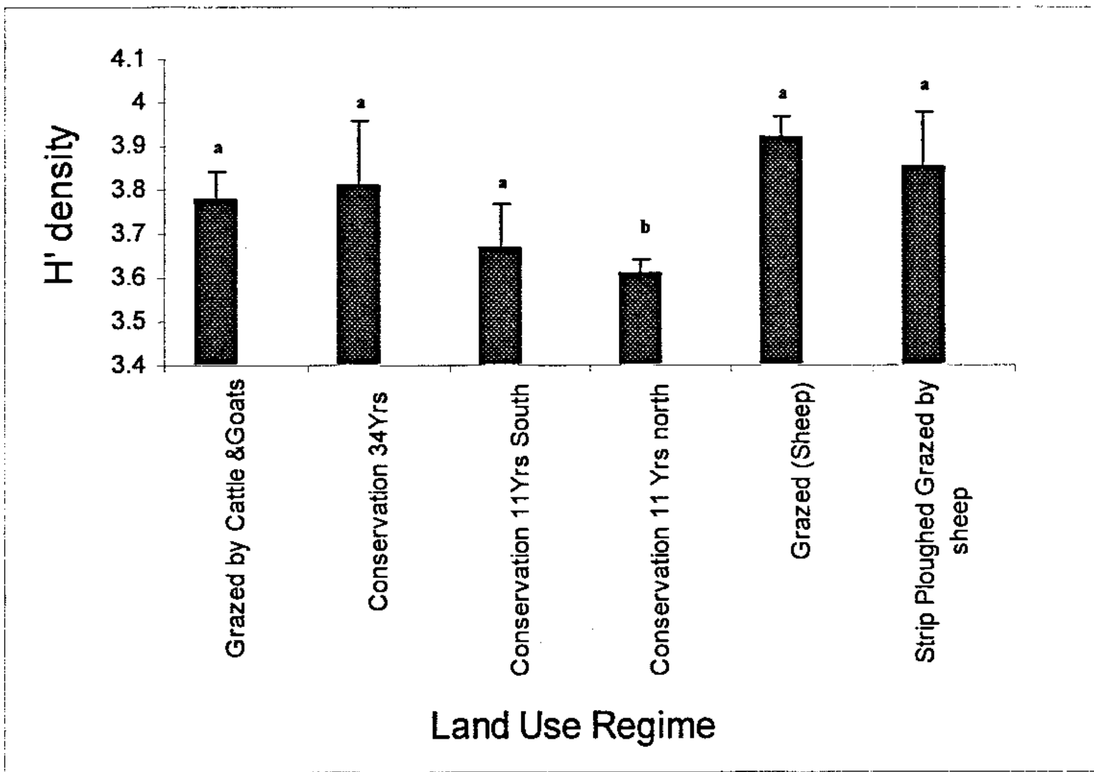
Table 3.2. Species not common to all land uses, showing species unique to a land use and only occurring in those land use (CG = grazed cattle and goats, C34 = conservation 34 years, C11s = conservation 11 years south, S = Natural veld grazed by sheep and SS = Strip-ploughed Natural veld grazed by sheep).

Species found in only specific land use regimes				
Species in land use regimes (1000 m^2)				
CG	C34	C11s	S	SS
Indigofera procumbens	*Cynanchum africanum*	*Pelargonium gibbosum*	*Ornithoglossum sp.*	*Aspalathus sp.*
Pelargonium triste		*Moraea gawleri*	*Unknown sp. (Small shrub)*	*Hermannia incana*
Nemesia strumosa		*Pelargonium sp.*	*Manochlamys albicans*	*Érucastrum sp.*
Cyanella sp.		*Oxalis sp.*	*Solanum guineense*	*Grielum humifusum*
Babiana sp.			*Senecio scapiflorus*	*Asparagus capensis*
Heliophila sp.			*Viscum capensis*	*Arctopus echinatus*
Lessertia sp.				*Senecio sp.*
Hordeum capense				*Disparago sp.*
				Lachenalia sp.
				Oncosiphon grandiflorum

Table 3.2.

Species common and found in all land use regimes.		
Rhus glauca	*Senecio sp. (Hanekom 102)*	*Zygophyllum morgsana*
Othonna cylindrica	*Unknown sp. (Hanekom 99)*	*Asparagus fasciculatus*
Asparagus declinatus	*Trachyandra sp. (Hanekom 76)*	*Ruschia subpaniculata*
Pteronia divaricata	*Unknown sp. (Hanekom 73)*	*Eriocephalus kingesii*
Heliophila digitata	*Poaceae (Hanekom 72)*	*Salvia lanceolata*
Pelargonium fulgidum	*Unknown sp. (Hanekom 70)*	*Hermannia scordifolia*
Droguetia iners	*Oxalis sp. (Hanekom 29)*	*Cyphia crenata*
Babiana tubulosa	*Hermannia sp. (Hanekom 27)*	*Willdenowia incurvata*
Silene undulata	*Ehrharta villosa*	*Tetragonia fruticosa*
Ehrharta brevifolia	*Melasphaerula ramosa*	*Wahlenbergia androsacea*
Hemimeris racemosa	*Wahlenbergia cf. ramulosa*	

Fig. 3.1. Shannon-Wiener diversity index (H'), with number of species and species density per land use as the measures of abundance showing means and standard deviations for each land use in the 1000 m^2 plots. Dissimilar superscripts denote significance differences between land use types at the $p<0.05$ level. NS = not significant and S = significant. (CG = grazed by cattle and goats, C34 = conservation 34 years, C11s = eleven years of conservation management south, C11n = eleven years of conservation management north, S = Natural veld grazed by sheep and SS = Strip-ploughed grazed by sheep).



CHAPTER 4

An evaluation of the impact of different land uses on the phytodiversity in different functional groupings of the West Coast Strandveld in and around Rocherpan Nature Reserve.

4.1. Introduction

In an earlier survey, it was found that only between 1 and 5 % of Strandveld was conserved (Edwards, 1974). Of the four conservation areas existing at the time, only Rocherpan was guaranteed permanence, being administered by the Province (Boucher & Jarman, 1977). Statistics (Jarman, 1986) show that about 192 000 ha of Strandveld have remained undisturbed in the West Coast (i.e. not removed for agricultural crop production but grazed by domestic animals), of which protected areas (including dune areas administered by South African National Parks) comprise 12.5% (approximately 24 000 ha). Some areas, however, consist of poor vegetation cover. The new vegetation map of South Africa classified the West Coast Strandveld as Langebaan Dune Strandveld (Mucina & Rutherford, 2003) and listed it as a vulnerable vegetation type in the South African National Spatial Biodiversity Assessment (Rouget *et al.*, 2004). Of the original 43 768 ha, only 28 607 ha have remained untouched (i.e. about 65 % of the original vegetation type coverage).

Agriculture occupies 86 percent of the land in the Western Cape. This presupposes that the practices associated with different agricultural activities could impact on the environment. Negative impacts pertain to soil degradation, water quality problems, loss of biodiversity and vegetation deterioration (Opperman, 2001).

The consequences of livestock grazing in semi-arid areas are diverse (Todd & Hoffman, 1999). Light grazing can result in an increase in species richness, as a result of reduced competition (Naveh & Whittaker, 1979; Waser & Price, 1981; Noy-Meir *et al.*, 1989). Selective grazing of palatable species can also result in a shift to assemblages dominated by toxic and spinescent woody plants (Westoby *et al.*, 1989; Milton & Hoffman, 1994). Where non-palatable or spinescent plants are not common, a frequently observed change associated with increasing grazing pressure is a shift from perennial to annual vegetation (Naveh & Whittaker, 1979; Milton *et al.*, 1994). Heavy grazing thus results in the loss of palatable plants and selects for weedy, generalist species (West, 1993). Succulent leafy shrubs are usually separated from woody shrubs as they tend to be comparatively short-lived relative to woody shrubs, and may also be more sensitive to overgrazing (Cowling *et al.*, 1994). Liengme (1987) has referred to the fact that annual and geophyte species increase in abundance in natural veld utilized by grazing animals.

There are various ways to evolve strategies for the management and sustainable use of West Coast Strandveld. The first step involves the analysis of the vegetation in order to describe it. This entails identifying the species present and assessing their relative abundances. Alternatively, the structure (i.e. the growth forms, layering, and arrangements) of the vegetation communities can be analyzed. Although this is an easy way around complexities and taxonomy, the structure of vegetation also tends to reflect limiting factors in the environment, irrespective of the plant species involved. My aim in this chapter was to concentrate on growth forms and other functional groupings in order to determine if species diversity, as identified in Chapters 2 and 3, differs between the different functional groupings.

The Raunkiaer's life form classification system was the first attempt at a general description of vegetation based on structural characters. It was devised in 1905 and has been extensively modified over the decades. It is now more or less obsolete but many of the terms coined for the system have remained current. The Raunkiaer's life form system emphasizes the mechanisms plants employ to survive unfavourable seasonal conditions, particularly the position of perennating buds with respect to the ground surface (Raunkiaer, 1937).

Fence-line contrasts, which are usually indicative of different grazing treatments, can be viewed as natural experiments (Todd & Hoffman, 1999) that provide a unique opportunity for testing the long-term consequences of heavy grazing. Little research has been carried out in Strandveld, which has been differentiated into South Coast and West Coast forms (Moll *et al.*, 1984). It is the latter which is the focus of this chapter, the aim of which is to determine the impact of different land uses on the phytodiversity in different functional groupings. This study uses a fence-line contrast between 34 years of conservation management, conservation for 11 years, natural veld grazed by sheep, natural veld grazed by a combination of cattle and goats and natural veld ploughed into strips and grazed by sheep to assess the effect of different land uses on the phytodiversity of identified functional groupings.

4.2. Materials and methods

4.2.1. Study site

Field experiments were conducted at Rocherpan Nature Reserve (18° 18' E 32° 36' S) 24 km north of the town Velddrif, South Africa, during September 2001. The site lies in the winter rainfall region of South Africa at an elevation 0 to 8 meter above sea level. The mean rainfall for the five year period from 1997 to 2001 is 236.78 mm. The year 2001 was a very wet year with a total of 160.22 mm more than the mean rainfall of 236.78 mm for the five years.

Scattered, low shrubs and small trees such as *Salvia lanceolata* and *Nylandtia spinosa* dominate West Coast Strandveld, with succulent shrubs such as *Zygophyllum morgsana, Euphorbia mauritanica* and *Euphorbia burmannii* as common species. Geophytes, annuals and species of the Cape Reed Family (Restionaceae) become more dominant where this vegetation type is associated with Sand Plain Fynbos (Low & Rebelo, 1996).

Data were collected in and around Rocherpan Nature Reserve as close as possible to the fence line to minimize the possible effect of topography and soil differences on plant diversity.

4.2.2. Different land uses

Grazed by a combination of cattle and goats.

This treatment consisted of a section of a farm called Bokkeram (not part of the Reserve) that was used for grazing by both cattle and goats since 1988. Although the total carrying capacity for the West Coast Strandveld is 25 ha per large stock unit, the study was conducted on a 440 ha field with a total of 20 cattle and 50 goats and a recommended carrying capacity of 20 (cattle) and 8.33 (goats) resulting in a total of 28.33 large stock units. Here, six goats are equal to one large stock unit. The current stocking rate of 15.5 ha/LSU for the area has resulted in overstocking by 11.75 %.

Thirty four years of conservation management.

Efforts to formally conserve the seasonal wetland, now known as Rocherpan, were initiated in 1965 and it was expropriated on 14 July 1967. The main activity on this land has been cattle farming. However no grazing has occurred in this part of the nature reserve since 1967.

Eleven years of conservation management (north and south).

The remainder of the farm, approximately 520 ha, was expropriated on 23 March 1990. The agriculutal activity on this land was cattle and house-raising before the establishment of the Nature Reserve, so no grazing has occurred in this part of the nature reserve since 1990.

Natural veld grazed by sheep.

A section of the farm called Modderfontein (not part of the reserve) was used for sheep grazing since 1985. The recommended carrying capacity for the West Coast Strandveld is 25 ha per large stock unit. The study was conducted on a 200 ha camp with a total of 200 sheep and a stocking rate of 33.3 large stock units. Six sheep are equal to one large stock unit. The recommended carrying capacity for the area, according to the South African Department of Agriculture, is 8 large stock units for the 200 hectares.

Strip-ploughed and natural veld grazed by sheep.

A section of the same vegetation type on the farm St Helenafontein (not part of the Reserve) was ploughed into strips and planted with pasture to increase the carrying capacity of the veld in 1985. Forty meter strips were ploughed while maintaining forty meters natural vegetation to prevent wind erosion. The plots selected for data collection were laid out in the natural veld strips, as far away as possible from the edge of the natural veld in order to minimize the effect of imported planted pastures on plant diversity. The veld was used for sheep grazing. The total carrying capacity for the West Coast Strandveld is 25 ha per large stock unit. The study was conducted on a 200 ha camp with a total of 200 sheep and a stocking rate of 33.3 large stock units. In this case six sheep were equal to one large stock unit. The carrying capacity for the area, according to the South African Department of Agriculture, is 8 large stock units for the 200 hectares.

4.2.3. Sampling procedures

4.2.3.1. Plot Layout

Three replicate samples were collected randomly from 20 m x 50 m area per land use so that they were representative of the different topographic units of the landscape. In each instance, the sample was situated well within a homogenous stand. A modified 20 m x 50 m Whittaker plot design with long-thin plot was used. The modified Whittaker plot design minimizes the problems in the original design by using consistent rectangle proportions in the subplots to remove the plot size-shape interactions (Stohlgren *et al.*, 1995). Like the original Whittaker plot design, the modified Whittaker plot is 20 m x 50 m. However, the 0.20 m x 0.50 m, 1 m x 1 m, 2 m x 5 m and 10 m x 10 m subplots were arranged systematically inside the perimeter of the 20 m x 50 m plot (See Appendix B). Likewise the 10 m x 10 m subplots were centred in the plot.

