

## CHAPTER 5

# ECOLOGICAL MANAGEMENT OBJECTIVES

### INTRODUCTION

Assessing the condition of the vegetation and determining possible trends is a prerequisite in the sound ecological management and conservation of an area. Various methods and approaches of quantifying veld condition have been developed over the past few decades (Foran *et al.* 1978; Tainton *et al.* 1978; Tainton *et al.* 1980; Vorster 1982; Hurt & Hardy 1989; Westoby *et al.* 1989). These veld condition techniques are based on estimates of proportional species composition and the manipulation of this data is determined by the objectives of various methods (Hurt & Bosch 1991). Several of these methods are based on ecologically accepted principles. Dyksterhuis (1949) first recognised the importance of using a benchmark or climax veld against which the veld condition of a certain area should be measured. This notion was ensued and several other ecologically-based techniques were developed (Van den Berg & Roux 1974; Foran *et al.* 1978; Barnes *et al.* 1984; Vorster 1982; Tainton *et al.* 1978; 1980; Heard *et al.* 1986). Although these techniques have been severely criticised, they formed the basis for monitoring and assessment of veld condition in the past two decades. The most important criticism against these ecologically-based methods are affirmed by Jordaan (1997). These methods are based on certain severely questionable assumptions which contests their objectivity and efficiency:

- The under-utilized climax vegetation is often regarded as the ideal situation or objective of veld management. In terms of biological diversity, veld composition under these circumstances tend to be homogenous. According to Mentis and Collinson (1979) maximal species diversity implies fair to good veld condition. In terms of wildlife management it is stated by various authors that game has

preferences in terms of vegetation structure and species (Grunow 1980; Jooste & Palmer 1982; Novellie 1990; Wentzel *et al.* 1991, Pietersen *et al.* 1993; Dekker *et al.* 1996). This implies that the objective of management does not always requires climax vegetation to be the ultimate aim with vegetation composition and structure.

- Ecologically-based techniques also assumes that grazing is the only factor inflicting changes in vegetation composition and structure, while other important determinants such as climate (Snyman 1989; Peel *et al.* 1991; O'Connor 1991) and fire (Le Roux 1988; Glen-Leary 1990; Trollope *et al.* 1996; Scholes *et al.* 1993) are often ignored.
- Veld condition assessments have to be ecologically interpretable to provide a scientific basis for management decisions. Most techniques developed to assess the condition of vegetation are based on a subjective knowledge of species response to grazing (Bosch 1989; Bosch & Kellner 1991; Janse van Rensburg & Bosch 1990; Bosch & Gauch 1991; Hurt *et al.* 1993). Species are allocated to ecological classes based on their assumed response to grazing, and also according to the assumption that all species respond to grazing, which is incorrect (Mentis 1982; Hurt *et al.* 1993). The use of subjectively derived ecological classes and non-responsive and rare species in the interpretation of monitoring results will reduce or distort the sensitivity of such techniques (Hurt *et al.* 1991; Hurt *et al.* 1993). It can therefore not be used to evaluate the extent to which management objectives is achieved accurately.
- According to Jordaan (1997) a relieve in prolonged grazing pressure will not necessarily result in a recovery of the vegetation to its original composition and structure, as changes in soil conditions do take place when vegetation cover is removed (Westoby 1980).

Multivariate techniques was developed to improve objectivity and interpretability during veld condition assessments. Some of these techniques included the



Weighted Key Species Method (Hurt & Hardy 1989), the Degradation Gradient Method (Mentis 1983; Bosch & Gauch 1991), Multiple Benchmark Sites (Bosch *et al.* 1987). Ordination procedures were also introduced to define and create an understanding of the degradation process by using data representing known compositional differences induced mainly by grazing.

No ecosystem has a fixed composition. It fluctuates in space and time, influenced by changes in the individual components it consists of (Siegfried & Davies 1982). To be able to quantify these changes, it is important that there should be an understanding of the dynamics and responses of a system to different external influences such as grazing and fire. Vegetation gradient analyses are useful to determine plant species reactions to environmental parameters (Walker 1988). Subjectively qualified information obtained by using ecologically-based techniques does not provide a gradient along which a sample site can be positioned. Neither does these techniques recognised multiple benchmarks that distinguished different domains of attraction (stable conditions) that develops with the process of degradation (Hurt *et al.* 1991) or provide for the absence of “favourable” or “decreaser” species in areas where the physical conditions do not allow them to grow (Martens *et al.* 1990). During the process of degradation, the veld condition may deteriorate to levels below the limits of resilience of that system and biophysical transformations such as a degradation in soil structure and organic contents can cause an irreversible change in the system (Bosch & Gauch 1991).

Managing for biological diversity should not aim at a fixed pattern, but at a general range of possibilities. With the development of degradation models for each of the vegetation units, quantifying the effect of existing management on a specific vegetation unit will be possible. It also enables the user to determine the ecological significance of a specific position on the gradient (Bosch 1989). By evaluating this vegetation gradient according to parameters specifically pertaining to the objectives of the reserve, eg. species diversity, stability and resilience of the system, an understanding of the desired state of the vegetation system on the reserve can be developed. Subsequent monitoring will reveal progress or regression in the achievement of management objectives.

## CONSTRUCTION OF THE DEGRADATION GRADIENT

Four management units were identified during the classification of the vegetation on Rustenburg Nature Reserve;

- I. *Selaginella dregei* - *Oldenlandia herbacea* Open Shrub land
- II. *Becium obovatum* - *Elionurus muticus* Tall Grassland
- III. *Ziziphus mucronata* - *Rhus leptodictya* Closed Woodland
- IV. *Pteridium aquilinum* - *Miscanthus junceus* Moist Grassland

The biological and physical characteristics of each of these management units were described in chapter 4.

### Methods

Species compositional data for management unit I, II and III were obtained. The *Pteridium aquilinum* - *Miscanthus junceus* High Closed Grassland Management Unit, associated with wet conditions, were disregarded for the following reasons:

- It consists of homogenous stands of *Phragmites australis* and *Pteridium aquilinum* and riverine vegetation dominated by *Buddleja salviifolia*, *Miscanthus junceus* and *Imperata cylindrica*.
- The vegetation structure in this unit is dense and tall and utilization by herbivores is minimal.
- This unit is confined to a small area on either side of streams and inside depressions where water accumulate, which complicates the development of a degradation gradient.

The nearest plant technique was used and the plant nearest to a marked pin on

a wheel-point apparatus (Tidmarsh & Havenga 1955) was recorded. The circumference of the wheel point is 3 m, resulting in a species recordence every 1.5m. A portable PSION organiser with a statistically justified point sampling programme PLANTS SURVEY<sup>7</sup>, was used to determine plot size. A precision limit of 97% was used, as this made this survey compatible with surveys undertaken in the past (Booyesen unpublished). After every set of 15 points, the programme statistically calculates a comparison index between the previous points and the succeeding set of 15 points. The influence of each addition of 15 points to the data set on the variation index is calculated and the survey is terminated as soon as the comparison index exceeds the variation limit (which was set for 97%) (Jordaan 1997).

Attention was given to the selection of plots, ensuring that the data represents the vegetation in various successional stages. Areas of animal concentration (e.g. areas of preferences, shade), distances from water points, under utilized areas along fences and outside the reserve were chosen. The management units were sampled as follows:

- *Selaginella dregei* - *Oldenlandia herbacea* Open Shrub land → 47
- *Becium obovatum* - *Elionurus muticus* Tall Grassland → 114
- *Ziziphus mucronata* - *Rhus leptodictya* Closed Woodland → 64

In addition certain habitat data were recorded at each sample plot, which included

- Geology: Parent rock was identified and recorded
- Soil Type: Soil type was established according to the classification of the National Soil Classification Working Group, and the soil map (Fig. 5)
- Effective Soil Depth: Effective soil depth was noted
- Slope: The slope was determined in degrees

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- Land Type: The position of the site in the landscape was subjectively determined and expressed as being in landscape 1 (crests), 2 (cliffs), 3 (scree slope), 4 (foot slope) or 5 (drainage lines)
- Aspect (N,E,S,W): The aspect of the slope was determined and noted.
- Stoniness: This was expressed as the percentage of the surface covered by stones; 1; 1 - 10%, 2; >10%

### Data analysis

Data analysis was done using the Integrated System for Plant Dynamics (ISPD) – package (Bosch & Gauch 1991; Booysen & Bosch 1992; Stols *et al.* 1992). The two main factors affecting plant growth and animal production, rainfall and soil type are beyond the control of management. Management options for wildlife managers in natural areas are limited to manipulating the stocking rate or the ratio of the different feeding classes of ungulates on an area/reserve/park, and thereby intensifying or reducing grazing pressure on a system, or the judicious use of controlled burning to change structure or composition of vegetation in an area (Scholes & Walker 1993). In the development of a monitoring system aimed at detecting changes in a system induced by management, an attempt should be made to isolate the effect of the former-mentioned management options on the system. The intent with this monitoring system is to aid the manager to apply the correct management option to obtain the appropriate ecological result and consistently endeavoured to achieve management objectives.

### INTEGRATED SYSTEM FOR PLANT DYNAMICS -ISPD

The ISPD-computer package has been developed as a comprehensive system using new and existing data as basis for veld condition and grazing capacity assessment (Bosch *et al.* 1992a; Bosch *et al.* 1992b). Different computer technologies and statistical analytical procedures were incorporated to develop

an integrated and comprehensive tool which can be used to analyse and develop vegetation models and species response curves.