The 20 m x 50 m plot was laid out starting from the centre of the plot. The centre point was marked with a pole and the GPS reading recorded. The plot was orientated with the 50 m border in an east/west and the 20 m border in a north/south direction. The plot was laid out and marked using a rope starting 25 m from the marked centre to both sides in an east/west direction and 20 m to the north. Ten 0.20 m x 0.50 m, ten 1 m x 1 m, two 2 m x 5 m and two 10 m x 10 m subplots were laid out in the 20 m x 50 m plot (See Appendix B).

4.2.3.2. Data collection

The subplots and 20 m x 50 m plot were scanned for species starting from the 0.20 m x 0.50 m, 1 m x 1 m, 2 m x 5 m, 10 m x 10 m and finally the 20 m x 50 m plot. All species present in these plots were recorded and marked with a star on the design vegetation data sheets (Appendix C). All subplots were handled separately. If a species was recorded in a subplot which was laid out inside another subplot the species was recorded as present for all the subplots. For instance, if species one was recorded in subplot 1, which was laid out in subplot 10 and in turn was laid out in the 20 m x 50 m plot, then that species was recorded as present in the three different subplots. Species that did not root in the subplot but spread their branches/leaves over the line were noted separately and marked by a plus sign. For instance, if a species was not rooted in the plot 0.20 m x 0.50 m (subplot 1), but the branches/leaves hung over the line and the species rooted in subplot 10, then the species was recorded by a plus sign in subplot 1 and marked with a star as present in the subplot 10 and inside 20 m x 50 m plot.

With each species noted, details were taken with regards to annual versus perennial species, annual leaf-shedding, annual stem shedding, woodiness, Raunkiaer's life forms (i.e. Phanerophytes, Chamaephytes, Hemicryptophytes, Cryptophytes or Therophytes), growth forms (erect, spreading, climber, prostrate, rosette or tussock), succulence (leaf, stem or leaf and stem succulent) and spinescence. Leafy succulent shrubs were separated from woody shrubs as they tend to be comparatively short-lived relative to woody shrubs, and may thus be more sensitive to overgrazing (Cowling *et al.*, 1994).

The vegetation information consisted of a full list of species found on the plot, which was collected following the standard Braun-Blanquet procedure in subplot 23, which measured 10 m x 10 m (Mueller-Dombois & Ellenberg, 1974). Plants that could not be identified in the veld were collected for later identification in the herbarium. A standard collection form accompanied each specimen. Two photographs were taken at each 20 m x 50 m plot and 10 m x 10 m subplot to document the landscape as well as the structure of the vegetation. The monitoring included the identification of all plant species in the plot, as well as the recording of all species present in the plot. Species that did not root in the plot but spread their branches/leaves over it were noted separately.

4.2.3.3. Information gathered at each sampling site

A special set of field data sheets was designed for this purpose (See Appendix C). A GPS reading was taken at the centre of the southern 50 m border. The GPS was set to the WGS 84 map datum. Additional location information included the Region, District, farm or name of area, and a short description of the locality. Habitat information included the slope, the terrain type, aspect, stone cover estimation, lithology (parent material), erosion severity, surface sealing/crusting and disturbances.

4.2.4. Database

The database contained information on the list of species known to occur in southern Africa, as prepared and updated by the National Botanical Institute in Pretoria, RSA (Arnold & de Wet, 1993).

4.2.5. Species diversity indices

With the data collected from this study, species richness, equitability, or both, were compared across the three grazing and three conservation treatments. The method used for expressing diversity was the Shannon-Wiener diversity index (Shannon & Wiener, 1963). The Shannon-Wiener diversity index is based on the proportional abundance of species, taking into account both equitability and richness. The index value usually falls between 1.5 and 3.5.

The Shannon-Wiener formula is expressed as:

$H' = -\sum pi \log pi$ (Shannon & Wiener, 1963).

where pi is the proportion of the total abundance arising from the ith species.

This method took into account species richness (number of species per land use) and species abundance (number recordings per species per land use) in the 20 m x 50 m plot 1000 m^2.

4.2.6. Raunkiaer's life forms

Phanerophytes

Here, the surviving buds or shoots are born on branches, which project into the air. There are evergreens without bud covering, evergreens with bud covering and deciduous with bud covering of less than 2 m high (Raunkiaer, 1937).

Chamaephytes

The surviving buds or shoot apices are born on shoots very close to the ground. There are suffruticose chamaephytes (i.e. those bearing erect shoots, which die back to the portion that bears the surviving buds), passive chamaephytes with persistent weak shoots that trail on or near the ground, active chamaephytes that trail on or near the ground because they are persistent and have horizontally growth and cushion plants (Raunkiaer, 1937).

Hemicryptophytes

According to Raunkiaer (1937), the surviving buds or shoot apices of hemicryptophytes are situated in the soil surface while protohemicryptophytes have aerial shoots that bear normal foliage leaves, but the lower ones of these are less perfectly developed. They could also be partial rosette plants bearing most of their leaves (and the largest) on short internodes near ground level or rosette plants bearing all their foliage leaves in a basal rosette (Raunkiaer, 1937).

Cryptophytes

Here, the surviving buds or shoots apices are buried in the ground (or under water). These include geocryptophytes or geophytes, which consists of forms such as rhizomes, or bulbs, stem tubers, root tubers and marsh plants (helophytes) as well as aquatic plants hydrophytes (Raunkiaer, 1937).

Therophytes

These are plants that complete their life cycle from seed and die within a season. This group also includes species that germinate in autumn and flower and die in the spring of the following year (Raunkiaer, 1937).

4.3. Statistical analysis.

The data obtained was analyzed using Species Diversity and Richness - PISCES Conservation Ltd (version 2.65) and Microsoft Excel. The mean was used as the measure of central tendency with standard deviation as the measure of variability. Parametric one-way analysis of variance (ANOVA), was used to test for statistically significant differences between the means of measured vegetation parameters across the five land uses.

4.4. Results

The number of annual species found within the 1000 m^2 plots were affected by land use regime. As shown in Fig 4.1.A, the number of annuals were significantly greater in land use regimes that were grazed by cattle and goats, by sheep or strip-ploughed and grazed by sheep. All the conservation regimes were markedly lower in their population of annual plant species (Fig. 4.1.A).

The number of herbaceous plants and tussock plants were similar in pattern to the annuals, in that all the grazing regimes produced significantly more numbers of herbs and tussocks compared to the conservation management regimes (Fig. 4.1.B and C). The number of deciduous plants as well as the number of prostrate plants and annual stem shedding plants, as assessed by the Shannon-Weiner index, was greater in the grazed by cattle and goats regime relative to the other land use systems (Fig. 4.2.A,B and C). The number of stem shedding annual plants in strip-ploughed and grazed by sheep regimes was however not significantly different from that of the grazed by cattle and goats (Fig.4.2.C).

However the number of non-deciduous plants was significantly higher with conservation for 34 years and 11 years north when compared to the grazing regimes (Fig. 4.3.B). With the Phanaerophytes, the number of plants in the conservation regimes (i.e. 34 years and 11 years south) and plots grazed by sheep were significantly greater than the other land use treatments (Fig.4.3.C). But the number of spinescent plants were significantly increased in the strip-ploughed and grazed by sheep land use regime (Fig. 4.3.D).

As shown in Fig. 4.A,B much fewer woody and climbing species were found in the conservation for 11 years (north) and the strip-ploughed and grazed by sheep regimes when compared to the other land use systems. With the Chamaephytes, only conservation management for 11 years north showed a reduced number of these plant species (Fig.4.4.C).

4.5. Discussion

The consequences of livestock grazing in semi-arid areas are diverse (Todd & Hoffman, 1999). Light grazing is reported to increase species richness as a result of reduced competition (Naveh & Whittaker, 1979; Waser & Price, 1981; Noy-Meir *et al.*, 1989). The findings of this study and the data in Chapter 3 agree with the results of these earlier studies (Naveh & Whittaker, 1979; Waser & Price, 1981; Noy-Meir *et al.*, 1989). All the land use regimes involving grazing showed greater species diversity with higher numbers of species found under the grazing systems (that is, grazed by cattle and goats, grazed by sheep, and the strip-ploughed and grazed by sheep). The only difference between this study and those by Naveh & Whittaker (1979); Waser & Price (1981) and Noy-Meir *et al.* (1989) rested on the fact that there was overgrazing based on the estimates on the carrying capacity by the South African Department of Agriculture for West Coast Strandveld. However results of Todd and Hoffman (1999) in Namaqualand, South Africa, showed an increase in vegetation cover by annual and geophytes in response to grazing despite maintaining a stocking rate approximately twice that of the local commercial farmers. That study however did not indicate whether the veld was overgrazed as assessed by the South African Department of Agriculture as in this study.

Selective grazing of palatable species can also result in a shift to assemblages dominated by toxic and spinescent woody plants (Westoby *et al.*, 1989; Milton & Hoffman, 1994). Where non-palatable or spinescent plants are absent, a frequently observed change associated with increasing grazing pressure is a shift from perennial to annual vegetation (Naveh & Whittaker, 1979; Milton *et al.*, 1994). The results found under strip-ploughed natural veld grazed by sheep land in this study showed a significantly higher number of spinescent plants. These numbers were higher as a result of *Emex australis,* a pioneer species dominant on these land uses but not palatable to livestock. The assumption that species use the spinescent mechanism to protect themselves from grazing pressure cannot be proven in absolute terms based on the data obtained from this study in West Coast Strandveld. There was not enough palatable and woody spinescent species within the study site and therefore the results showed no pattern when compared with the findings by Westoby *et al* (1989) and, Milton and Hoffman (1994). However, the data compared favourably with the report by

Naveh & Whittaker (1979) and Milton *et al* (1994) which showed that in the absence of enough palatable and woody spinescent species, an increase in grazing pressure would most likely result in a shift from perennial to annual species. The findings of this study are however consistent with those of other studies in arid and semi-arid Mediterranean regions which showed that heavy grazing resulted in a shift from perennial to annual vegetation (Naveh & Whittaker 1979; Olsvig-Whittaker *et al,*. 1993).

Heavy grazing is known to result in the loss of palatable plants, which indirectly selects for weedy, generalist species (West, 1993). Under grazing land use systems the therophytes, annuals, tussocks and herbaceous plants were significantly higher in numbers relative to conservation. These results agree with the report by West (1993) who showed that heavy grazing selected for weedy plants.

According to Liengme (1987), as the utilization of West Coast Strandveld increases, the number of geophytes would also increase. Similar results in a study in the Namaqualand of South Africa by Todd and Hoffman (1999) also showed increase in annuals and geophytes in response to grazing on the communal rangeland, despite maintaining a stocking rate approximately twice that of the local commercial farmers. Although the strip-ploughed veld grazed by sheep revealed the highest species numbers and species abundance, the geophyte species exhibited no significant differences under the different land use regimes, suggesting that the geophytes probably had the same species diversity throughout all the land use system. This finding does not compares with the results of Liengme (1987) who showed that an increase in the utilization of West Coast Strandveld, increased the number of geophytes. Similar data on the increase in the number of geophytes with land use were obtained in a study by Noy-Meir *et al.* (1989).

This study assumed at the onset that deciduous and stems-shedding species would be more susceptible to grazing, leading to grazing pressure on them and dominance by non-deciduous species and species not shedding their stems on an annual basis with grazing. However, the results obtained here do not support this hypothesis. In fact, more recordings of deciduous species, stem-shedding and semi-stem shedding species were found on the grazing land use regimes than the conservation land use systems.

Succulent leafy shrubs are reported to be generally separated from woody shrubs because they tend to be more short-lived relative to woody shrubs, and may also be more sensitive to overgrazing (Cowling *et al.*, 1994). According to Liengme (1987), however, the succulents tend to increase in numbers in the West Coast Strandveld under overgrazing conditions. But the results of this study showed no significant differences under the different land use regimes, and do not therefore agree with Liengme's (1987) data. However, the findings of a study by Todd and Hoffman (1999) in Namaqualand, South Africa, showed more leafy succulent species unique to the commercial rangelands, compared to the communal rangelands, suggesting that they may have become locally extinct on the latter, which maintained a stocking rate approximately twice that of the former.

The results of another study by Noy-Meir *et al.* (1989) in a Mediterranean grassland showed that plants with a prostrate growth form were mostly grazing-increaser species and increased in abundance in response to very heavy grazing intensity. That finding is consistent with the results of this study which showed significantly increased number and abundance of prostrate plants species with grazing by cattle and goats. In fact, high species numbers were also found under the other two grazing land use regimes, namely, grazed by sheep, and strip-ploughed grazed by sheep in comparison with the conservation land use regimes. In conclusion, the biodiversity of various functional groups were affected by the different land use regimes.

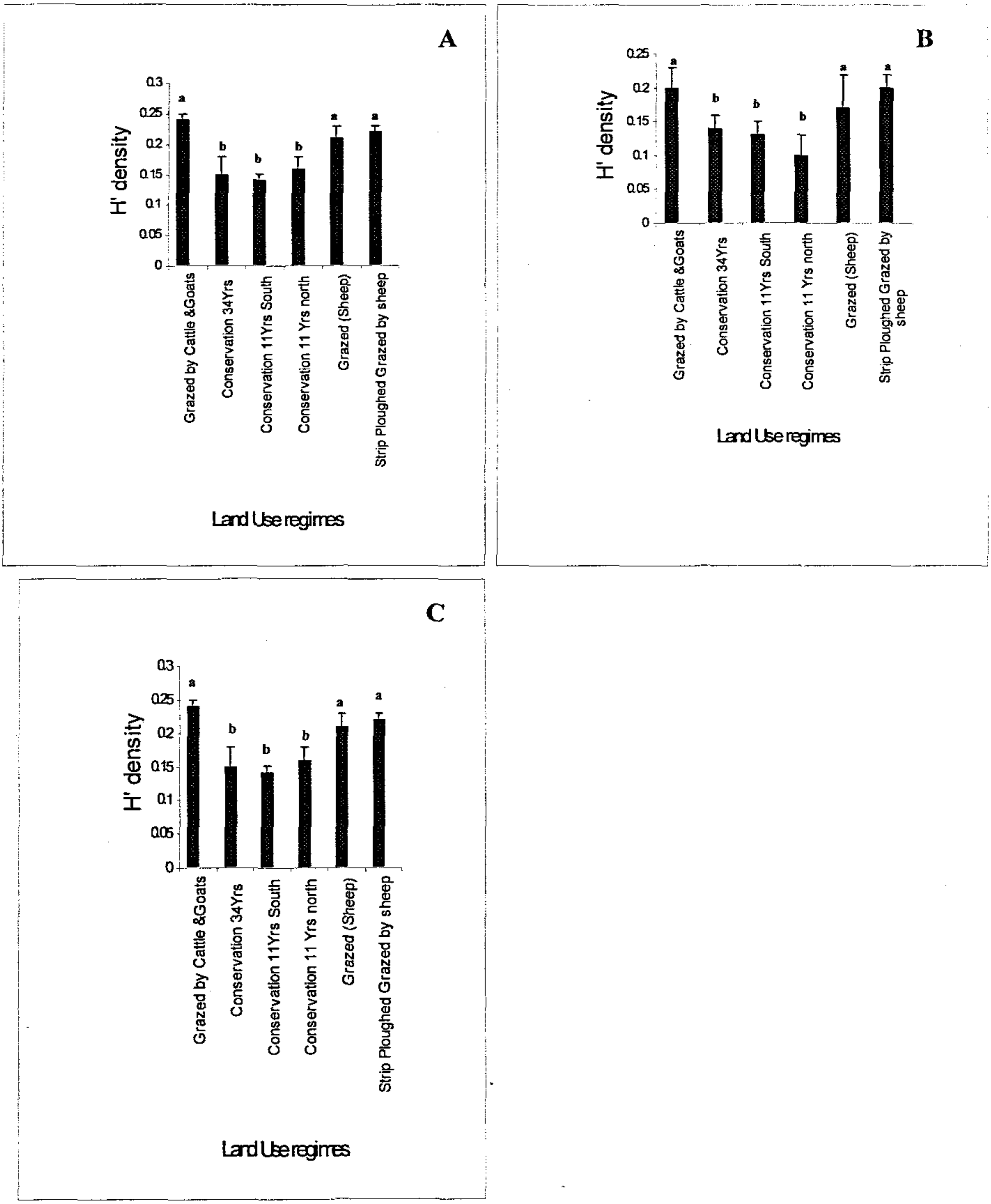


Fig. 4.1. Shannon-Weiner H' density values recorded in different land use regimes under A) annual plants, B) tussock plants and C) herbaceous plants.

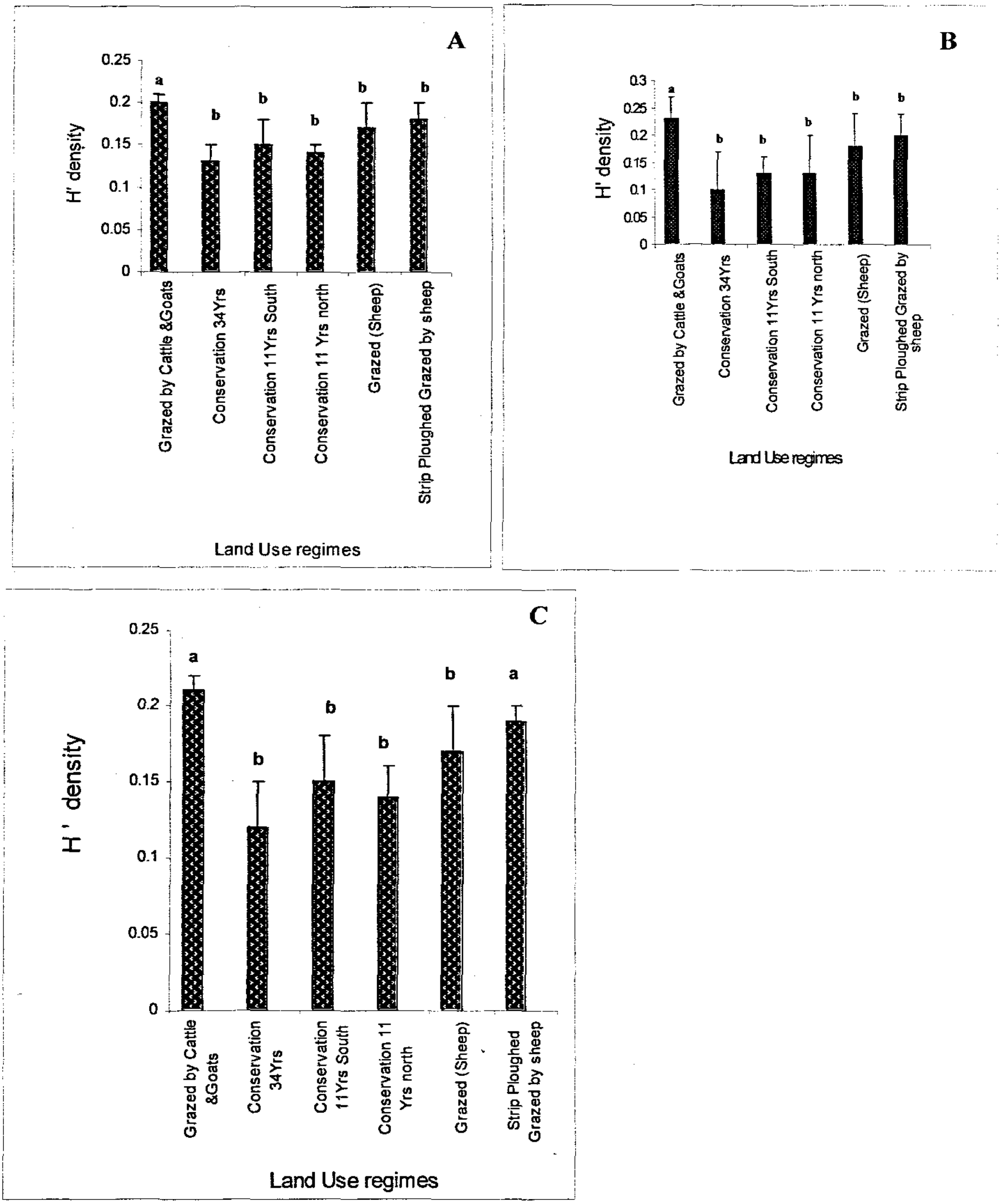


Fig. 4.2. Shannon-Weiner H' density values recorded in different land use regimes under A) deciduous plants, B) prostrate plants and C) annual stem-shedding plants.

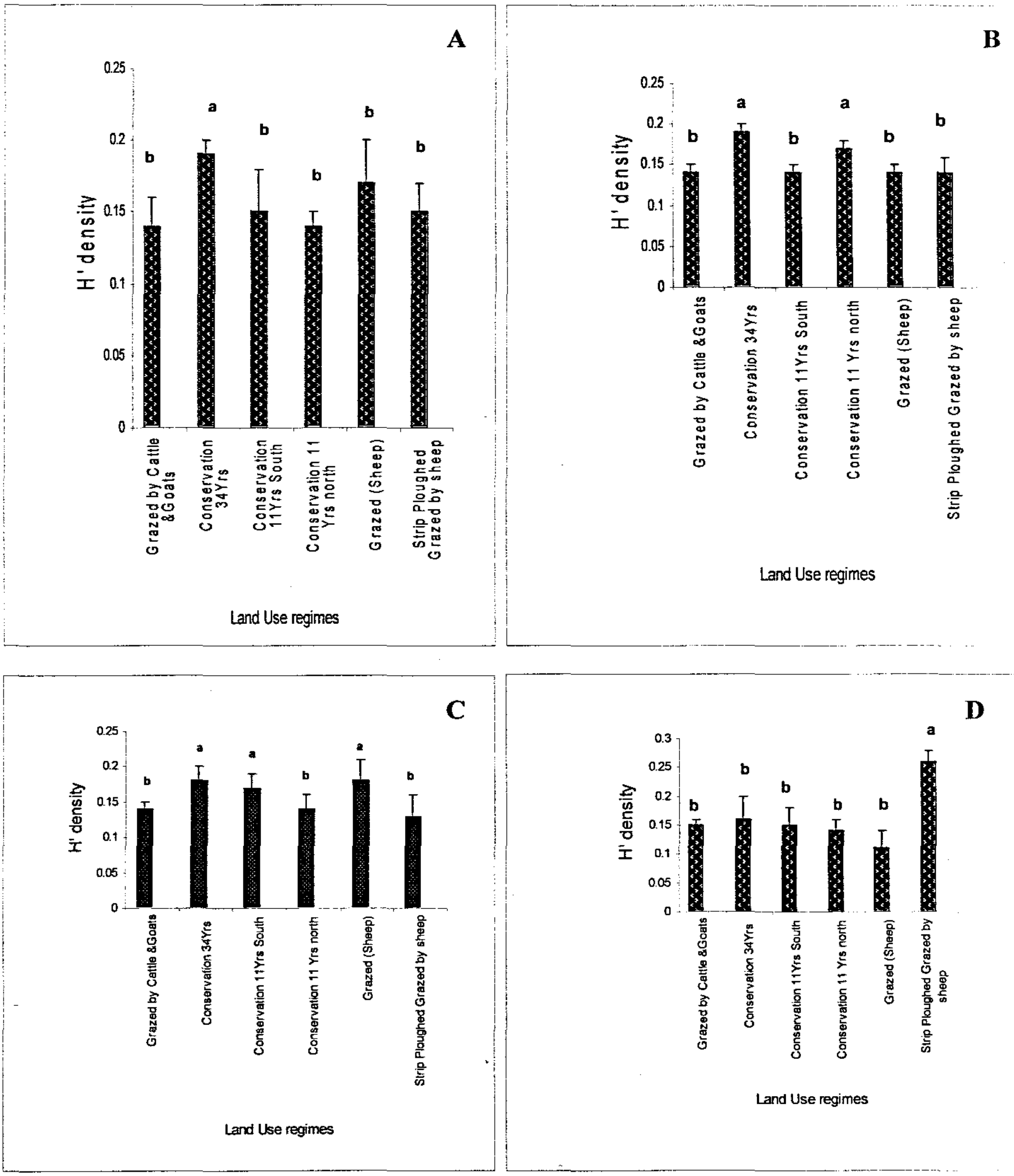


Fig. 4.3. Shannon-Weiner H' density values recorded in different land use regimes under A) non deciduous plants, B) plants not shedding their stems annually, C) Phanerophytes plants and D) spinescent plants.

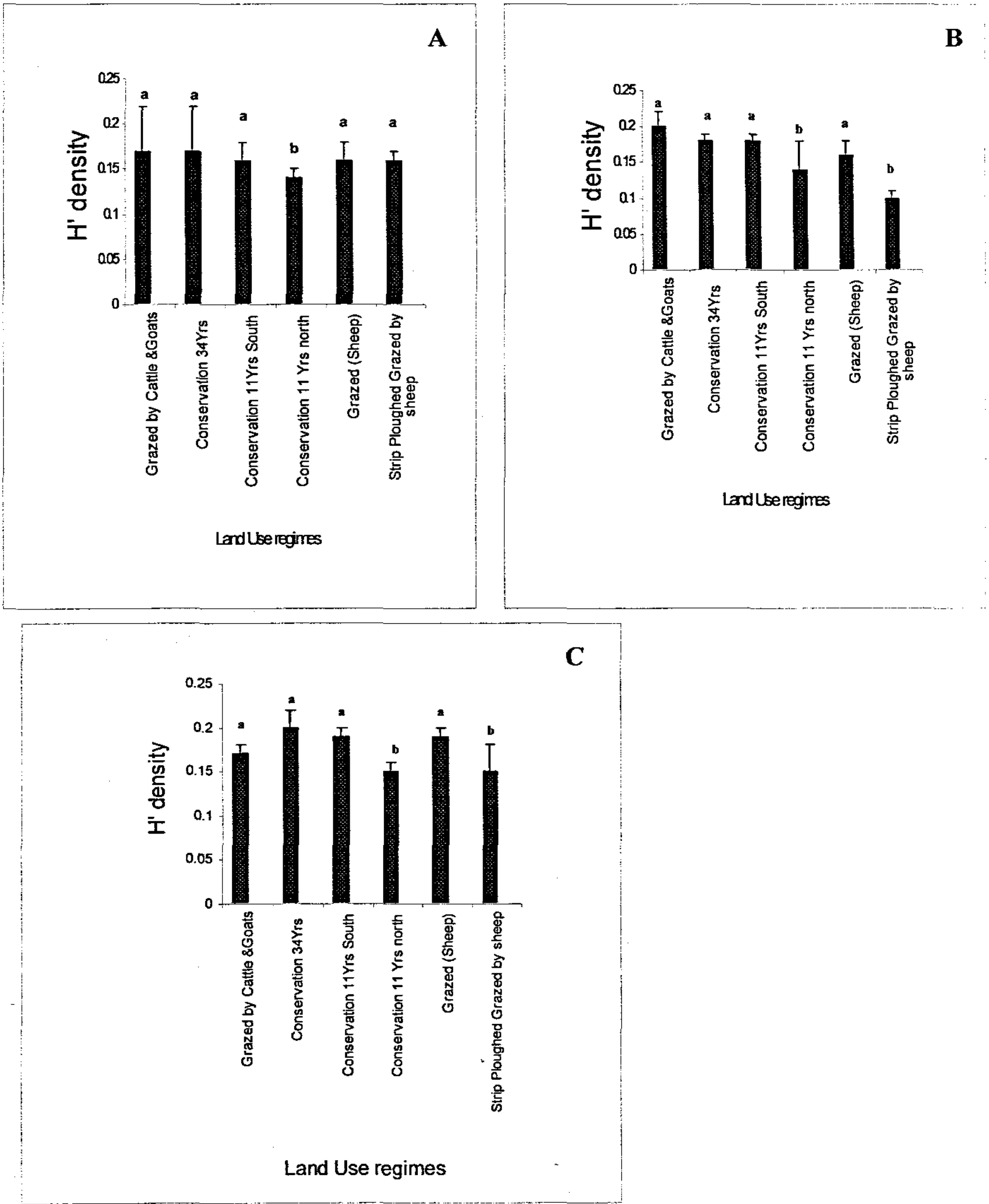


Fig. 4.4. Numbers found in the different land use regimes Shannon-Weiner H' density values recorded in different land use regimes under A) Chamaephytes plants, B) climber plants and C) woody plants.