The system consists of the following modules: (Figure 24)

- ❑ A relational Data Base that handles all the storage needs for the total system (Bosch *et al.* 1992a)
- ❑ The Analytical Module, that use different multiple statistical analytical techniques:
  - DECORANA (Gauch 1982), where two ordination procedures namely Detrended Correspondence Analysis (DCA) and Reciprocal Averaging (RA) is used, and
  - Degradation Model Construction (Bosch & Kellner 1991) that uses Centred Principle Component Analysis (PCA), Standard PCA and Reciprocal Averaging (RA)
- ❑ the Veld Condition Assessment Module, that can determine the condition of an area by means of either a quantitative or qualitative approach (Bosch *et al.* 1992a; Jordaan 1997)
- ❑ the Grazing Capacity Module, that calculates the grazing potential of an area through an expert system approach (Bosch *et al.* 1992a; Jordaan 1997)

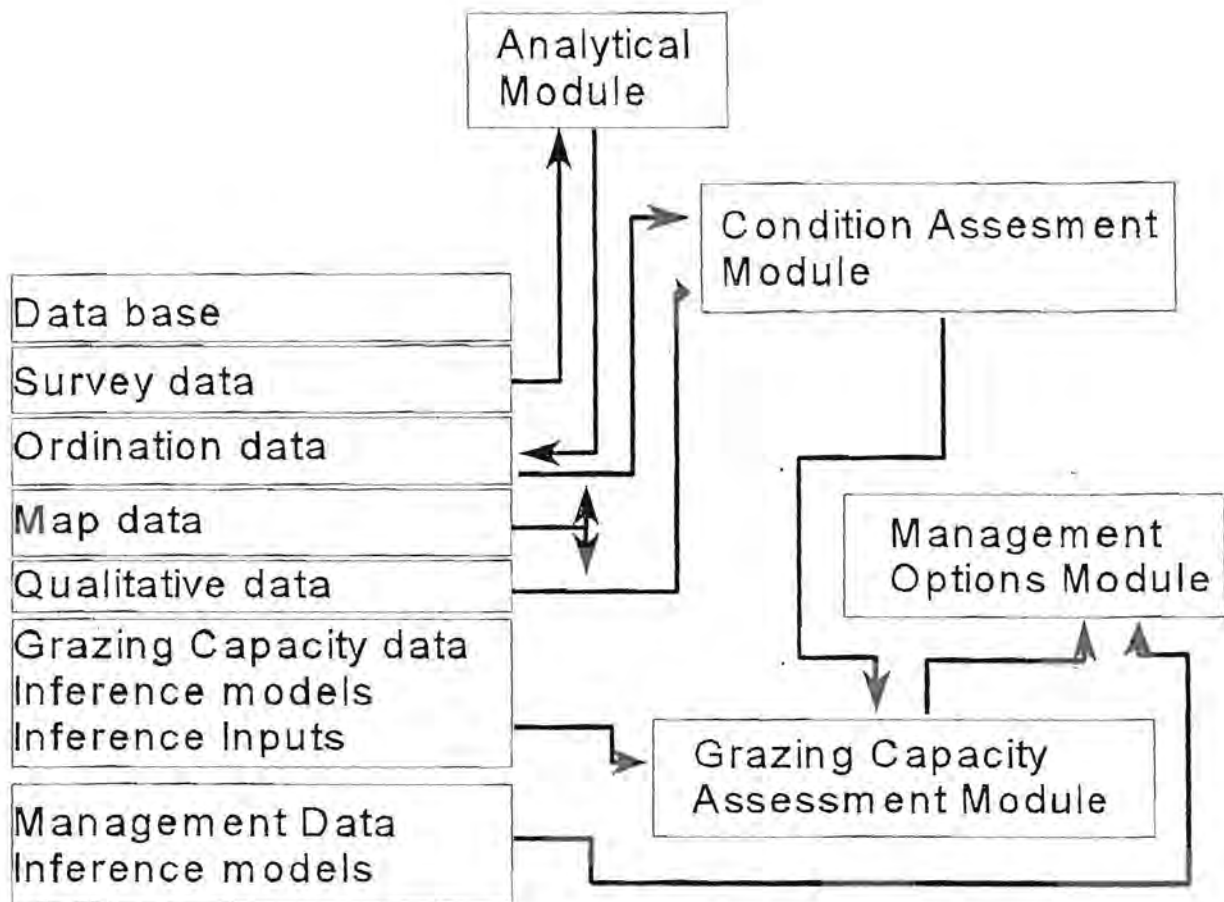


Figure 24: A diagrammatical representation of the ISPD computer system (Bosch *et al.* 1992)



ISPD is developed to be utilized by land managers directly as a decision support system. The main advantages of the system are: (Bosch & Booysen 1992a)

- The interdisciplinary approach ensures that all aspects of vegetation dynamics are considered;
- By integrating the various computer technologies the efficiency of the use of the computer medium is increased;
- Existing data can be used to obtain a workable system;
- The various stages of quantitative and qualitative data allow easy participation of specialists in various disciplines to contribute their knowledge in a particular section;
- The system is developed in such a way that data can be accommodated easy and inexpensive
- All the information needed for decision making are combined in a single outcome, although the opinions of all experts are included.
- The system can be applied universally, regardless of the amount of information available.

### **Identification and development of the vegetation-habitat groups of the three data sets**

Variation in data due to differences in soil characteristics, management history, and time of survey does exist within a relative homogenous management unit. These differences can lead to large variations or noise in data sets (Gauch 1982) which can make the identification of reliable degradation gradients impossible (Bosch *et al.* 1991; Jordaan 1997). In the analysis of this data set, variation in habitat differences was minimized and particular attention was paid to include only vegetation data resulting from different grazing pressures.

Species composition data for each of the management units were ordinated separately to validate and redefine sub-data sets. Each of the three data sets was subjected to Detrended Correspondence Analysis (DCA) (Hill & Gauch 1980) and

Reciprocal Averaging (RA). These ordination procedures are suitable to delineate relative homogenous vegetation units from broad data sets (Bosch *et al.* 1991; Jordaan 1997).

### Definition of a degradation gradient

Quantifying a degradation gradient within each management unit has been done by using **Degradation Model Construction (DMOC)** (Jordaan 1997). DMOC included three ordination methods (Bosch *et al.* unpublished)<sup>8</sup>:

- Standardized Principal Component Analysis;  
*which performs a standardized transformation before a principal component analysis is performed;*
- Centred Principal Component Analysis  
*which performs a centering transformation before a principal component analysis is performed;*
- and Reciprocal Averaging (RA)  
*which performs a repeated weighted averages on species and sample vectors until the two vectors stabilized*

Principle Component Analysis are very useful where ordination of data sets with a relative short vegetation gradient. All three these techniques were compared as each technique accentuate different properties of the data set (Jordaan 1997)

As the vegetation samples were separated by DCA into suitable subsets and the sites were deliberately selected to represent different degrees of vegetation degradation, the principal variation in these subsets ought to be associated with the degradation and were expected to appear on the first axis of the ordinations (Bosch & Gauch 1991; Bosch & Kellner 1991). The remaining (residual) variation should be as small as possible and be attributed to various other smaller effects such as habitat differences, sampling techniques, ect. These degradation

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<sup>8</sup> Bosch, O.J.H., Gaugh, H.G., Booysen, J., Gouws, G.A., Nel, M.W., Stols, S.H.E. and van Zyl, F. Undated. User's Guide. Integrated System for Plant Dynamics.

gradients were confirmed by noting the positions of sites with known grazing histories in the ordinations.

In refining the degradation gradient, sample plots with residuals larger than an arbitrary 50% of the Euclidean length of axis 1 was considered outliers and subsequently discarded from the data matrix (Bosch & Gauch 1991; Bosch & Kellner 1991). The ordination was then repeated.

The responses of species to different levels of grazing impacts were modelled using regression techniques. Species abundance curves on the degradation gradient were fitted separately for each vegetation unit (Janse van Rensburg & Bosch 1990). This was done to determine the ecological status of species under different environmental and physical conditions, and to identify key species that will be used in the interpretation of the degradation gradients in each vegetation unit.

## **Results**

The three data sets were located to new data sets in ISPD and an ordination for each data set was conducted. Both RA and DCA was applied to the data. The results of these ordinations are depicted in figure 25 (a, b & c).



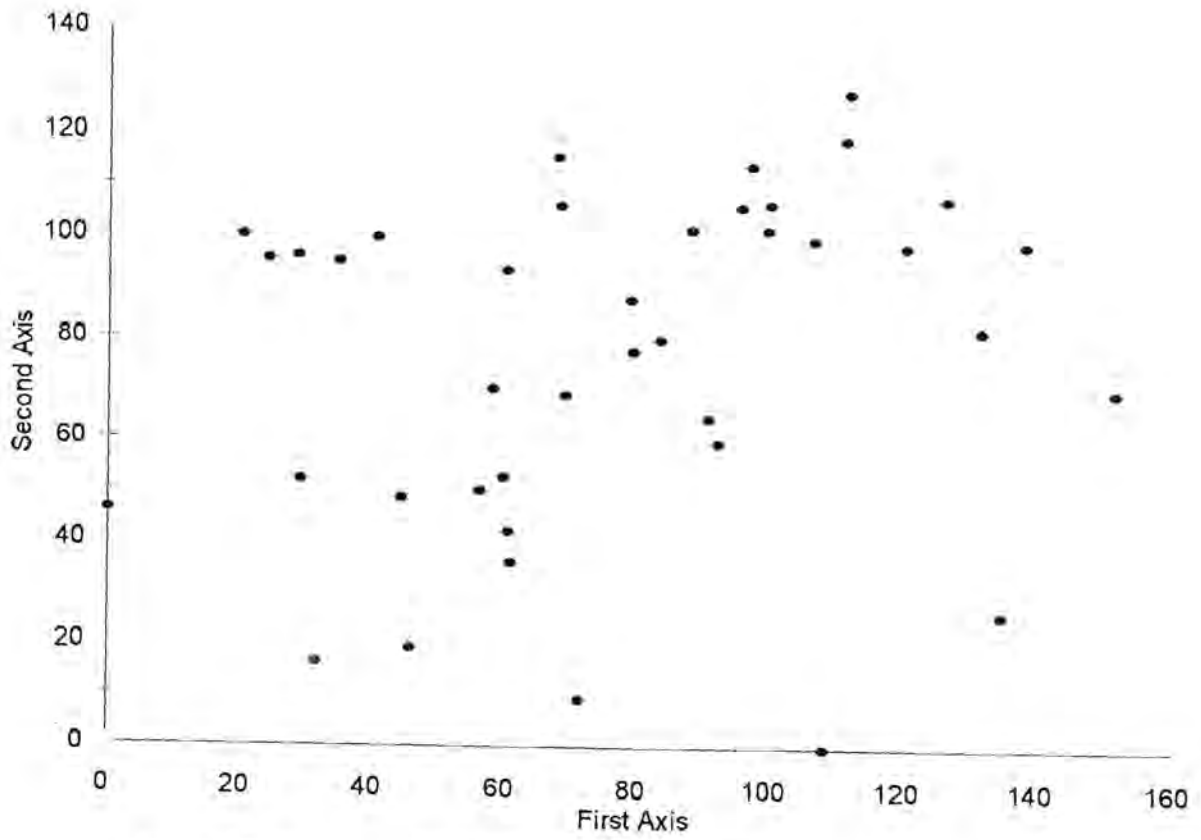


Figure 25 (a): Spatial distribution of the survey sites on the first and second axis of the DCA-ordination for Management unit 1.