CHAPTER 5

Effect of land use regimes on mineral nutrient concentrations in soils of the Rocherpan Nature Reserve

5.1. Introduction

In general, soil properties can influence the type of vegetation cover that develops in a given locality. Conversely, plant species also affect the chemical properties of soil (Brady, 1990). For example, legumes with ability to fix N_2 tend to improve soil N status, which can lead to the development of nitrophilous species. Root exudates from N_2-fixing legumes are also known to alter rhizosphere chemistry (Dakora & Phillip, 2002) and affect soil microflora and microfauna. Plants and soil therefore interact directly and indirectly via a soil-plant continuum. In the absence of plant roots and plant organic matter, which influence soil characteristics, the chemical features of a soil are derived from the parent material during soil formation (Brady, 1990). In natural ecosystems, the chemical properties of a soil are therefore derived from the inhabiting plant population and the parent rock material, while in agricultural systems the provision of chemical fertilizer also contributes to soil properties. The West Coast Strandveld around Langebaan has been studied before and the soil properly characterized for A and B horizons by Boucher and Jarman (1977). However to understand the effects of the land use regimes on soil properties of the West Coast Strandveld, and *vice versa,* would require data from bulk soil and from under plant stands of that environment. The aim of this study was to assess the effect of five land use regimes on soil chemical properties in the West Coast Strandveld.

5.2. Materials and Methods

5.2.1. Study site

Field experiments were conducted at Rocherpan Nature Reserve (18° 18' E 32° 36' S) 24 km north of the town Velddrif, South Africa, during

September 2001. The site lies in the winter rainfall region of South Africa at an elevation 0 to 8 meter above sea level. The mean rainfall for the five year period from 1997 to 2001 is 236.78 mm. The year 2001 was a very wet year with a total of 160.22 mm more than the mean rainfall of 236.78 mm for the five years

Acocks (1975) described the Strandveld as containing a veld type vegetation containing two variations: a dense, dwarf, semi-succulent scrub, and the Strandveld proper, which is an open semi-succulent scrub of fynbos and an intermediate between the Coastal Fynbos and the Succulent Karoo. He also mentioned bush clumps on the hillocks or "heuweltjies". Acocks (1975) describe a dense Standveld scrub at Yzerfontein, 30 km south of Langebaan town, as being about 1 m high and very dense, a lilliputian forest, and the Strandveld proper as being rather clumpy ... with species of the dense scrub in the bush clumps and a variety of smaller bushes, annuals and grasses in the spaces between the larger shrubs.

Data were collected in and around Rocherpan Nature Reserve as close as possible to the fence line to minimize the possible effect of topography and soil differences on plant diversity.

5.2.2. Soil sampling and analysis

5.2.2.1. Collection and preparation of bulk soil

Soil samples were collected with auger (0-50 cm depth) within each land use replicate plot under the bush clumps, in-between bush clumps, and in open spaces where no vegetation was growing, and mixed for determination of the initial nutrient concentrations in the soil. The soil samples were air-dried in the laboratory, and sieved (2 mm) for analysis of nutrients and determination of pH. The same procedure was followed during both winter and summer sampling.

5.2.2.2. Measurement of soil pH

The pH of the soil was measured in 0.01 M $CaCl_2$ solution using a 1:2.5 soil-to-solution ratio.

5.2.2.3. Determination of plant-available macro and micro nutrients in soil

The determination of S in soil was done by adding 20 g of soil in 0.01M $Ca(H_2PO_4)_2.H_2O$ extracting solution (Anon, 1974), followed by filtering, and S determined by direct aspiration on a calibrated simultaneous inductively coupled plasma (ICP) spectrophotometer (IRIS/AP HR DUO Thermo Electron Corporation, Franklin, Massachusettes, USA).

The extractable P, K, Na, Ca and Mg were determined by citric acid method as developed by Dyer (1894) and modified by the Division of Chemical Services (Anon, 1956) and Du Plessis and Burger (1964). A 20 g air-dried soil sample was extracted in 200 ml of 1% citric acid, heated to 80 ^{0}C, shaken for 2 min at 10 min intervals over a total period of 1 hour and filtered. A 50 ml aliquot was heated to dryness on a water bath, digested with 5 mL of concentrated HCl and HNO_3, evaporated to dryness on a water bath, and 5 mL of concentrated HNO_3 and 20 ml of de-ionised water added. The mixture was heated to dissolve the dry residue, and the sample filtered. Measurements of P, K, Na, Ca and Mg were then done directly by direct aspiration on a calibrated simultaneous ICP spectrophotometer (IRIS/AP HR DUO Thermo Electron Corporation, Franklin, Massachusettes, USA).

The micronutrients Cu, Zn, Mn, Fe, and Al were extracted from soil using di-ammonium ethylenediaminetetraacetic (EDTA) acid solution [Trierweiler and Lindsay, (1969), as modified by Beyers and Coetzer, (1971)]. The extractants were analyzed for Cu, Zn, Mn, Fe, and Al using a calibrated simultaneous ICP spectrophotometer (IRIS/AP HR DUO Thermo Electron Corporation, Franklin, Massachusettes, USA). Boron in the soil was determined following the method of Anon (1974) and values measured using ICP spectrophotometer.

5.3. Soils Statistical analysis.

A 2-factorial design (2-way ANOVA) was used to statistically analyze soil pH and nutrient concentrations in the soils. However, a one-way ANOVA was used to compare nutrient concentrations. The analysis was done using the software of STATISTICA program 1997. Fisher's least significant difference was used to compare treatment means at $P \leq 0.05$, $P \leq 0.01$ or $P \leq 0.001$ depending on the level of significance (Steel and Torrie, 1980). Correlation coefficients and the Student's t-test were used to test the statistical relationship between pH and nutrient concentration in the soil.

5.4. Results

Effect of land use regimes on soil nutrient concentrations.

Of the land use regimes, the strip-ploughed and grazed by sheep was by far more significantly different in soil chemical properties, followed by the conservation 11 years north (Table 5.1). Soil pH was significantly lower in the strip-ploughed and grazed by sheep land use regime relative to the other land use systems. The concentrations of K, S, Na, Cu and Fe in soil collected from strip-ploughed and grazed by sheep were significantly much greater than those of other land use regimes. The conservation 11 years north also showed relatively higher concentrations of C, P, Mg and Ca in soil sampled from that land use regime (Table 5.1). The conservation 11 years south had the lowest organic C level compared to conservation 11 years north or the other land use regimes (Table 5.1).

Sampling soils from open spaces, (bulk soil), from in-between plants, and from under plant stands or bush clumps provided data that permitted plant effects on changes in soil nutrient concentrations to be observed. As shown in Table 5.2, the pH of soils from under bush clumps was significantly higher compared to bulk soil from open spaces (without plants) and soil from in-between plants. The concentrations of organic C, P, K, Mg, Ca, Na, Cu, Mn, and B were all significantly higher under bush clumps compared to bulk soil from open spaces or soil from in-between plants (Table 5.2). There was however no significant difference between the nutrient concentrations of bulk soil and soil from in-between plants (Table 5.2).

The soil samples collected during winter and summer permitted assessment of seasonal changes and differences in soil nutrient concentrations. As shown in Table 5.3, the soil concentration of P, K, Mg, Ca, S, Zn, and Fe were all significantly higher in the wetter winter compared to the drier summer. Only Cu showed an increased concentration in soil sampled during the summer.

The interaction between land use regimes and sampling time (season) were significant for Mg, Ca, Mn and Fe. As shown in Fig 5.1.A,B,C and D, except for the grazing by sheep land use regime, which showed lower concentrations of Mg, Ca, Mn, and Fe in winter, analysis of soil from all the other land use systems revealed significantly greater concentrations of Mg, Ca, Mn and Fe in winter than in summer. The interactive affects of land use regime, sampling time and sampling site (i.e. open, in-between and under bush clumps) within a land use regime were also significant for K and Mg. As shown in Fig 5.2.A and B, the concentration of Mg and K in soils collected from under the bush clumps were consistently greater than those from in-between plants or open spaces for all land use regimes, except for strip-ploughed and grazed by sheep land use system. The concentrations of Mg or K in bulk soil and from in-between plants were also not significantly different for all land use systems, except for the strip-ploughed and grazed by sheep regime (Fig 5.2.A and B). The soil concentration of nutrients was generally greater during winter than summer.

5.5. Discussion

Analysis of soils collected from different land use systems revealed significant changes in extractable nutrient concentrations. The concentrations of K, S, Na, Cu, and Fe were significantly greater in the strip-ploughed and grazed by sheep land use regime, while C, P, Mg and Ca showed significantly increased levels in the conservation management 11 years north. The high concentrations of mineral nutrients in soil could either suggest lower uptake by plants or increased release from organic matter (Marschner, 1995). In this regard, the conservation management 11 years north showed the lowest species diversity, the lowest numbers of individual species counted, and the lowest numbers of perennials and annuals (see Chapter 3), suggesting that the greater concentrations of minerals in that land use regime probably reflected low uptake by plant roots in comparison to the land use systems where species diversity and numbers of individuals were higher. Among the grazing regimes, the strip-ploughed and grazed by sheep treatment showed the lowest species diversity and low numbers of perennials. Such lower plant numbers would imply lower rates of nutrient uptake by roots compared to where plant density is higher per unit area. Additionally, the strip-ploughed treatment would have also initially led to organic release of mineral nutrients, which would accumulate in soil if only taken up by a relatively small plant population. Put together, the greater levels of K, S, Na, Cu, and Fe in soil from the strip-ploughed and grazed by sheep regime as well as the higher concentrations of C, P, Mg, and Ca in conservation management 11 years north were more likely due to lower uptake as a result of smaller plant diversity and frequency of occurrence relative to the other land use regimes where phytodiversity was higher and frequent in occurrence.

Analyses of soils collected from different sites within a land use system (i.e. open space, in-between plants, and under bush clumps) revealed a gradient in extractable plant-available nutrient concentrations, with levels increasing from open spaces to under bush clumps. The higher nutrient levels in soil from under bush clumps should be expected as organic matter accumulate from above- and below-ground parts would most likely contribute to nutrient turnover under the plant canopy and around the rhizosphere. That way the decomposition of soil organic matter would increase the concentration of various nutrients such as P, K, Mg, Ca, Na, Cu, Mn, and B as shown in this study (Table 5.2). That organic matter transformation in soil from under bush clumps was probably the cause of the increased concentrations of minerals in the sampling sites is supported by the data in Table 5.2, where organic C concentrations was about 1.5-fold greater in soil from under bush clumps compared to open spaces or in-between plants.

In addition to soil organic matter altering nutrient levels under bush clumps, soil pH was also modified. As shown in Table 5.2, the pH of soil from under bush clumps was significantly higher relative to open spaces or in-between plants. The higher pH would, no doubt, promote organic matter transformation and mineralization, leading to increased nutrient release and accumulation in soil. Conversely, the lowering of soil pH caused by the strip-ploughed and grazed by sheep regime could result in increased concentrations of trace elements such as Cu and Fe (Table 5.1), which tend to accumulate in soil under low pH conditions (Brady, 1990).

Sampling soils during winter and summer revealed seasonal changes in soil nutrient concentrations. Because the Western Cape has a Mediterranean type climate, the winters are generally wetter while the summers are drier. As a result, plant growth and interaction with soil would be expected to be optimal in the winter when water is available for ecosystem functioning. Thus, plant root activity, whether relative to nutrient uptake or exudation, would be greater in winter. In fact, symbiotic legumes, such as *Lebeckia multiflora,* which is a common species in the conservation management 11 years north land use regime, nodulate and fix N_2 in the winter with water availability from rainfall. In conclusion, soil chemical properties including nutrient concentrations were altered under different land use regimes. But whether the differences in extractable soil nutrients observed in this study were due to the effect of the land use systems, or caused by the phytodiversity within the land use regimes, remains to be properly assessed.

Table 5.1. Effect of land use systems on plant-available nutrients concentrations in soil

	pH		C		P		K		Mg		Ca		S		Na		Cu		Fe	
Treatment	($CaCl_2$)										(mg.kg)									
Land Uses																				
Grazed by Cattle &Goats	**5.1**	**±0.1b**	**6450**	**±917ab**	**19.8**	**±1.8ab**	**46.6**	**±5.6b**	**72.0**	**±11.5ab**	**334.7**	**±50.3ab**	**1.5**	**±0.2b**	**21.2**	**±2.9b**	**0.28**	**0.01bc**	**33.20**	**1.68b**
Conservation Management for 34Yrs	**5.5**	**±0.1a**	**4811**	**±781bc**	**13.5**	**±1.3c**	**36.3**	**±3.7b**	**73.0**	**±12.1ab**	**389.5**	**±68.6ab**	**1.1**	**±0.2b**	**17.7**	**±1.1b**	**0.29**	**0.02bc**	**26.77**	**2.17b**
Conservation Management for 11Yrs South	**5.3**	**±0.1ab**	**3533**	**±290c**	**19.6**	**±1.5ab**	**41.2**	**±3.0b**	**50.0**	**±5.4b**	**267.2**	**±36.6b**	**0.9**	**±0.1b**	**18.5**	**±1.0b**	**0.27**	**0.01bc**	**22.24**	**1.45b**
Conservation Management for 11 Yrs north	**5.2**	**±0.1ab**	**7250**	**±1075a**	**21.0**	**±2.3a**	**47.6**	**±7.4b**	**85.2**	**±15.6a**	**467.7**	**±71.6a**	**1.5**	**±0.2b**	**19.8**	**±3.8b**	**0.25**	**0.01c**	**28.00**	**2.70b**
Grazed By Sheep	**5.2**	**±0.1ab**	**5539**	**±766abc**	**11.8**	**±0.9c**	**37.0**	**±3.4b**	**69.8**	**±11.5ab**	**346.8**	**±59.1ab**	**1.4**	**±0.2b**	**19.3**	**±2.9b**	**0.30**	**0.02b**	**21.53**	**1.68b**
Strip-ploughed Grazed by sheep	**4.8**	**±0.1c**	**3789**	**±485bc**	**15.1**	**±2.1bc**	**69.8**	**±12.3 a**	**80.6**	**±12.4ab**	**230.0**	**±64.9b**	**3.5**	**±1.4a**	**50.6**	**±20.5 a**	**0.34**	**0.02a**	**58.97**	**9.83a**
Statistics	**3.27***		**4.52****		**6.02*****		**6.26*****		**2.27***		**2.91***		**2.27***		**2.91***		**5.11*****		**13.52*****	