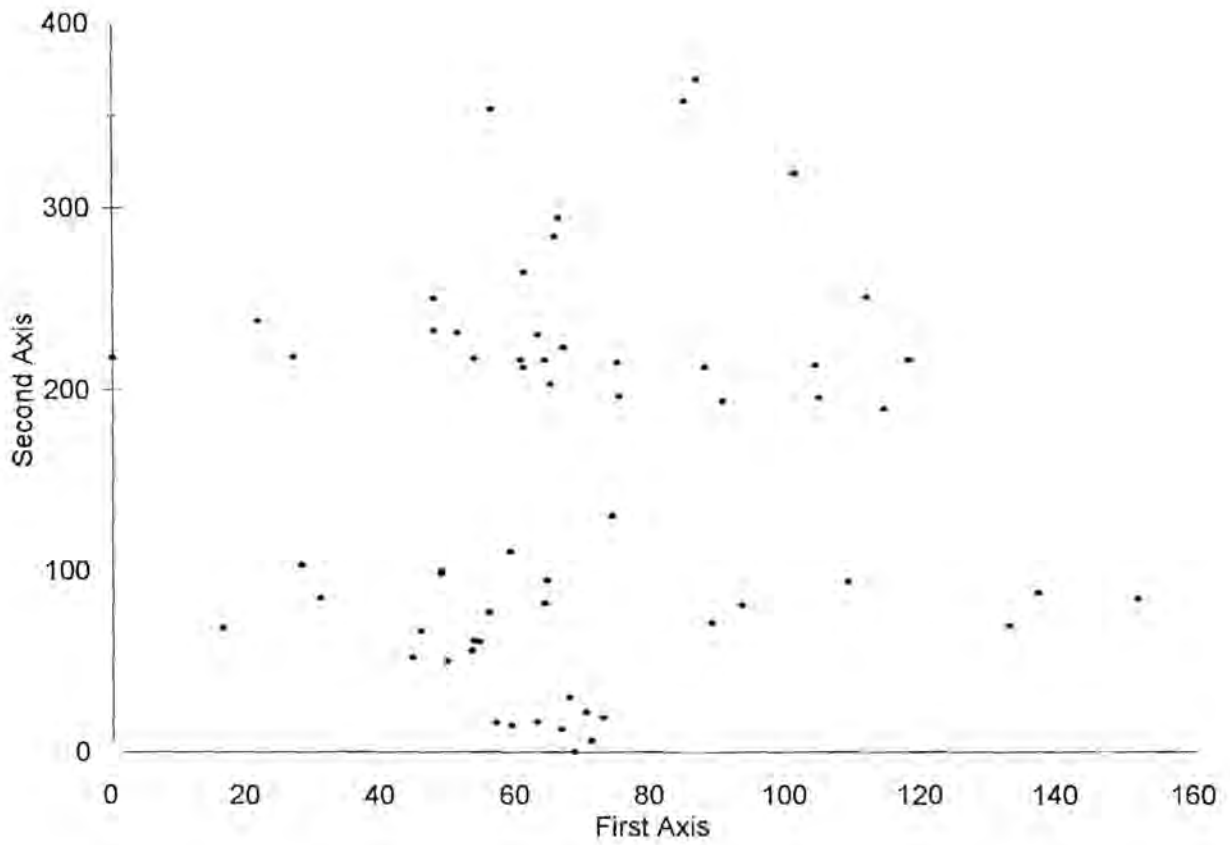


Figure 25 (b) Management Unit 2 (43 sites)

Figure 25 (b): Spatial distribution of the survey sites on the first and second axis of the DCA-ordination for Management unit 2.

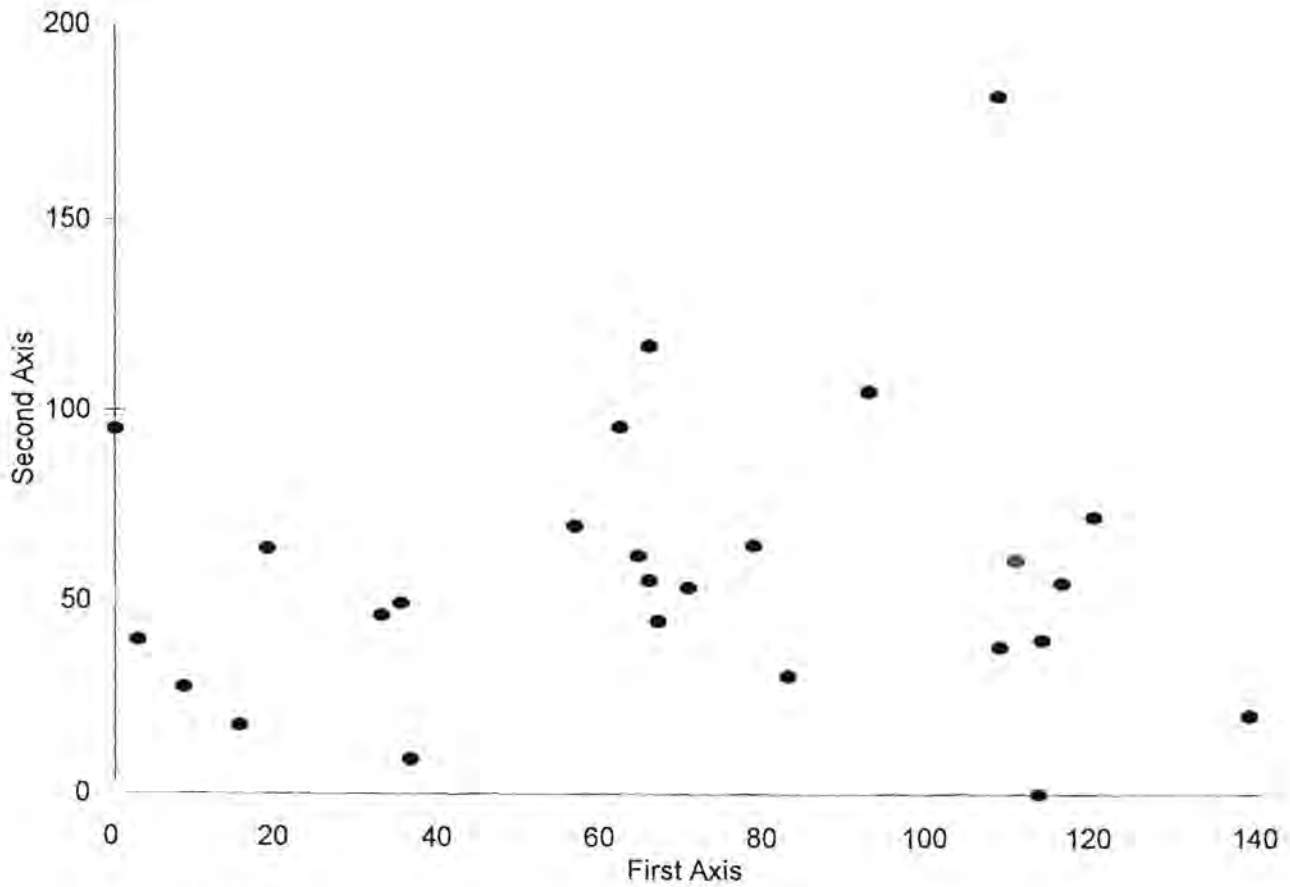


Figure 25 (c) Management Unit 3 (32 sites)

Figure 25 (c): Spatial distribution of the survey sites on the first and second axis of the DCA-ordination for Management unit 3.



These ordinations were refined and outliers were removed until a satisfactory eigen value for each of the ordination could be established. In the final ordination of the three management units 65, 43 and 32 sites respectively were used. From a management point of view the *Becium obovatum* - *Elionurus muticus* Tall Grassland management unit is the most important unit, as it does not only cover the largest area, but is more readily occupied by game. The *Selaginella dregei* - *Oldenlandia herbacea* Open Shrub land management unit is limited to the crests and upper slopes and are inhabited by Mountain Reedbuck and Klipspringers. The *Ziziphus mucronata* - *Rhus leptodictya* Closed Woodland management unit is confined to the bottom lands in the valleys on the reserve and comprise a relative small area on the reserve.

#### **Construction of a degradation gradient for the *Selaginella dregei* - *Oldenlandia herbacea* Open Shrub land - Management Unit I**

The spatial distribution of the sample sites according to the first and second axis of the CPCA, SPCA and RA ordination is illustrated in Figure 26 a, b and c. Evident is that the SPCA and RA (Fig 26 b and c) produced an unsatisfactory distribution of the sites along the first axis. A number of sites were also positioned above the Maximum Acceptable Residual Value. The CPCA (Fig. 26a) displayed an even arrangement of the sites along the first axes, representing the utilization of vegetation at various levels.

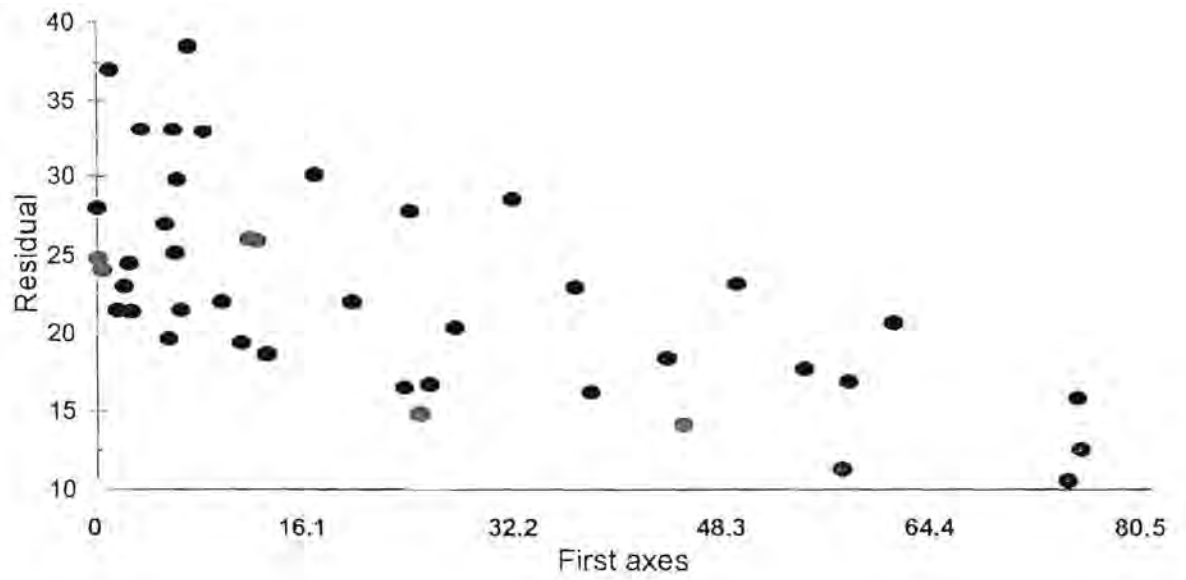
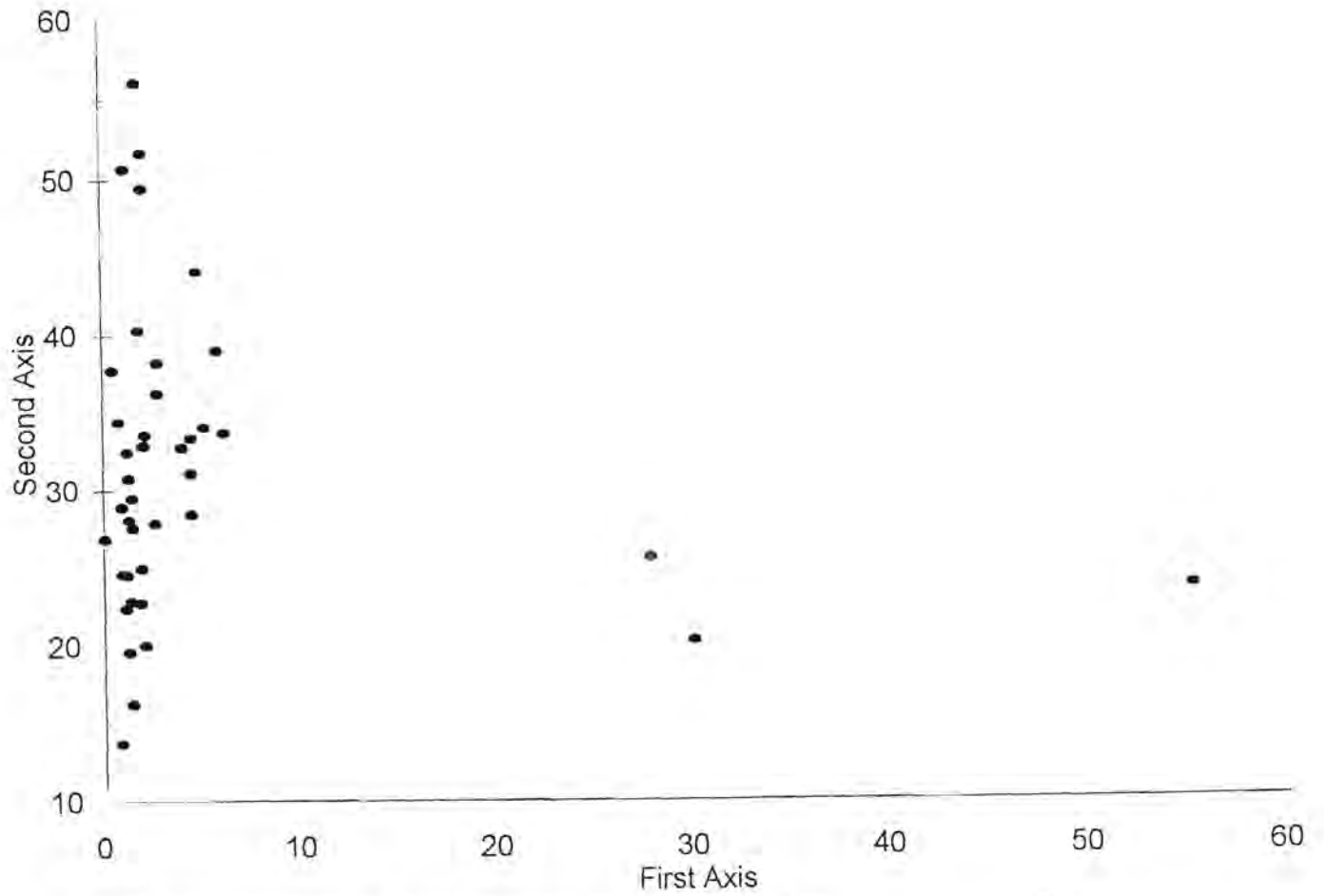


Figure 26(a): The spatial distribution of the sample sites in **Management Unit I** according to the first and second axis of the a Centralized Principal component analyses.



Management unit 1: Results of the Standardized PCA

Figure 26(b): The spatial distribution of the sample sites in **Management Unit I** according to the first and second axis of the Standardized Principal Component Analyses.



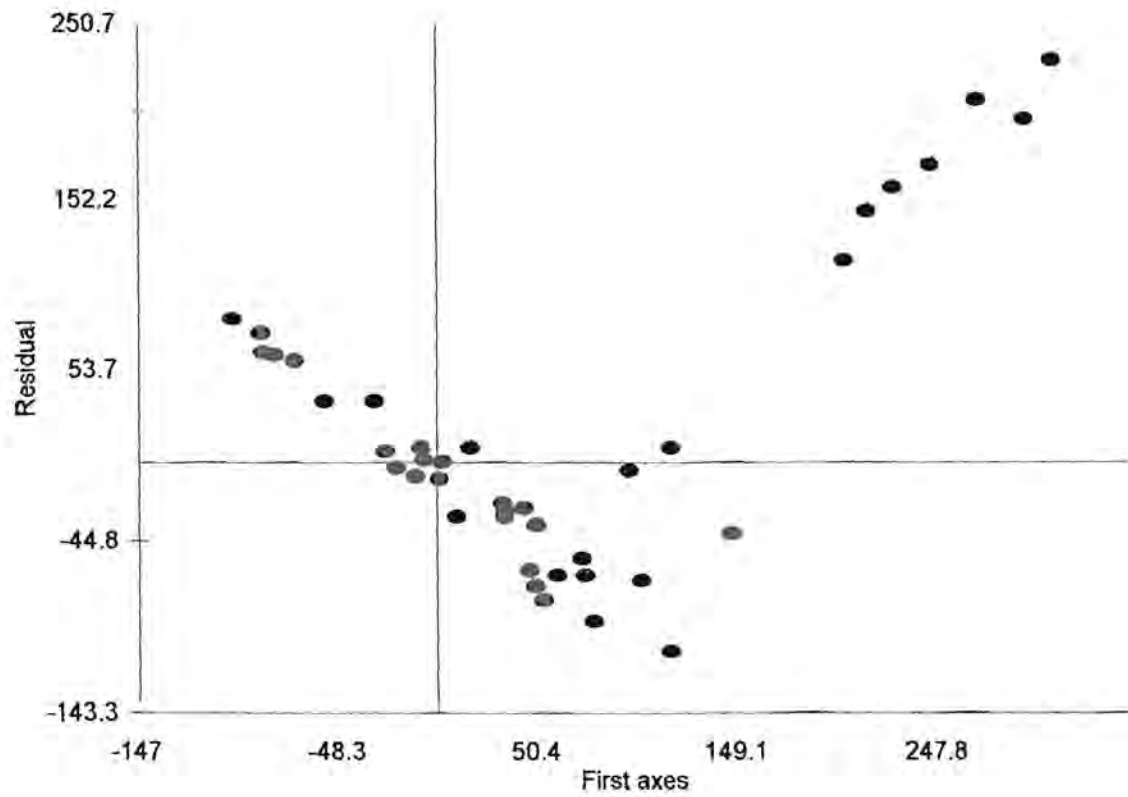
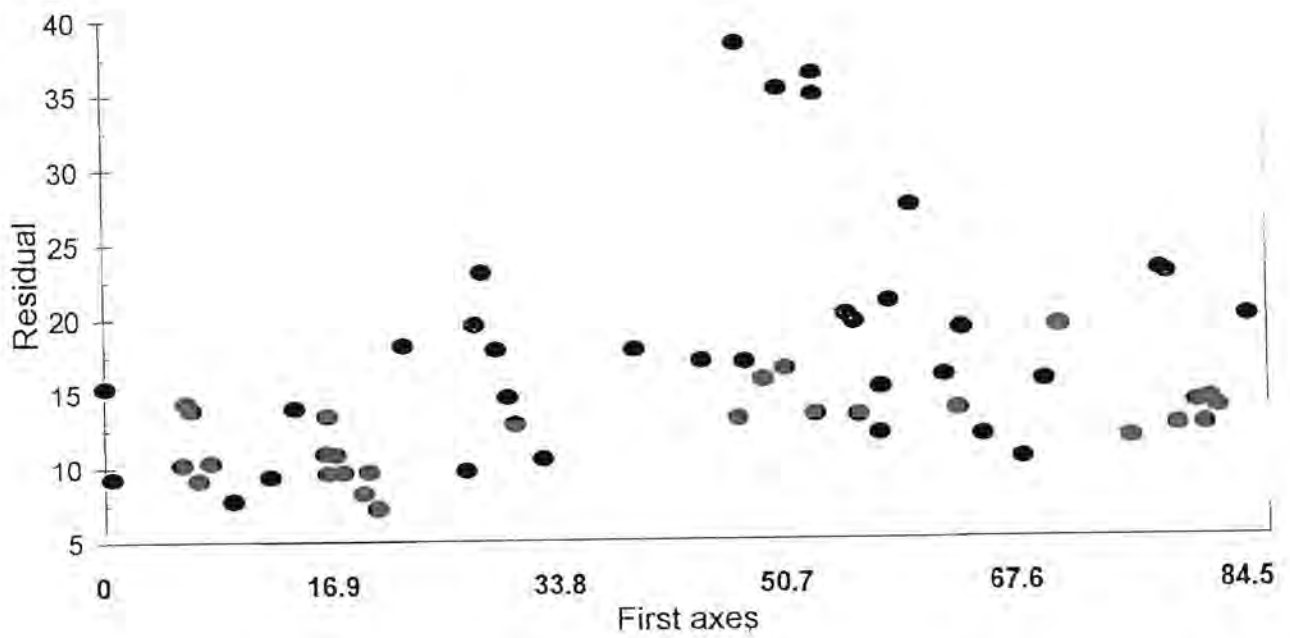


Figure 26(c): The spatial distribution of the sample sites in **Management Unit I** according to the first and second axis of the Reciprocal Averaging ordination.