Table 5.2. Effect of site of soil sampling on nutrient concentrations in land use systems

	pH		C		P		K		Mg		Ca		Na		Cu		Mn		B	
Treatment	($CaCl_2$)										(mg.kg)									
Systems																				
Open	**5.0**	**±0.0b**	**4125**	**±455b**	**14.4**	**±1.0b**	**35.9**	**±4.0b**	**51.4**	**±5.4b**	**255.4**	**±34.1b**	**17.6**	**±2.2b**	**0.28**	**±0.01b**	**7.11**	**±0.96b**	**0.17**	**±0.02b**
In Between	**5.0**	**±0.0b**	**4422**	**±464b**	**15.2**	**±1.3b**	**36.5**	**±2.1b**	**49.2**	**±4.2b**	**242.5**	**±31.8b**	**16.9**	**±1.0b**	**0.27**	**±0.01b**	**6.42**	**±0.57b**	**0.20**	**±0.03b**
Bush Clump	**5.5**	**±0.1a**	**7138**	**±652a**	**20.7**	**±1.4a**	**66.8**	**±6.2a**	**114.7**	**±9.4a**	**520.0**	**±46.3a**	**39.0**	**±10.3 a**	**0.32**	**±0.01a**	**11.40**	**±1.31a**	**0.41**	**±0.04a**
Statistic	**8.89*****		**11.57*****		**9.67*****		**25.63*****		**42.50*****		**19.73*****		**5.16****		**6.03*****		**8.53*****		**17.75*****	

Table 5.3. Effect of sampling times (season) on nutrient concentrations in soil from land use systems

	pH		P		K		Mg		Ca		S		Cu		Zn		Fe	
Treatment	($CaCl_2$)									(mg.kg)								
Sampling Season																		
Winter	5.23	±0.09a	**19.52**	**±1.25a**	**53.63**	**±4.97a**	**82.53**	**±7.66a**	**389.53**	**±39.98a**	**2.34**	**±0.48a**	**0.26**	**±0.01b**	**0.65**	**±0.04a**	**36.74**	**±3.97a**
Summer	5.19	±0.07a	**14.13**	**±0.78b**	**39.26**	**±2.76b**	**61.04**	**±5.66b**	**289.17**	**±28.76b**	**1.05**	**±0.14b**	**0.32**	**±0.01a**	**0.45**	**±0.03b**	**26.83**	**±1.39b**
Statistic	0.15		**17.98*** **		**12.66*** **		**10.64** **		**6.07** *		**7.41** **		**22.74*** **		**17.90*** **		**10.18** **	

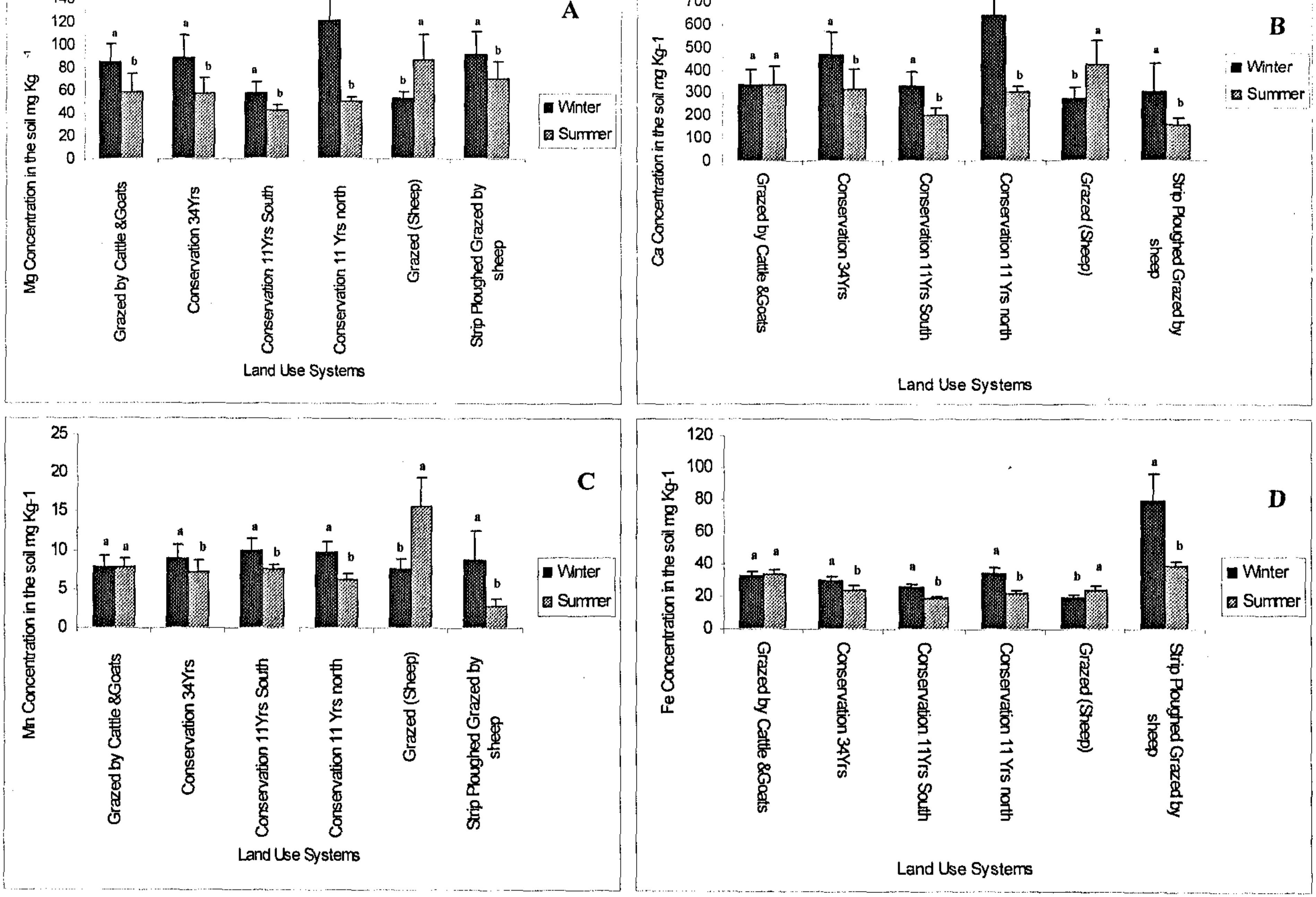
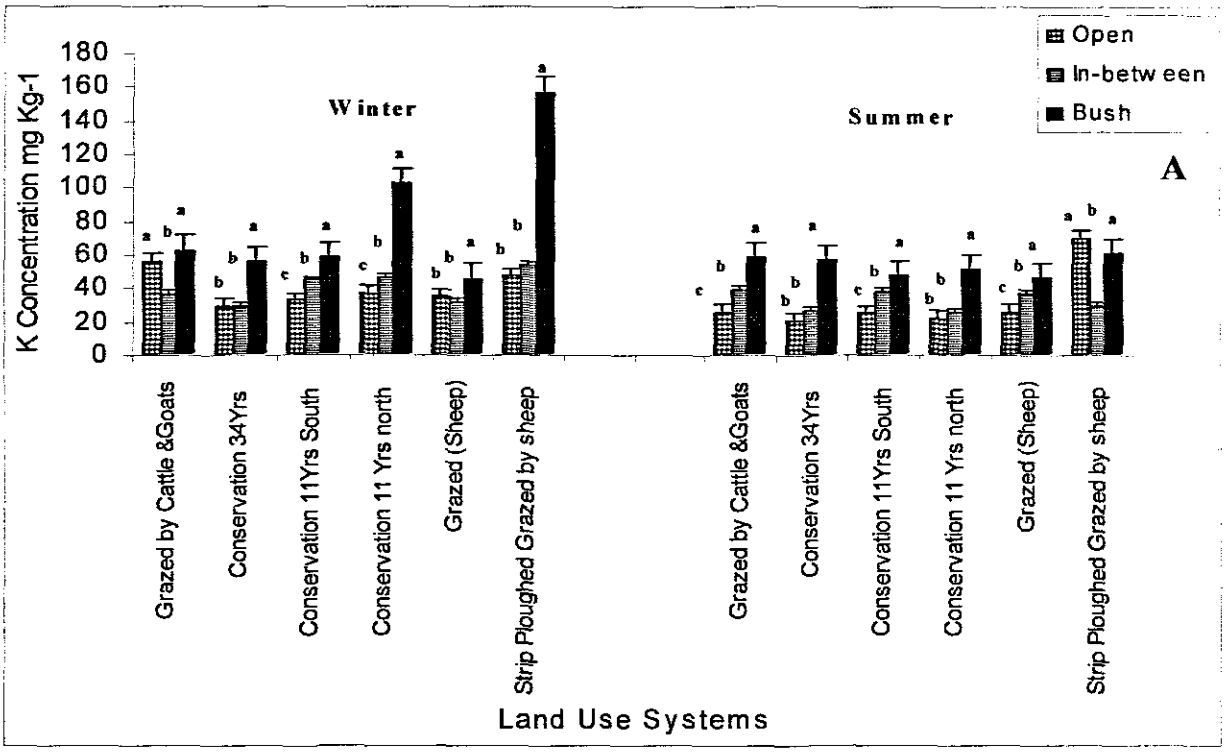


Figure 5.1. Interactive effects of land use and sampling season on soil concentration of A) Mg, B) Ca, C) Mn, and D) Fe



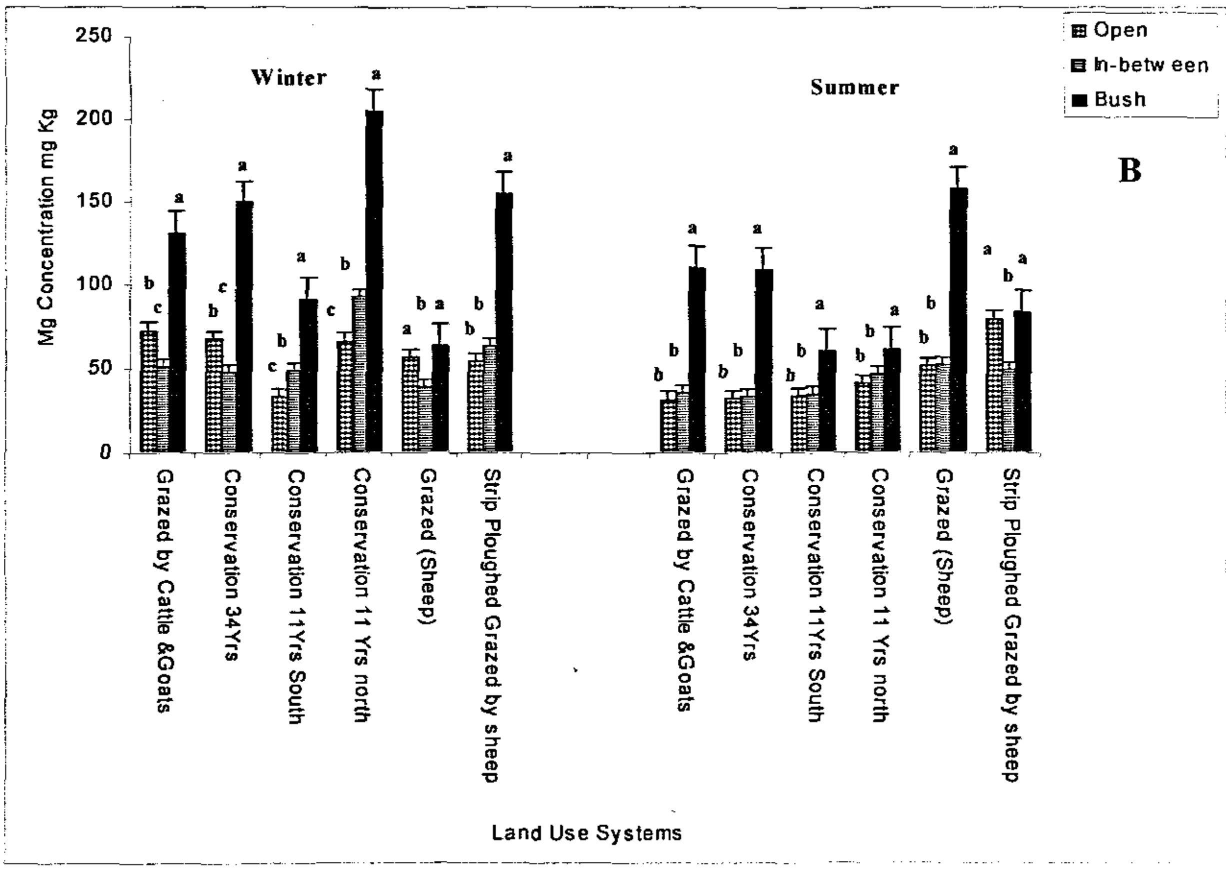


Figure 5.2. Interactive effects of sampling season, land use system and sampling site on A) K, and B) Mg concentration in soil.

CHAPTER 6

General Discussion, Conclusions and Management Recommendations

The phytodiversity of the West Coast Strandveld in and around Rocherpan Nature Reserve is 136 species (Chapter 3). Because of the intensity and scale of the field observations, it is likely that results obtained here truly reflect the plant species diversity of the West Coast Strandveld, especially in and around Rocherpan Nature Reserve.