Variations on the residual axis could be due to various habitat factors, such as clay content, soil depth, aspect, etc. as there still exists considerable variation in this macro unit. It could also be because of different compositions that have developed during the process of change (Bosch & Kellner 1991)

**Construction of a degradation gradient for the *Becium obovatum* -  
*Elionurus muticus* Tall Grassland - Management Unit II**

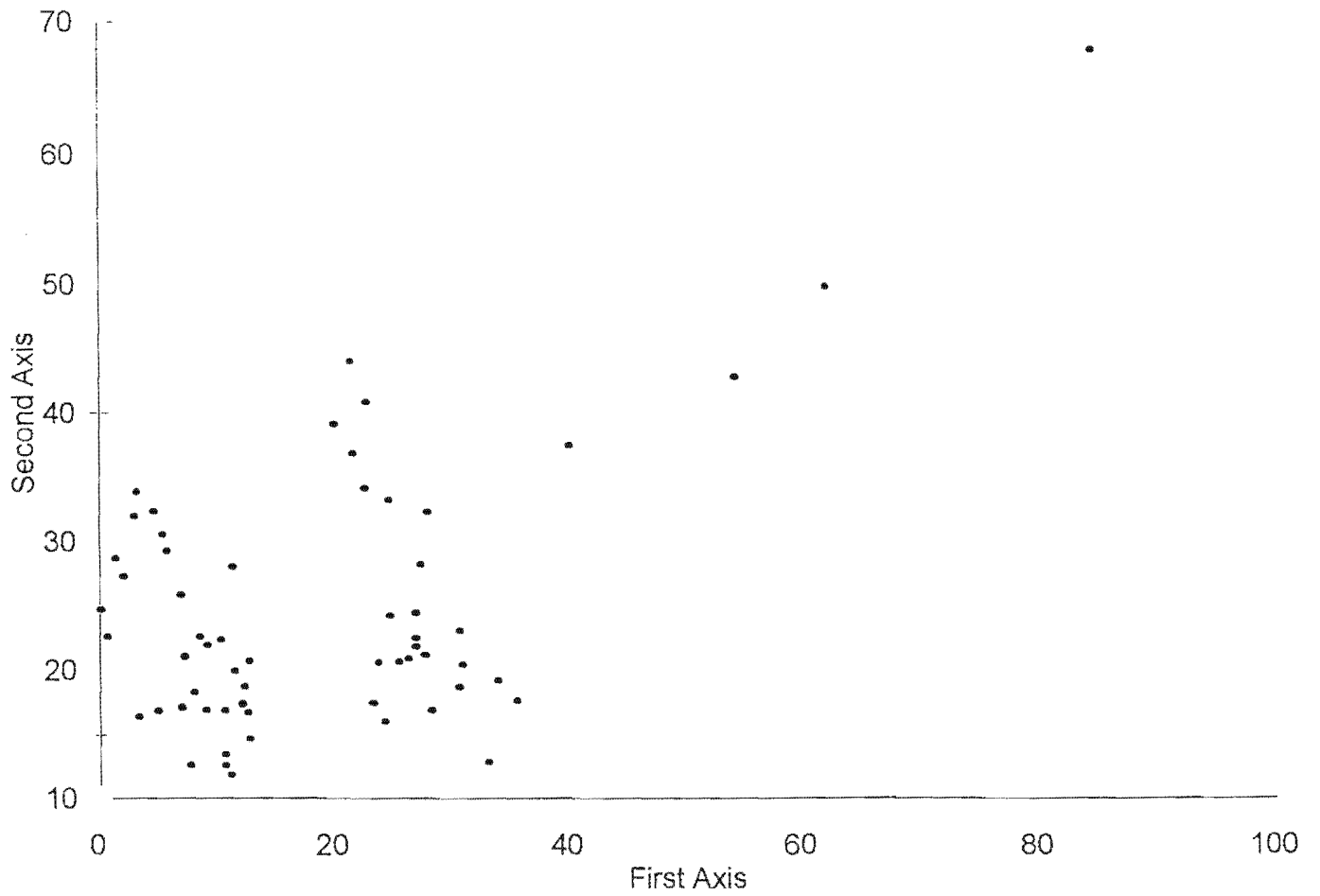
The results of the ordination of Management unit II is shown in Figure 27 a, b and c. Evident from the ordination is that the RA and standardized PCA (SPCA) tend to arrange the survey sites to the left of the scatter diagram (Figure 27 b and c). These ordinations also arranged a number of sites above the Maximum Acceptable Residual value, making the further use of these ordinations impossible. The Centered PCA (CPCA) (Fig 27 a) displayed an even arrangement of the sites along both axes. This is explained in terms of the relative low diversity acquired within each management unit, for which PCA is generally suitable (Bosch & Gauch 1991) . The maximum residual value of the ordination of these sample plots is 38.3.



Management unit 2: Results of the Centralized PCA

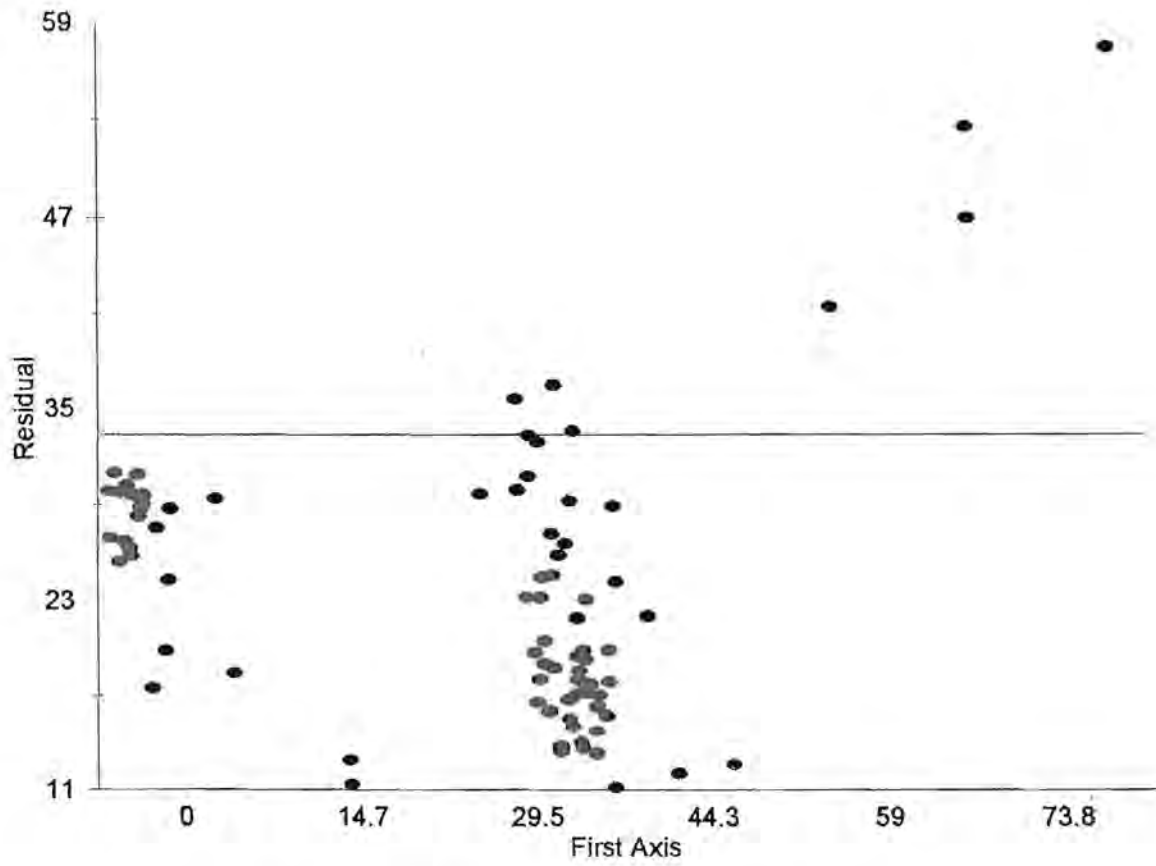
Figure 27(a): The spatial distribution of the sample sites in **Management Unit 2** according to the first and second axis of the Centralized Principal Component Analyses.





Management unit 2: Results of the Standardized PCA

Figure 27(b): The spatial distribution of the sample sites in **Management Unit 2** according to the first and second axis of the Standardized Principal Component Analyses



Management unit 2: Results of the Reciprocal Averaging ordination

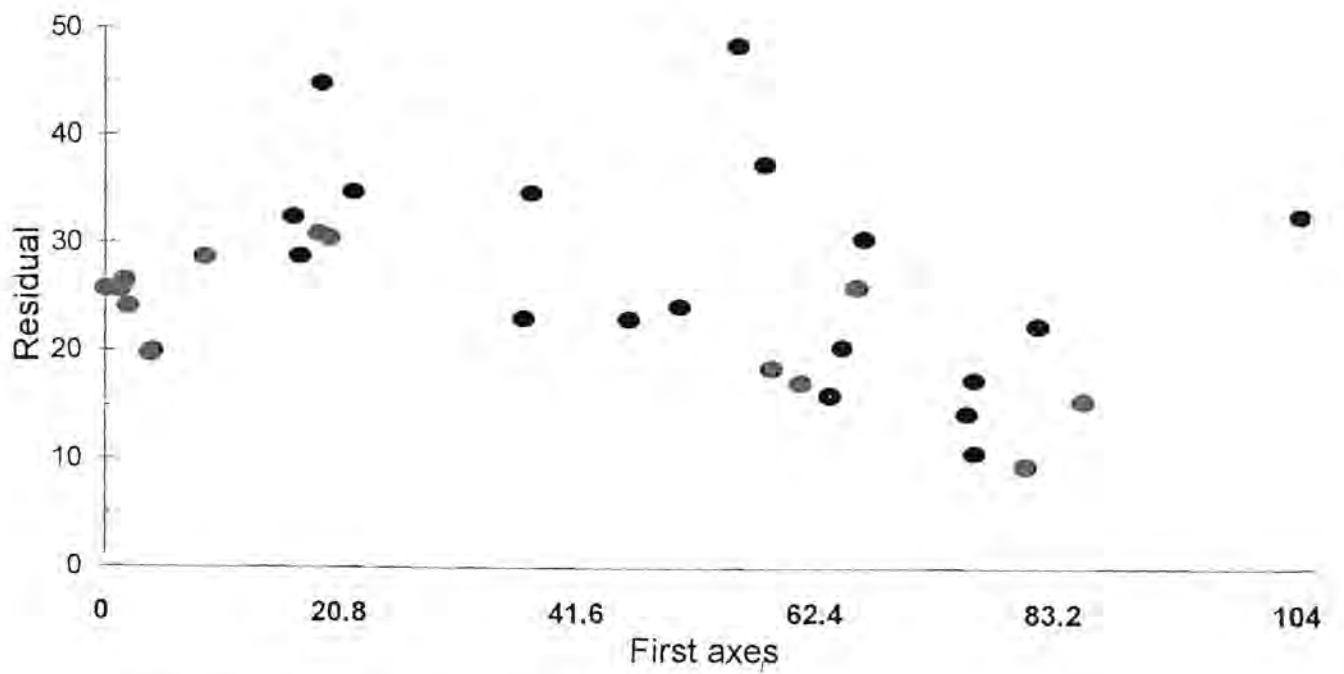
Figure 27(c): The spatial distribution of the sample sites in **Management Unit 2** according to the first and second axis of the Reciprocal Averaging.

The first axis of the CPCA ordination (Fig 27 a) represents a degradation gradient from left to right. The ungrazed plots are spatially distributed to the left of the scattered diagram, while the plots in grazed areas are located to the right of the diagram. The distribution of the plots along the first axis from ungrazed to grazed are confirmed by notes made during fieldwork on the level of utilization of the plots by game. No data on long term grazing pressures could be obtained and the gradient is therefore only described as varying from ungrazed to grazed. Species compositional data on the extremes of the gradient (severely grazed and ungrazed) were also not available and thus the gradients only represent the middle sector (moderately utilized to moderately unutilized) of a possible longer degradation gradient.

**Construction of a degradation gradient for the *Ziziphus mucronata* -  
*Rhus leptodictya* Closed Woodland - Management Unit III**

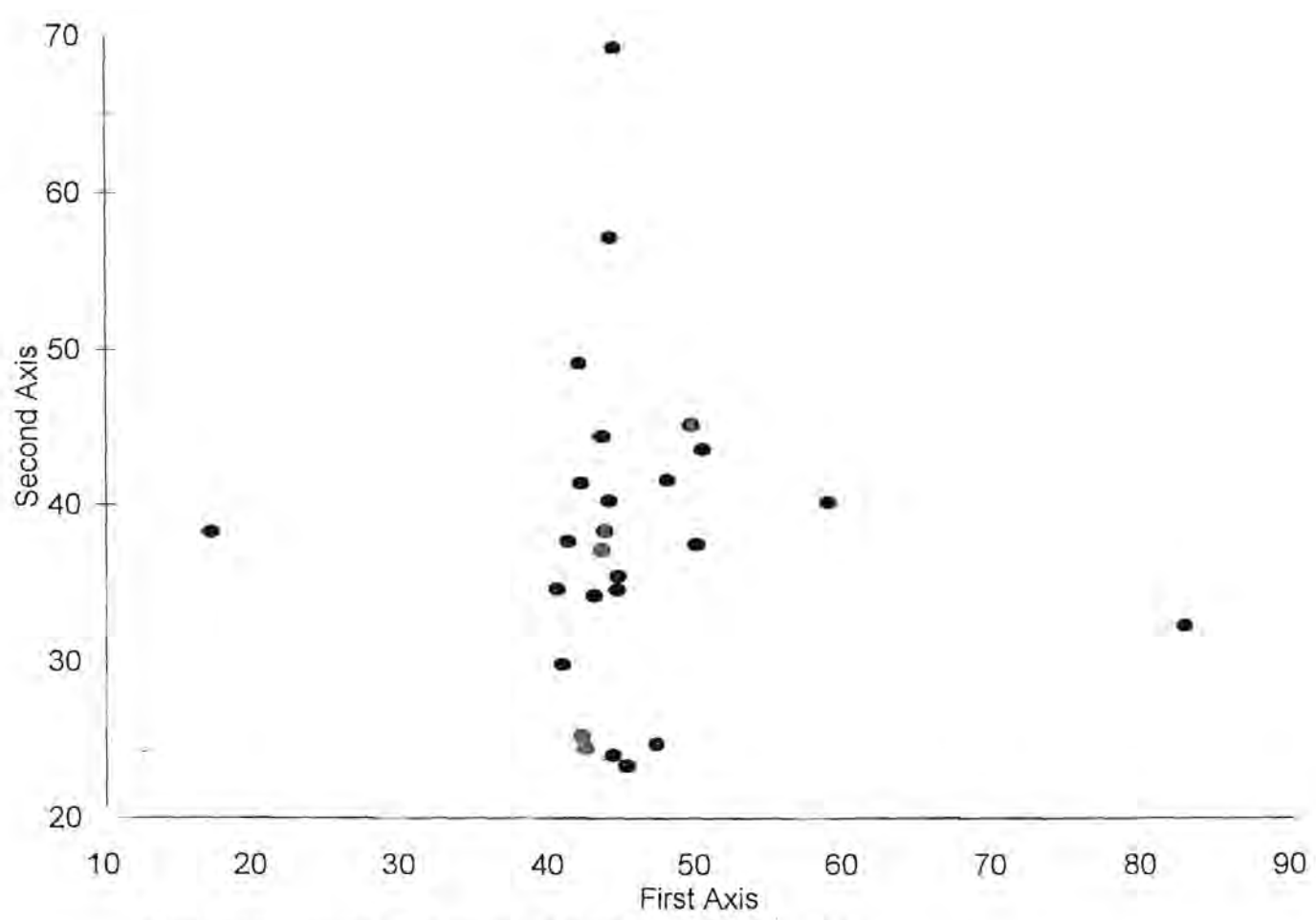
The results of the CPCA, SPCA and RA ordination in this unit is given in Figure 28 a,b & c respectively. The results obtained with SPCA and RA (Fig 28 b and c) in this unit are unsuitable for the construction of a degradation gradient. CPCA (Fig 28 a) provided better results with a maximum residual value of 48.5.





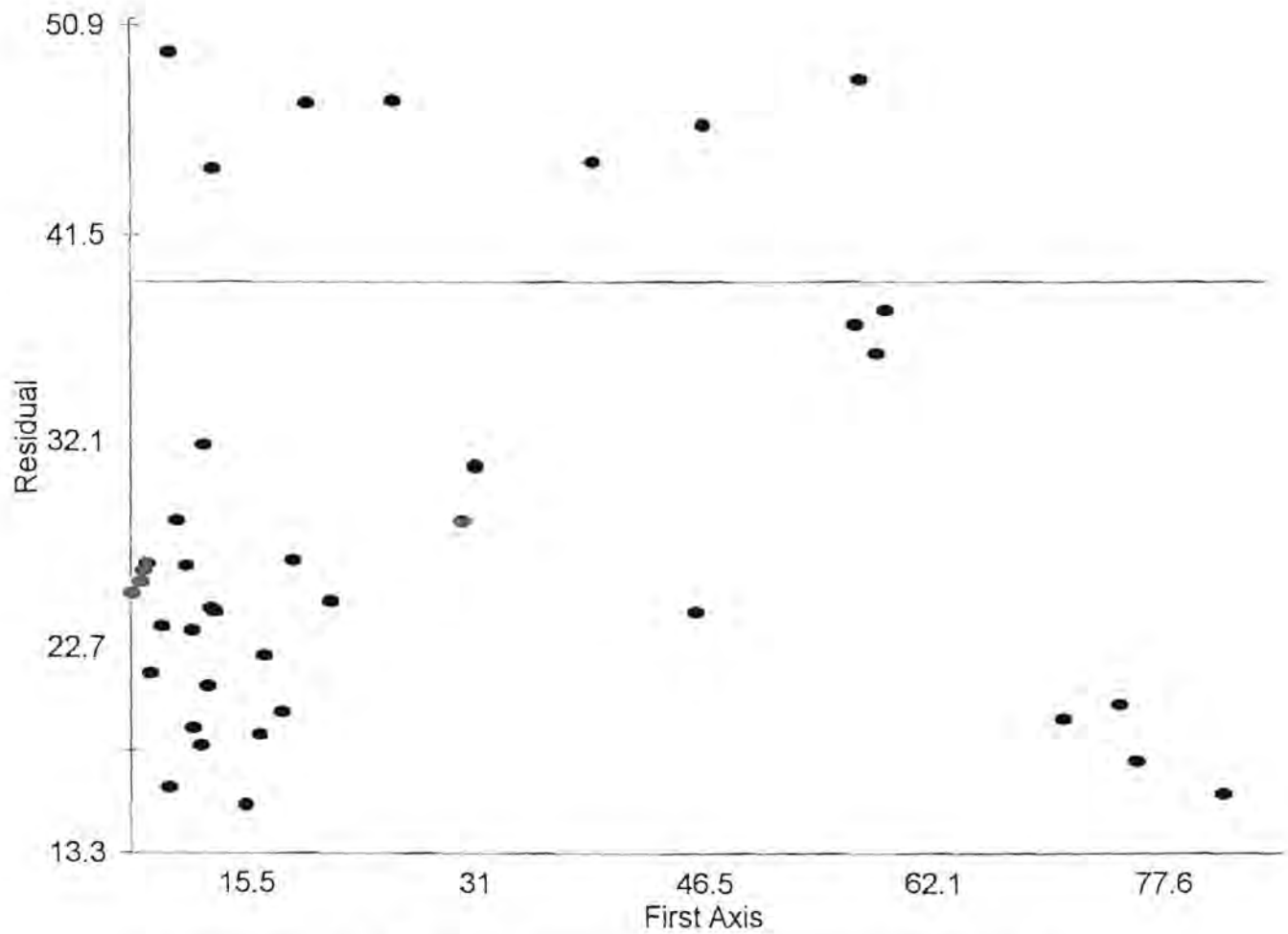
Management unit 3: Results of the Centralized PCA

Figure 28(a): The spatial distribution of the sample sites in **Management Unit 3** according to the first and second axis of the Centralized Principal Component Analyses



Management unit 3: Results of the Standardized PCA

Figure 28(b): The spatial distribution of the sample sites in Management Unit 3 according to the first and second axis of the Standardized Principal Component Analyses.