Because plant diversity was higher with grazing, developing the West Coast Strandveld into grazing land is unlikely to have negative impacts on phytodiversity. However, biodiversity is something that has evolved over evolutionary time, while the time-spans researched although long in human time are not long in evolutionary time. Thus, the precautionary principle should be invoked. Right now it seems that various land use practices do not seem to be threatening biodiversity but this situation could well be a product of the short evolutionary time-spans researched. Although grazing increased phytodiversity in this study, it could impact negetatively on vegetation structure and functional groupings, by altering species dominance towards annual plants. The results of this study confirmed the visual observation of higher and thicker stands of shrubs, making movement difficult through a section of the northern part of Rocherpan Nature Reserve. Results of this study show significant differences with lower number of species and higher number of shrubs in the northern section of Rocherpan Nature Reserve. The lack of significant differences between the conservation 11 years north and the other land use systems suggest that the species diversity in the conservation management 11 years north could potentially increase in years to come as a result of differences in soil nutrient levels.

In general, the strip-ploughing management practise in West Coast Strandveld had no negative impacts on phytodiversity as found in this study.

Therefore, these strip-ploughing and grazing can be useful in conservation planning, especially to serve as ecological corridors. In any case, strip-ploughed areas that are not re-ploughed easily recover and revert back to natural veld as has been observed in some parts of the West Coast.

The concerns raised by Opperman (2001) are important to note. Her results showed that the Rocherpan Nature Reserve could be under some pressure from agricultural activities such as soil accumulation of fertilizers and pesticides used by the potato farmers in the surrounding area. Although the impact of burning was not assessed in this study, it is a major factor affecting vegetation in the West Coast. While it has been recognized that some of these vegetation types need fire, the burning cycle is more than 40 years. Frequent burning can change the vegetation structure, remove key soil nutrients as smoke and favour the emergence of new vegetation types, especially where higher levels of nutrients accumulating from agricultural activities outside the reserve. The end result is an alteration in vegetation structure.

In conclusion, Rocherpan Nature Reserve should be used as a site for further research, especially with the existence of the BIOTA Southern Africa program. The concept of minimum interference such as no grazing or burning activities should be pursued on the reserve until further research is done to determine the use of burning as a management tool for West Coast Strandveld. Further research programs should use Rocherpan Nature Reserve as a site for assessing the impact of conservation management.

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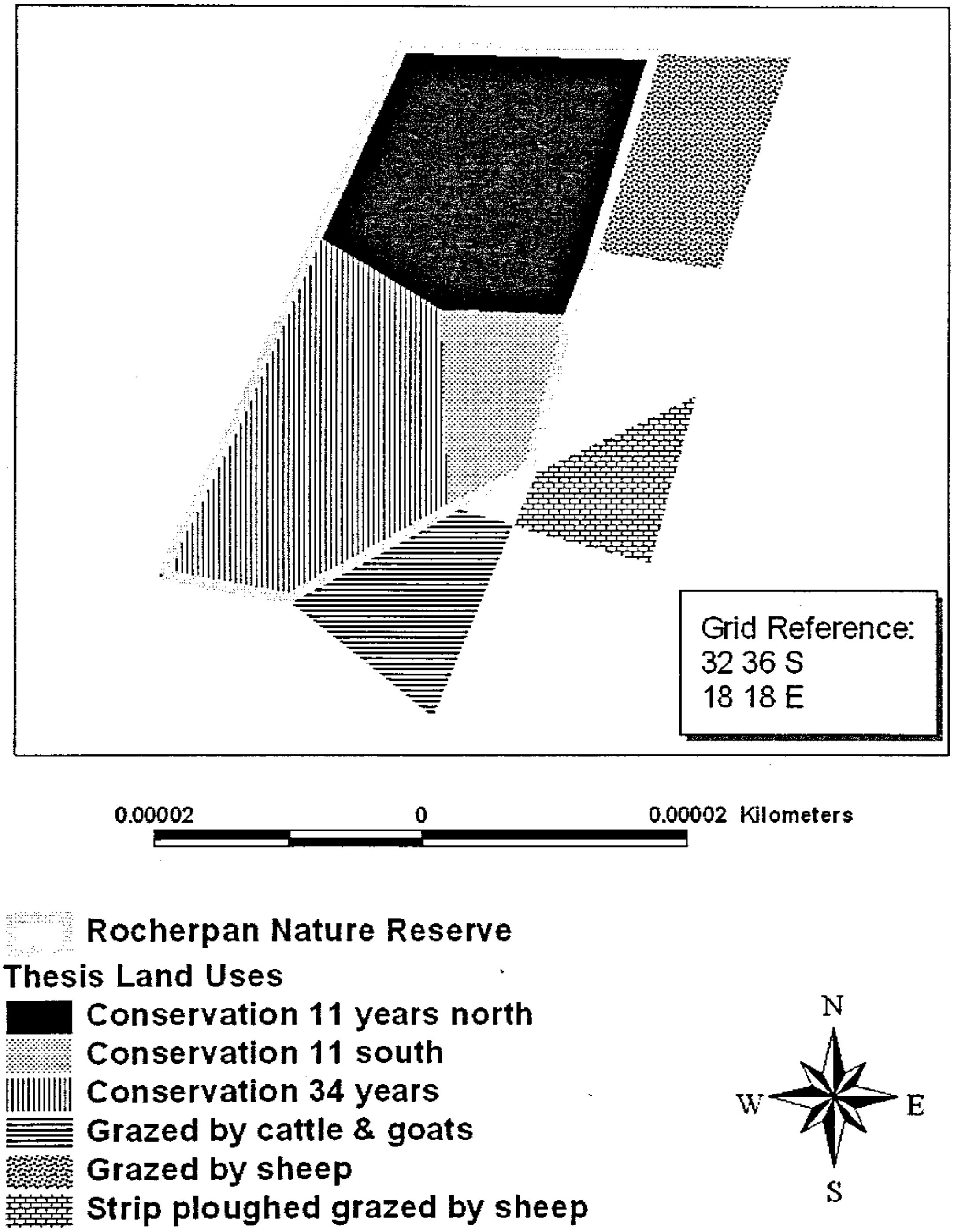
APPENDIX A

Layout of different land uses

Appendix A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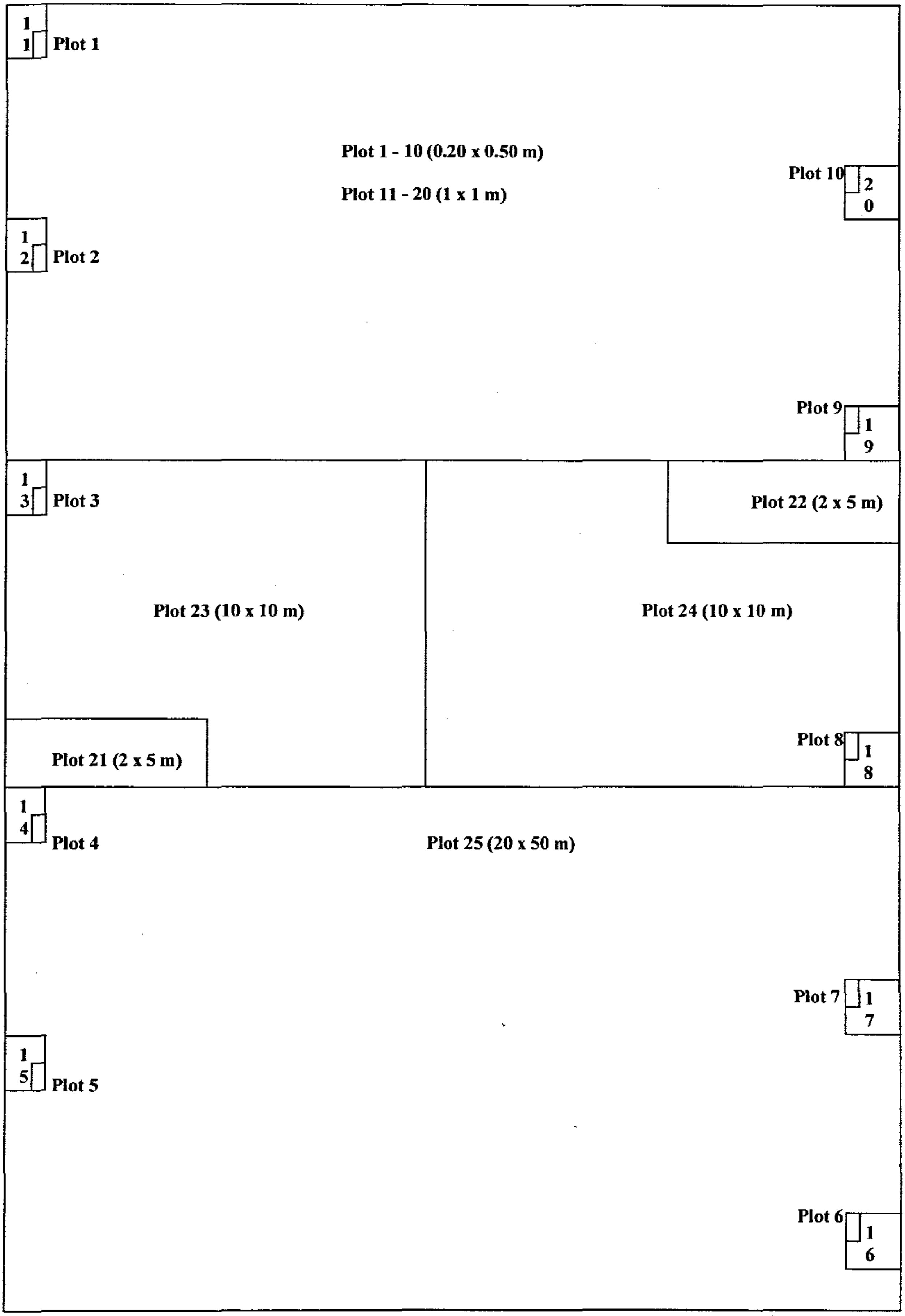
32 36 S
18 18 E
0.00002
0
0.00002 Kilometers
Rocherpan Nature Reserve
Thesis Land Uses
Conservation 11 years north
Conservation 11 south
Conservation 34 years
Grazed by cattle & goats
Grazed by sheep
Strip ploughed grazed by sheep
N
W
E
S

APPENDIX B

Design of modified Whittaker plot (20 m x 50 m) sampling plots



Plot 1 - 10 (0.20 x 0.50 m)
Plot 11 - 20 (1 x 1 m)
Plot 1
11
Plot 2
12
Plot 10
20
Plot 9
19
Plot 3
13
Plot 22 (2 x 5 m)
Plot 23 (10 x 10 m)
Plot 24 (10 x 10 m)
Plot 21 (2 x 5 m)
Plot 8
18
Plot 4
14
Plot 25 (20 x 50 m)
Plot 7
17
Plot 5
15
Plot 6
16

Appendix C
DATA RECORDINGS SHEET

Vegetation Data

		.20x50	.20x50	.20x50	.20x50	.20x50	.20x50	.20x50	.20x50	.20x50	.20x50	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	1x1	2x5	2x5	10x10	BB	BB	10x10	20x50
Cn	Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	%	H	24	25
1		*										*		*					*	*		*	*	*	2	.01	*	*
2		*			*		*					*			*	*	*											*
3			*		*								*		*	*	*					*		*	1		*	*
4			*		*	*	*			*		*	*		*	*	*	*	*	*		*	*	*	3	0.2	*	*
5			*			*		*					*			*		*		*	*						*	*
6			*			*		*					*			*	*	*		*		*		*	3	0.6	*	*
7			*	*	*	*	*	*	*				*	*	*	*	*	*	*			*		*	4	0.5	*	*
8			*				*	*	*				*				*	*	*			*		*	4	0.01	*	*
9			*				*	*	*				*				*	*	*			*		*	5	0.01	*	*
10			+			*			*		*		*	*	*	*			*		*	*	*	*	35	1.0	*	*
11				*	*							*		*	*							*	*	*	1	0.2	*	*
12			+											*									*	*	5	1.0	*	*
13								*						*				*			*			*	3	1.2	*	*
14					*					*					*		*	*		*		*	*	*	3	1.0	*	*
15															*							*	*	*	6	0.01	*	*
16															*												*	*
17									*			*	*						*		*	*		*	2	0.2	*	*
18													*															*
19							+						*			*		*									*	*
20													*															*
21							*			*	*	*					*	*	*	*		*	*	*			*	*
22							*										*											*
23							*			*							*			*	*	*	*	*	+	0.15	*	*
24																	*	*						*	1	1.2	*	*
26								*										*										*
28									*										*			*		*	1	0.2	*	*
29																			*								*	*
30																			*			*		*	1	0.1	*	*
31										*										*		*	*	*	1	1.0	*	*

32																				*			*				*	*
34											*											*	*					*
35																								*	1	0.01		*
36																						*		*	1	0.05		*
37																						*	*	*	2	0.5	*	*
38																						*		*	1	0.05		*
39																						*		*	+	0.02		*
40																						*		*	+	0.02		*
41																							*	*	+	0.02	*	*
	G orgidiflorus																										*	*
43																											*	*
44																							*				*	*
45																							*				*	*
46																								*			*	*
47																											*	*
48																											*	*
49																											*	*
50																											*	*
51																								*	1	1.1	*	*
52																											*	*
53																								*	1	0.2		*
54																												*
55																												*
56																												*
57																												*
58																												*
59																												*
60																												*
61																												*
62																											*	*

Appendix D

Species collected and their numbers recorded in 1000 m^2 plots. Plot 1-3 (Land use: Grazed by Cattle and Goats), plot 4-5 (Land use: Conservation 34), plot 6-8 (Land use: Eleven years of conservation management south), plot 9-11 (Land use: Eleven years of conservation management north), plot 12-15 (Land use: Natural veld grazed by sheep) and plot 16-18 (Land use: Strip-ploughed and natural veld grazed by sheep

Species No	Species name/ Plot number (Arnold & De Wet, 1993)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
1	Indigofera procumbens	3	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
2	Arctotis leptorhiza	3	4	8	0	0	0	0	0	0	0	0	0	0	1	5	5	4	2	32
3	Diascia sp. (Hanekom 3)	7	15	10	2	2	1	0	0	0	6	5	4	8	4	6	0	0	0	70
4	Hemimeris racemosa	18	12	18	0	8	12	4	1	2	10	12	7	5	11	11	4	3	2	140
5	Wahlenbergia androsacea	15	9	10	5	10	7	0	7	13	2	10	0	10	3	11	4	0	3	119
6	Wahlenbergia cf. ramulosa	5	7	12	8	2	3	0	8	3	3	2	2	4	4	11	3	5	0	82
7	Ehrharta brevifolia	19	22	18	6	9	3	2	0	6	3	5	7	6	8	14	13	5	7	153
8	Isolepis antarctica	12	11	12	1	0	0	0	0	0	2	4	5	9	3	10	8	3	0	80
9	Crassula thunbergiana thunbergiana	11	8	12	0	0	4	0	0	0	2	4	2	5	7	12	2	0	0	69
10	Lebeckia multiflora	8	1	14	6	5	3	4	2	1	2	3	4	8	7	6	0	0	0	74
11	Melasphaerula ramosa	5	1	10	6	4	3	8	3	0	11	7	8	8	2	4	4	7	0	91
12	Euclea racemosa	0	5	5	0	5	6	9	0	2	0	1	0	1	0	5	0	0	0	39
13	Tetragonia fruticosa	10	7	7	4	7	6	3	9	2	6	10	12	6	13	5	6	4	0	117
14	Willdenowia incurvata	6	7	11	7	7	11	6	6	8	3	5	6	8	6	15	6	7	5	130
15	Cyphia crenata	7	15	12	6	6	8	7	10	18	3	4	0	3	1	5	2	2	0	109
16	Microloma sagittatum	0	1	3	2	0	2	3	3	2	2	3	1	2	2	5	0	0	0	31
17	Hermannia scordifolia	0	0	9	0	5	0	4	0	4	14	8	0	0	0	10	0	4	3	61
18	Pelargonium triste	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
19	Salvia lanceolata	8	4	5	2	2	8	4	7	5	6	6	0	9	6	6	4	1	1	84
20	Lapeirousia anceps	0	0	2	0	3	0	0	3	0	0	0	0	0	0	3	2	2	4	19
21	Ehrharta villosa	0	6	13	4	9	4	9	6	10	9	15	2	5	5	1	8	15	8	129
22	Heliophila sp. (Hanekom 22)	0	0	3	0	0	0	2	0	0	0	0	3	0	0	0	0	0	0	8
23	Silene undulata	10	2	10	1	0	0	0	2	0	0	0	2	6	4	0	5	2	0	44
24	Cysticapnos vesicarius	6	1	5	0	0	2	0	0	0	3	1	5	3	3	3	4	1	3	40
25	Aspalathus sp. (Hanekom 25)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
26	Adenocline violifolia	0	0	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
27	Hermannia sp. (Hanekom 27)	3	10	3	6	0	1	0	2	0	0	0	6	10	11	0	4	0	0	56
28	Nemesia strumosa	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
29	Oxalis sp. (Hanekom 29)	1	0	3	3	9	2	8	4	6	0	0	0	3	0	6	0	6	4	55
30	Dimorphotheca pluvialis	5	13	5	0	0	0	0	3	0	0	0	1	3	1	4	8	6	2	51
31	Eriocephalus kingesii	4	10	7	9	8	8	7	8	6	3	3	2	3	8	9	5	15	7	122
33	Unknown sp. (Hanekom 33)	0	2	4	7	0	0	7	0	0	0	0	0	10	0	0	0	0	0	30
34	Stoeberia utilis	3	3	4	5	5	3	6	8	4	5	7	11	0	12	6	0	0	0	82
35	Limeum africanum	0	3	2	1	0	0	2	0	0	0	0	0	0	0	5	3	2	0	18
36	Adrenogramma littoralis	3	9	3	0	0	0	0	3	0	0	4	1	4	2	3	9	14	17	72
37	Ruschia subpaniculata	8	4	5	6	5	3	4	9	5	5	3	1	8	6	4	3	10	11	100
38	Wahlenbergia paniculata	0	0	3	0	0	0	0	1	0	0	0	0	0	0	4	0	0	2	10
39	Cyanella sp. (Hanekom 39)	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
40	Babiana sp. (Hanekom 40)	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
41	Babiana tubulosa	1	0	4	0	1	2	0	4	1	2	1	0	0	2	0	3	6	1	28
42	Ornithoglossum sp. (Hanekom 42)	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	4
43	Unknown sp. (Hanekom 43)	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	5
44	Droguetia iners	15	8	3	0	0	7	2	3	2	3	3	0	3	0	4	0	2	0	55
45	Unknown sp. (Hanekom 45)	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	9
46	Asparagus fasciculatus	3	1	3	4	3	2	5	3	0	2	2	7	1	0	7	2	0	3	48
47	Trachyandra falcata	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	2	0	1	6

49	Albuca flaccida	5	0	2	1	0	1	0	0	0	1	2	1	1	0	0	2	0	2	18
50	Heliophila sp. (Hanekom 50)	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
51	Felicia heterophylla	1	4	3	0	0	0	0	1	0	0	0	0	1	2	0	7	4	8	31
52	Rhus longispina	2	4	2	0	0	10	7	0	1	0	8	7	0	0	7	0	0	0	48
53	Moraea fugax	2	0	2	0	2	3	0	0	2	0	0	0	0	3	0	0	2	0	16
54	Ballota africana	2	0	1	0	0	3	0	0	0	2	2	2	1	0	0	0	0	1	14
55	Felicia bergeriana	0	5	1	0	0	0	0	0	0	0	0	0	2	2	1	0	0	0	11
56	Pelargonium fulgidum	0	1	1	5	5	0	3	5	2	1	1	0	1	0	3	0	4	0	32
57	Hyobanche sanguinea	0	0	1	2	1	0	0	2	0	0	0	0	0	0	0	0	0	0	6
58	Melianthus minor	1	1	1	5	3	1	0	3	1	0	0	0	0	0	0	0	3	0	19
59	Pteronia onobromoides	0	0	1	1	11	2	3	1	10	0	0	0	0	0	3	0	0	0	32
60	Cyanella hyacinthoides	0	0	1	0	0	0	0	0	2	2	0	0	2	3	0	3	2	6	21
61	Heliophila digitata	1	4	1	0	0	1	0	2	1	0	1	0	2	3	0	1	0	0	17
62	Euphorbia burmannii	0	4	2	0	7	3	6	4	3	0	0	0	0	5	6	3	9	3	55
63	Putterlickia pyracantha	0	0	0	1	0	0	0	0	0	0	2	1	4	0	0	0	9	0	17
64	Unknown sp. (Hanekom 64)	0	2	0	2	0	0	0	0	4	0	0	0	0	0	0	0	0	0	8
65	Leysera gnaphalodes	0	0	0	7	3	2	0	2	0	0	0	0	0	1	0	2	2	5	24
66	Senecio aloides	0	0	0	6	10	4	8	16	7	3	0	1	3	0	3	0	0	0	61
67	Cynanchum africanum	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
68	Euclea racemosa	1	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
69	Helichrysum hebelepis	5	2	0	6	7	5	6	3	1	1	1	0	5	6	6	0	0	0	54
70	Unknown sp. (Hanekom 70)	3	0	0	0	2	7	1	3	2	8	3	3	4	2	0	0	2	1	41
71	Cissampelos capensis	0	0	0	5	4	0	2	6	0	0	4	2	0	0	12	0	0	0	35
72	Poaceae (Hanekom 72)	3	0	0	10	5	7	7	7	10	0	0	1	3	0	5	6	2	6	72
73	Unknown sp. (Hanekom 73)	4	10	0	6	9	5	7	0	4	8	11	2	10	8	7	0	3	6	100
74	Pteronia divaricata	3	10	0	7	6	9	4	4	4	4	10	3	4	4	4	3	1	0	80
75	Trachyandra divaricata	0	0	0	4	1	2	0	3	0	2	10	2	2	3	1	1	0	0	31
76	Trachyandra sp. (Hanekom 76)	4	3	0	3	2	2	0	2	0	3	0	2	1	2	10	2	5	0	41
78	Nemesia bicornis	5	7	0	0	1	0	0	0	0	2	3	2	5	2	4	1	0	0	32
79	Euphorbia caput-medusa	0	0	0	2	5	0	0	0	2	0	0	0	0	0	0	1	1	2	13
80	Ferraria divaricata	0	0	0	2	1	0	2	0	2	1	0	1	1	3	1	0	2	1	17
81	Crassula glomerata	0	0	0	2	1	0	0	0	0	0	0	1	1	0	0	0	0	3	8
82	Diospyros villosa	0	0	0	2	0	0	3	0	0	0	0	0	0	0	0	0	0	0	5
84	Tylecodon paniculatus	0	0	0	1	0	2	0	0	0	0	0	1	0	0	0	0	0	0	4
86	Asparagus declinatus	2	0	0	0	3	3	2	0	2	7	1	3	0	4	2	1	1	0	31
87	Unknown sp. (Hanekom 87)	0	1	0	0	5	0	2	0	0	0	0	0	2	2	2	0	4	0	18
88	Apatesia helianthoides	2	8	0	0	0	0	3	3	2	0	0	1	1	3	1	8	5	6	43
89	Unknown sp. (Hanekom 89)	0	0	0	0	7	0	2	2	0	0	0	0	0	0	0	0	0	0	11
90	Chrysanthemoides incana	0	0	0	0	0	0	0	1	3	1	0	0	3	1	0	0	0	0	9
91	Rhus laevigata	0	0	0	0	0	0	1	2	2	0	0	2	4	0	1	1	0	1	14
92	Othonna cylindrica	0	3	0	0	0	6	1	0	5	0	0	0	0	1	0	4	5	4	29
93	Hermannia trifurca	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	7	7	8	25
94	Unknown sp. (Hanekom 94)	1	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	4
95	Capnophyllum africanum	4	0	0	0	0	0	0	0	0	4	10	2	0	0	0	1	3	3	27
96	Zygophyllum morgsana	7	7	0	0	6	6	0	7	1	4	7	5	5	6	7	12	4	3	87
97	Unknown sp. (Hanekom 97)	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2
98	Oxalis sp. (Hanekom 98)	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3
99	Unknown sp. (Hanekom 99)	1	0	0	0	3	1	0	4	2	2	6	2	3	1	8	1	2	6	42

100	Euclea tomentosa	0	0	0	0	4	0	0	0	2	2	0	2	0	0	0	0	0	0	10
102	Senecio sp. (Hanekom 102)	6	0	0	0	2	0	0	2	0	0	0	1	0	2	4	1	3	2	23
103	Trachyandra sp. (Hanekom 103)	0	3	0	0	0	2	0	0	0	0	0	1	2	3	2	0	0	0	13
104	Pelargonium gibbosum	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
105	Crassula oblanceolata	0	7	0	0	5	0	0	0	1	2	5	0	4	0	10	0	0	0	34
106	Unknown sp. (Hanekom 106)	0	0	0	0	4	0	0	0	0	0	2	0	3	2	3	5	7	6	32
107	Lycium sp. (Hanekom 107)	0	0	0	0	0	0	0	0	0	1	0	0	1	0	5	2	1	0	10
108	Unknown sp. (Hanekom 108)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
109	Manochlamys albicans	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2
110	Ursinia sp. (Hanekom 110)	0	3	0	0	0	0	0	0	1	0	0	0	4	0	0	1	4	0	13
111	Hermannia incana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	3	2	11
112	Erucastrum sp. (Hanekom112)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	2	0	10
113	Solanum guineense	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
114	Ifloga sp. (Hanekom 114)	0	1	0	0	0	0	0	0	0	0	2	0	2	0	0	10	3	2	20
115	Tribolium echinatum	0	16	0	0	0	0	0	0	0	0	0	0	5	2	0	14	11	16	64
116	Senecio sp. (Hanekom 116)	2	7	0	0	0	0	0	0	0	0	0	0	1	3	0	5	6	7	31
117	Grielum humifusum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
118	Erodium cicutarium	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	5	0	2	8
119	Emex australis	0	3	0	0	0	0	0	0	0	0	0	8	0	0	0	2	0	1	14
122	Rhus glauca	2	0	0	0	6	0	0	5	0	10	0	0	5	8	0	3	2	3	44
123	Lessertia sp (Hanekom 123)	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
124	Unknown sp. (Hanekom 124)	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	5
125	Cotyledon orbiculata	0	0	0	0	4	0	0	0	0	0	0	0	0	3	0	0	0	0	7
126	Pharnaceum lanatum	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	3	0	0	6
127	Argyrolobium sp. (Hanekom 127)	0	3	0	0	2	5	0	0	0	0	0	0	0	5	0	0	2	0	17
128	Galium tomentosum	0	1	0	0	2	1	0	3	0	3	0	0	0	3	0	0	0	0	13
129	Lyperia triste	0	3	0	0	3	0	0	0	0	0	0	0	0	3	0	0	0	0	9
130	Gladiolus speciosus	0	0	0	0	2	0	0	6	0	0	0	0	0	0	0	1	3	0	12
131	Gladiolus undulatus	0	0	0	0	0	2	0	3	0	0	1	0	0	1	0	3	0	0	10
132	Senecio scapiflorus	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2
134	Asparagus capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
135	Arctopus echinatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	4
137	Unknown sp. (Hanekom 137)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	3
138	Crassula muscosa	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	6
139	Hordeum capense	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
140	Moraea gawleri	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
142	Disparago sp. (Hanekom 142)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
143	Unknown sp. (Hanekom 143)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	4
144	Oncosiphon grandiflorum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	9	13	28
146	Mesembryanthemum guerichianum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1	5
147	Gladiolus orchidiflorus	0	0	2	0	3	0	0	2	0	0	0	0	2	0	0	0	1	0	10
148	Viscum capensis	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	4