Management unit 3: Results of the Reciprocal Averaging ordination

Figure 28(c): The spatial distribution of the sample sites in **Management Unit 3** according to the first and second axis of the Reciprocal Averaging ordination.



It was noted that more variation occurs in this unit than the other two. This variation can be attributed to dissimilarities in various habitat factors, such as clay content, soil depth, aspect, which, from a practical management point of view, had to be merged.

### **Identification of key species in different vegetation units**

Regression analysis was used to establish the reaction of the individual species to the process of change of vegetation due to herbivory. Gaussian models provided the best fit for species abundance data on the degradation gradients. Species with a low index of agreement (D-statistics; Wilmott 1982) were regarded as non-responsive to the process of retrogression of vegetation caused by grazing. These species cannot be considered as indicators of the probable position of a site along the degradation gradient. The result of the ordination of the species according to their response to different levels of grazing is illustrated in table 10.

Table 10 Identification of key species in the different vegetation units based on their response to grazing.

Category	Species	Management unit 1 D-stat	Management unit 2 D-stat	Management unit 3 D-stat
Decreasers	<i>Urelytrum agropyroides</i>	0.766	-	-
	<i>Eustachys paspaloides</i>	-	-	0.566
	<i>Aristida junciformis</i>	0.934	-	-
	<i>Hyparrhenia tamba</i>	-	-	0.819
	<i>Heteropogon contortus</i>	-	-	0.925
	<i>Eragrostis lehmanniana</i>	-	-	0.997
	<i>Eragrostis chloromelas</i>	0.994	0.509	-
	<i>Brachiaria brizantha</i>	-	-	0.94
	<i>Loudetia simplex</i>	0.843	-	-
	<i>Melinis nerviglumis</i>	0.562	-	0.994
	<i>Aristida transvaalensis</i>	0.57	-	-
	<i>Schizachyrium sanguineum</i>	0.669	-	-
	<i>Tristachya leucotrix</i>	0.537	0.813	-
	<i>Bewisia biflora</i>	-	0.817	-
	<i>Aristida congesta barbicollis</i>	-	-	0.784
	<i>Triraphis andropogonooides</i>	0.853	0.952	-
	<i>Eragrostis nindensis</i>	0.668	-	-
	<i>Digitaria eriantha</i>	-	0.998	0.989
	<i>Setaria sphacelata</i>	-	-	0.973
	<i>Themeda triandra</i>	-	0.994	0.961
Increaser 1	<i>Aristida junciformis</i>	0.926	-	-
	<i>Bewisia biflora</i>	0.985	-	-
	<i>Andropogon schirensis</i>	0.998	-	-
	<i>Setaria sphacelata</i>	0.967	0.621	-
	<i>Tristachya rehmannii</i>	0.736	-	-
	<i>Eragrostis racemosa</i>	0.666	-	-
	<i>Schizachyrium sanguineum</i>	0.895	-	-
<i>Digitaria eriantha</i>	0.974	-	-	

Category	Species	Management unit 1 D-stat	Management unit 2 D-stat	Management unit 3 D-stat
	<i>Eragrostis curvula</i>	0.979	-	-
	<i>Andropogon schirensis</i>	0.999	-	-
	<i>Setaria nigrirostris</i>	-	0.613	-
	<i>Trachypogon spicatus</i>	-	-	0.944
	<i>Asclepias aurea</i>	-	0.791	-
	<i>Cymbopogon excavatus</i>	0.591	-	-
	<i>Heteropogon contortus</i>	0.566	-	-
	<i>Panicum coloratum</i>	-	0.999	-
	<i>Hermannia depressa</i>	-	0.956	-
	<i>Eragrostis rigidior</i>	-	-	0.989
	<i>Setaria pallide-fusca</i>	-	0.999	-
	<i>Elephantorrhiza elephantina</i>	-	0.5	-
	<i>Hyparrhenia hirta</i>	-	0.994	-
	<i>Tristachya rehmannii</i>	-	0.781	-
	<i>Eragrostis chloromelas</i>	-	0.509	-
	<i>Urelytrum agropyroides</i>	-	0.828	-
	<i>Themeda triandra</i>	0.835	-	-
Increaser 2	<i>Aristida congesta barbicollis</i>	-	0.849	-
	<i>Aristida congesta congesta</i>	-	0.999	-
	<i>Diheteropogon amplexans</i>	-	0.469	-
	<i>Cymbopogon excavatus</i>	0.871	-	-
	<i>Tagetes minuta</i>	-	-	0.586
	<i>Eragrostis chloromelas</i>	-	-	0.795
	<i>Hyparrhenia hirta</i>	-	-	0.566
	<i>Parinari capensis</i>	-	0.956	-
	<i>Heteropogon contortus</i>	-	0.926	-
	<i>Eustachys paspaloides</i>	-	0.888	-
	<i>Pogonarthria squarrosa</i>	-	-	0.928
Increaser 3	<i>Eragrostis racemosa</i>	0.894	0.903	-
	<i>Indigofera melionodes</i>	-	0.577	-
	<i>Cyperus rupestris</i>	-	0.595	-

Category	Species	Management unit 1 D-stat	Management unit 2 D-stat	Management unit 3 D-stat
Increaser 4	<i>Schizachyrium sanguineum</i>	-	0.472	-
	<i>Elephantorrhiza elephantina</i>	-	0.5	-
	<i>Brachiaria nigropedata</i>	-	0.923	-
	<i>Cymbopogon plurinodes</i>	-	0.903	-
	<i>Coleocloa setifera</i>	0.994	-	-
	<i>Bulbostylis burchellii</i>	-	0.781	-
	<i>Sporobolus africanus</i>	-	-	0.984
Non responsive	<i>Cynodon dactylon</i>	-	-	0.993
	<i>Aristida transvaalensis</i>	-	0.421	-
	<i>Brachiaria serrata</i>	0.245	0.269	-
	<i>Trachypogon spicatus</i>	0.348	0	-
	<i>Melinis repens</i>	-	0.25	-
	<i>Elionurus muticus</i>	-	0.413	-
	<i>Diheteropogon amplexans</i>	0.46	-	-
<i>Eragrostis chloromelas</i>	0.459	-	-	
	<i>Panicum maximum</i>	-	-	0.372

It was possible to establish the individual species reaction to degradation and according to the Gaussian curve obtain through the regression analysis, responsive species could be divided into Decreasers, Increaser 1, Increaser 2, Increaser 3 and Increaser 4 categories. (Janse van Rensburg 1987; Janse van Rensburg & Bosch 1990; Jordaan 1997).

- **Decreasers:** *Species that occur in veld which is lightly to moderately utilized, but decreases in abundance when the vegetation is over-utilized.*
- **Increaser 1:** *Species that occur in veld which is not utilized, or under-utilized and increase in abundance when the vegetation is continuously under-utilized.*
- **Increaser 2:** *Species that do not occur in well-managed veld, and increases in abundance when the vegetation is moderately*



*over-utilized.*

- **Increaser 3:** *Species that do not occur in well-managed veld, and increases in abundance when the vegetation is moderately to seriously over-utilized.*
- **Increaser 4:** *Species that do not occur in well-managed veld, and increases in abundance when the vegetation is seriously over-utilized.*

The responses of these species are indicated in Figure 29, 30 and 31. A definite pattern in the occurrence of certain species along the degradation gradient in the different management units can be noticed. It is also evident from these analysis that species responded differently to grazing impacts under different physical and environmental conditions (Bosch & Janse van Rensburg 1987). *Urelytrum agropyroides*, *Eustachys paspaloides*, *Heterpogon contortus*, *Digitaria eriantha*, *Themeda triandra*, *Setaria sphacelata*, *Eragrostis curvula* and *Triraphis andropogonoides* can be classified into more than one category, indicating that they react differently to grazing in the three different management units. Each management unit also demonstrated a different set of key species indicating the level of utilization of that particular management unit. Certain key species also responded inconsistent to degradation between the different management units.

Also evident from these species response curves are the misperception that species tend to react similar to grazing impact and that a generally accepted ecological status can therefore be allocated to it (Vorster 1982; Tainton 1988; Pauw 1989; van Oudtshoorn 1992; Smith 1992; Nel 1992). *Brachiaria serratta*, *Trachypogon spicatus*, *Melinis repens*, *Elionurus muticus*, *Panicum maximum*, *Diheteropogon amplexans* and *Eragrostis chloromelas* are species which have historically been classified into very specific ecological classes, but did not show any significant response to grazing impact in this study ( $D < 0.500$ ). This confirms that the broad standardization of species is of no real value in the objective interpretation of monitoring results (Janse van Rensburg & Bosch 1990; Jordaan 1997)