Appendix E

Species collection number, species names and family

Species No	Species name	Family
13	Tetragonia fruticosa	AIZOACEAE
33	Unknown sp. (Hanekom 33)	AIZOACEAE
34	Stoeberia utilis	AIZOACEAE
37	Ruschia subpaniculata	AIZOACEAE
88	Apatesia helianthoides	AIZOACEAE
146	Mesembryanthemum guerichianum	AIZOACEAE
109	Manochlamys albicans	AMARANTHACEAE
52	Rhus longispina	ANACARDIACEAE
91	Rhus laevigata	ANACARDIACEAE
122	Rhus glauca	ANACARDIACEAE
95	Capnophyllum africanum	APIACEAE
135	Arctopus echinatus	APIACEAE
16	Microloma sagittatum	APOCYNACEAE
67	Cynanchum africanum	APOCYNACEAE
46	Asparagus fasciculatus	ASPARAGACEAE
86	Asparagus declinatus	ASPARAGACEAE
134	Asparagus capensis	ASPARAGACEAE
47	Trachyandra falcata	ASPHODELACEAE
75	Trachyandra divaricata	ASPHODELACEAE
76	Trachyandra sp. (Hanekom 76)	ASPHODELACEAE
103	Trachyandra sp. (Hanekom 103)	ASPHODELACEAE
2	Arctotis leptorhiza	ASTERACEAE
30	Dimorphotheca pluvialis	ASTERACEAE
31	Eriocephalus kingesii	ASTERACEAE
51	Felicia heterophylla	ASTERACEAE
55	Felicia bergeriana	ASTERACEAE
59	Pteronia onobromoides	ASTERACEAE
65	Leysera gnaphalodes	ASTERACEAE
66	Senecio aloides	ASTERACEAE
69	Helichrysum hebelepis	ASTERACEAE
74	Pteronia divaricata	ASTERACEAE
90	Chrysanthemoides incana	ASTERACEAE
92	Othonna cylindrica	ASTERACEAE
102	Senecio sp. (Hanekom 102)	ASTERACEAE
110	Ursinia sp. (Hanekom 110)	ASTERACEAE
114	Ifloga sp. (Hanekom 114)	ASTERACEAE
116	Senecio sp. (Hanekom 116)	ASTERACEAE
132	Senecio scapiflorus	ASTERACEAE
142	Disparago sp. (Hanekom 142)	ASTERACEAE
144	Oncosiphon grandiflorum	ASTERACEAE
22	Heliophila sp. (Hanekom 22)	BRASSICACEAE
50	Heliophila sp. (Hanekom 50)	BRASSICACEAE
61	Heliophila digitata	BRASSICACEAE
112	Erucastrum sp. (Hanekom112)	BRASSICACEAE
5	Wahlenbergia androsacea	CAMPANULACEAE
6	Wahlenbergia cf. ramulosa	CAMPANULACEAE
15	Cyphia crenata	CAMPANULACEAE
38	Wahlenbergia paniculata	CAMPANULACEAE
23	Silene undulata	CARYOPHYLLACEAE
63	Putterlickia pyracantha	CELASTRACEAE
42	Ornithoglossum sp. (Hanekom 42)	COLCHICACEAE

9	Crassula thunbergiana thunbergiana	CRASSULACEAE
81	Crassula glomerata	CRASSULACEAE
84	Tylecodon paniculatus	CRASSULACEAE
105	Crassula oblanceolata	CRASSULACEAE
125	Cotyledon orbiculata	CRASSULACEAE
138	Crassula muscosa	CRASSULACEAE
8	Isolepis antarctica	CYPERACEAE
68	Euclea racemosa	EBENACEA
12	Euclea racemosa	EBENACEAE
82	Diospyros villosa	EBENACEAE
100	Euclea tomentosa	EBENACEAE
26	Adenocline violifolia	EUPHORBIACEAE
62	Euphorbia burmannii	EUPHORBIACEAE
79	Euphorbia caput-medusa	EUPHORBIACEAE
127	Argyrolobium sp. (Hanekom 127)	FABACEAE
1	Indigofera procumbens	FABACEAE
10	Lebeckia multiflora	FABACEAE
25	Aspalathus sp. (Hanekom 25)	FABACEAE
123	Lessertia sp (Hanekom 123)	FABACEAE
24	Cysticapnos vesicarius	FUMARIACEAE
18	Pelargonium triste	GERANIACEAE
56	Pelargonium fulgidum	GERANIACEAE
104	Pelargonium gibbosum	GERANIACEAE
118	Erodium cicutarium	GERANIACEAE
49	Albuca flaccida	HYACINTHACEAE
11	Melasphaerula ramosa	IRIDACEAE
20	Lapeirousia anceps	IRIDACEAE
40	Babiana sp. (Hanekom 40)	IRIDACEAE
41	Babiana tubulosa	IRIDACEAE
53	Moraea fugax	IRIDACEAE
80	Ferraria divaricata	IRIDACEAE
130	Gladiolus speciosus	IRIDACEAE
131	Gladiolus undulatus	IRIDACEAE
140	Moraea gawleri	IRIDACEAE
147	Gladiolus orchidiflorus	IRIDACEAE
19	Salvia lanceolata	LAMIACEAE
54	Ballota africana	LAMIACEAE
17	Hermannia scordifolia	MALVACEAE
27	Hermannia sp. (Hanekom 27)	MALVACEAE
93	Hermannia trifurca	MALVACEAE
111	Hermannia incana	MALVACEAE
58	Melianthus minor	MELIANTHACEAE
71	Cissampelos capensis	MENISPERMACEAE
35	Limeum africanum	MOLLUGINACEAE
36	Adenogramma littoralis	MOLLUGINACEAE
126	Pharnaceum lanatum	MOLLUGINACEAE
117	Grielum humifusum	NEURADACEAE
57	Hyobanche sanguinea	OROBANCHACEAE
29	Oxalis sp. (Hanekom 29)	OXALIDACEAE
98	Oxalis sp. (Hanekom 98)	OXALIDACEAE
7	Ehrharta brevifolia	POACEAE
21	Ehrharta villosa	POACEAE

72	Poaceae (Hanekom 72)	POACEAE
115	Tribolium echinatum	POACEAE
139	Hordeum capense	POACEAE
119	Emex australis	POLYGONACEAE
14	Willdenowia incurvata	RESTIONACEAE
128	Galium tomentosum	RUBIACEAE
3	Diascia sp. (Hanekom 3)	SCROPHULARIACEAE
4	Hemimeris racemosa	SCROPHULARIACEAE
28	Nemesia strumosa	SCROPHULARIACEAE
78	Nemesia bicornis	SCROPHULARIACEAE
129	Lyperia tristis	SCROPHULARIACEAE
107	Lycium sp. (Hanekom 107)	SOLANACEAE
113	Solanum guineense	SOLANACEAE
39	Cyanella sp. (Hanekom 39)	TECOPHILAEACEAE
60	Cyanella hyacinthoides	TECOPHILAEACEAE
44	Droguetia iners	URTICACEAE
148	Viscum capensis	VISCACEAE
96	Zygophyllum morgsana	ZYGOPHYLLACEAE
43	Unknown sp. (Hanekom 43)	Unknown
45	Unknown sp. (Hanekom 45)	Unknown
64	Unknown sp. (Hanekom 64)	Unknown
70	Unknown sp. (Hanekom 70)	Unknown
73	Unknown sp. (Hanekom 73)	Unknown
87	Unknown sp. (Hanekom 87)	Unknown
89	Unknown sp. (Hanekom 89)	Unknown
94	Unknown sp. (Hanekom 94)	Unknown
97	Unknown sp. (Hanekom 97)	Unknown
99	Unknown sp. (Hanekom 99)	Unknown
106	Unknown sp. (Hanekom 106)	Unknown
108	Unknown sp. (Hanekom 108)	Unknown
124	Unknown sp. (Hanekom 124)	Unknown
137	Unknown sp. (Hanekom 137)	Unknown
143	Unknown sp. (Hanekom 143)	Unknown

Appendix F

Species numbers for the different life / growth forms for the different land uses, with Shannon-Wiener diversity indices (H') with number of species and species density per land use as the measures of abundance showing means and standard deviations for each land use. Results of analysis of variance are indicated in the (Sig) column. NS = not significant. CG = grazed cattle and goats, C34 = conservation 34 years, C11s = eleven years of conservation management south, C11n = eleven years of conservation management north, S = Natural veld grazed by sheep and SS = Strip-ploughed Natural veld grazed by sheep.

1 = Number of species.

2 = Total number of species.

3 = Number of perennial species.

4 = Number of annual species.

5 = Number of Deciduous species: A = Yes, B = No.

6 = Number of annual stem shedding species: A = Yes, B = No.

7 = Number of Spinescens species: A = Yes, B = No.

8 = Raunkiaer's life forms: A = Phanerophytes, B = Chamaephytes, C = Hemicryptophytes, D = Cryptophytes, E = Therophytes, F = Parasite.

9= Growth forms: A = Erect B = Spreading, C = Climber, D = Prostate, E = Rosette, F = Tussock.

10 = Woodiness: A = Woody, B = Herbaceous, C = Semi woody.

11 = Succulence: A = Leaf, B = Leaf and Stem.

	CG					C 34					C11s					C11n					S					SS				
	tot	mn	±	SD	sig	tot	mn	±	SD	sig	tot	mn	±	SD	sig	tot	mn	±	SD	sig	tot	mn	±	SD	sig	tot	mn	±	SD	sig
1	93					85					76					70					89					88				
2	920					670					579					566					818					774				
3	374	0.14	±	0.02	ns	489	0.17	±	0.02	ns	452	0.15	±	0.03	ns	339	0.14	±	0.01	ns	448	0.17	±	0.03	ns	376	0.16	±	0.02	ns
4	546	0.23	±	0.02	s	181	0.11	±	0.01	ns	127	0.15	±	0.03	ns	227	0.14	±	0.01	ns	370	0.18	±	0.03	s	393	0.19	±	0.01	s
5																														
A	737	0.20	±	0.01	s	388	0.13	±	0.02	ns	359	0.15	±	0.03	ns	394	0.14	±	0.01	ns	571	0.17	±	0.03	ns	592	0.18	±	0.02	ns
B	183	0.14	±	0.02	ns	282	0.19	±	0.01	s	220	0.15	±	0.03	ns	172	0.14	±	0.01	ns	247	0.17	±	0.03	ns	182	0.15	±	0.02	ns
6																														
A	652	0.21	±	0.01	s	258	0.12	±	0.03	ns	237	0.15	±	0.03	ns	307	0.14	±	0.02	ns	431	0.17	±	0.03	ns	519	0.19	±	0.01	s
B	220	0.14	±	0.01	ns	372	0.19	±	0.01	s	305	0.14	±	0.01	ns	209	0.17	±	0.01	ns	324	0.14	±	0.01	s	226	0.14	±	0.02	ns
7																														
A	16	0.15	±	0.01	ns	15	0.16	±	0.04	ns	10	0.15	±	0.03	ns	7	0.14	±	0.02,	ns	9	0.11	±	0.03	ns	35	0.26	±	0.02	s
8																														
A	184	0.14	±	0.01	s	262	0.18	±	0.02	ns	246	0.17	±	0.02	ns	195	0.14	±	0.02	s	257	0.18	±	0.03	ns	160	0.13	±	0.03	s
B	72	0.17	±	0.05	ns	92	0.17	±	0.05	ns	71	0.16	±	0.02	ns	26	0.14	±	0.01	s	69	0.16	±	0.02	ns	68	0.16	±	0.01	ns
C	11 3	0.16	±	0.05	ns	104	0.15	±	0.00	ns	95	0.15	±	0.03	ns	103	0.14	±	0.01	ns	108	0.15	±	0.05	ns	142	0.19	±	0.00	ns
D	54	0.13	±	0.09	ns	70	0.19	±	0.08	ns	64	0.14	±	0.01	ns	43	0.14	±	0.01	ns	63	0.16	±	0.02	ns	94	0.20	±	0.03	ns
E	496	0.24	±	0.01	s	139	0.10	±	0.02	ns	101	0.15	±	0.03	ns	199	0.14	±	0.01	ns	317	0.18	±	0.03	s	310	0.18	±	0.02	s
F	1	0	±	1	ns	3	1	±	1	ns	2	1	±	1	ns	0	0	±	0	ns	4	1	±	2	ns	0	0	±	0	ns
9																														
A	574	0.18	±	0.01	ns	456	0.16	±	0.02	ns	379	0.14	±	0.02	ns	394	0.14	±	0.01	ns	540	0.17	±	0.00	ns	508	0.17	±	0.02	ns
B	10	0.18	±	0.02	ns	28	0.15	±	0.09	ns	16	0.09	±	0.06	ns	30	0.18	±	0.02	ns	24	0.17	±	0.02	ns	37	0.16	±	0.03	ns
C	67	0.20	±	0.02	ns	56	0.18	±	0.01	ns	59	0.18	±	0.01	ns	33	0.14	±	0.04	s	52	0.16	±	0.02	ns	23	0.10	±	0.01	s
D	84	0.23	±	0.04	s	19	0.10	±	0.07	ns	17	0.13	±	0.03	ns	35	0.13	±	0.07	ns	58	0.18	±	0.06	ns	66	0.20	±	0.04	ns
E	55	0.18	±	0.00	ns	41	0.15	±	0.04	ns	55	0.18	±	0.06	ns	18	0.12	±	0.06	ns	51	0.17	±	0.06	ns	47	0.17	±	0.02	ns
F	81	0.20	±	0.03	s	48	0.14	±	0.02	ns	44	0.13	±	0.02	ns	26	0.10	±	0.03	ns	66	0.17	±	0.05	s	84	0.20	±	0.02	s
10																														
A	243	0.17	±	0.01	ns	331	0.20	±	0.02	ns	305	0.19	±	0.01	ns	213	0.15	±	0.01	s	292	0.19	±	0.01	ns	207	0.15	±	0.03	s
B	652	0.24	±	0.01	s	311	0.15	±	0.03	ns	252	0.14	±	0.01	ns	339	0.16	±	0.02	ns	497	0.21	±	0.02	s	549	0.22	±	0.01	s
C	24	0.19	±	0.04	ns	25	0.20	±	0.03	ns	20	0.17	±	0.02	ns	14	0.14	±	0.03	ns	29	0.21	±	0.06	ns	18	0.16	±	0.02	ns
11																														
A	99	0.17	±	0.01	ns	92	0.17	±	0.02	ns	96	0.17	±	0.04	ns	90	0.16	±	0.03	ns	120	0.20	±	0.01	ns	116	0.19	±	0.01	ns
B	10	0.00	±	0.00	ns	17	0.18	±	0.05	ns	21	0.20	±	0.04	ns	5	0.10	±	0.02	ns	20	0.19	±	0.09	ns	20	0.19	±	0.06	ns