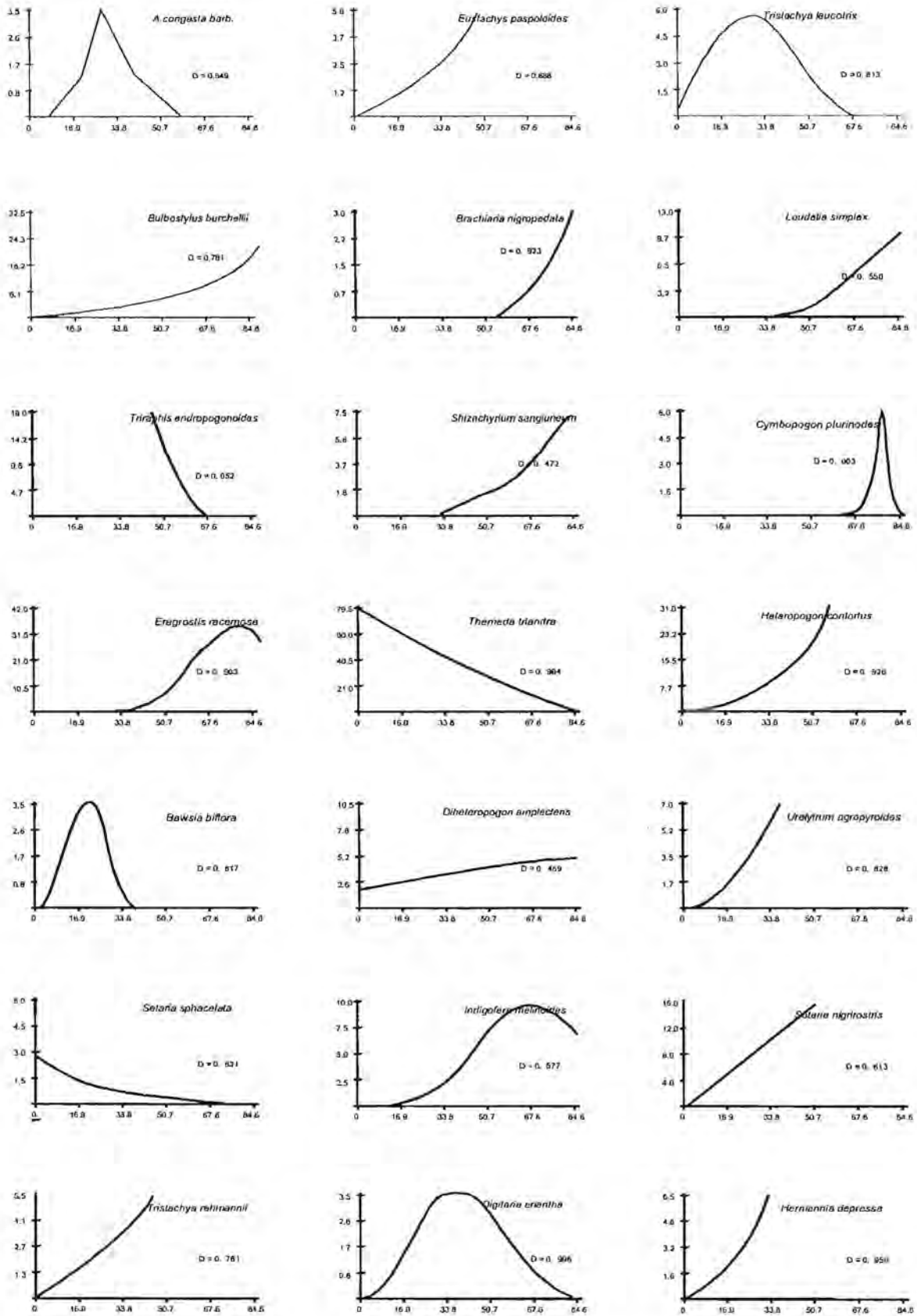


Fig 29: The classification of individual species in Management Unit I according to their response to different levels of utilization

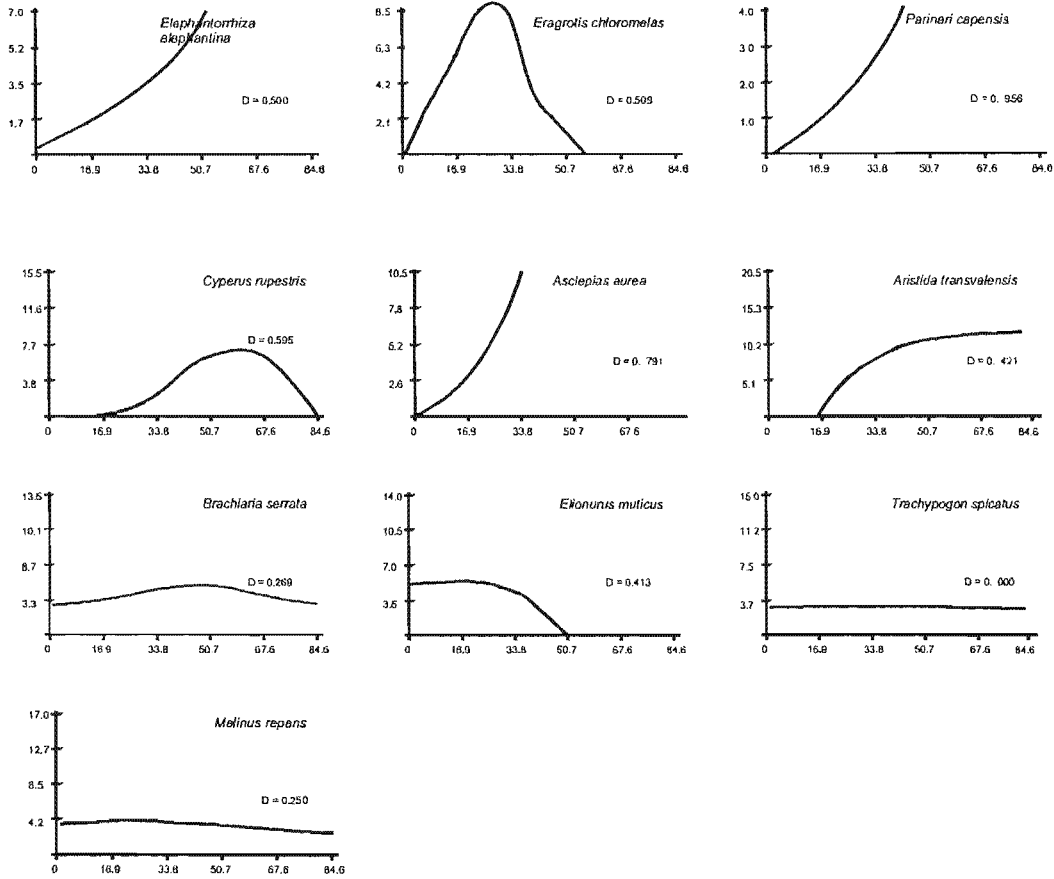


Fig 29 (cont.): The classification of individual species in Management Unit I according to their response to different levels of utilization

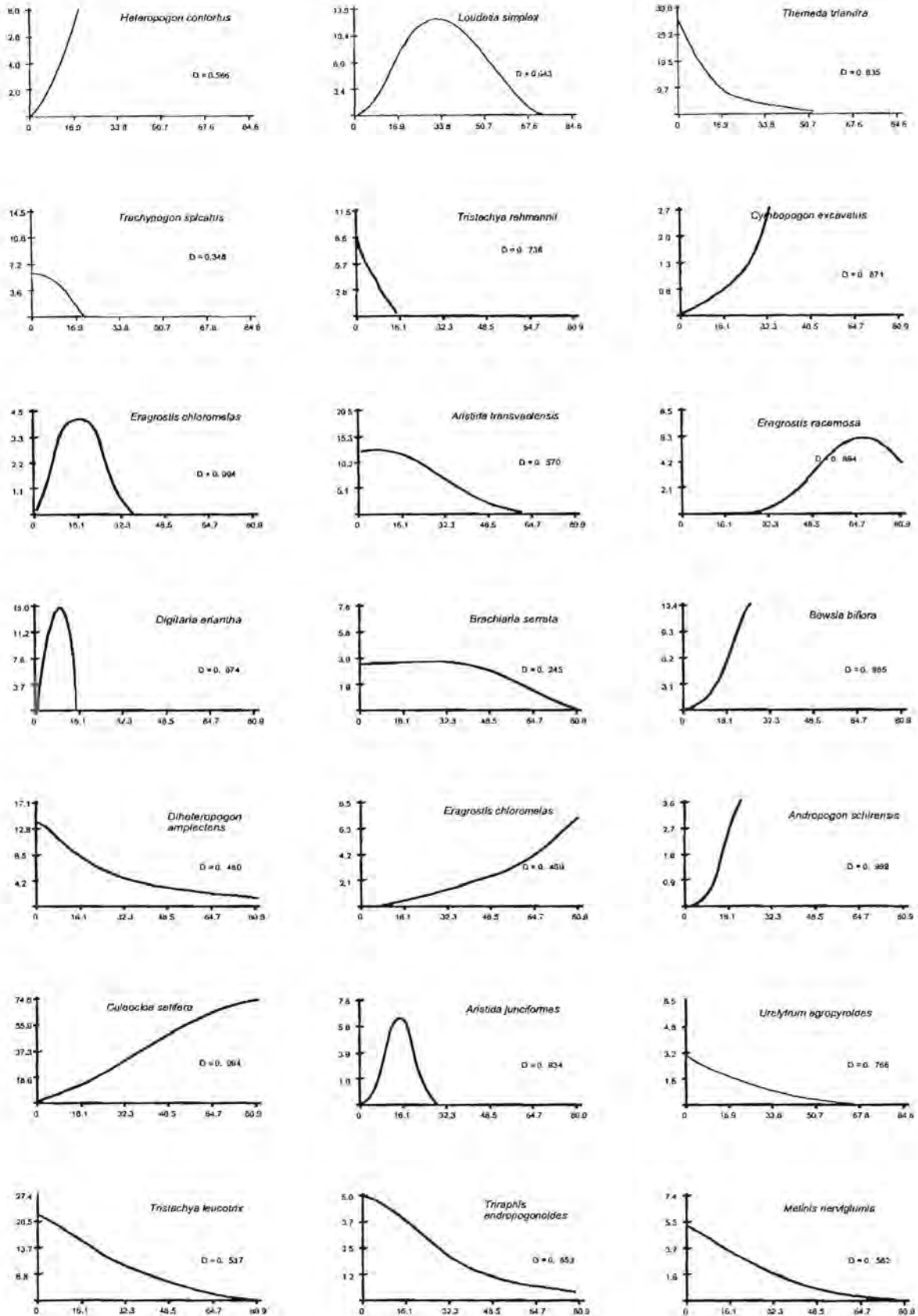


Fig 30: The classification of individual species in Management Unit II according to their response to different levels of utilization



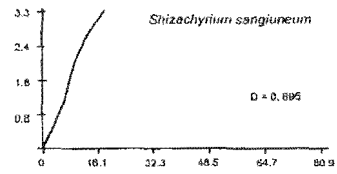
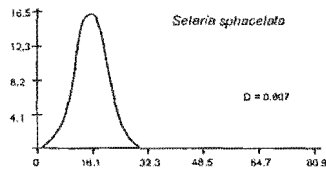
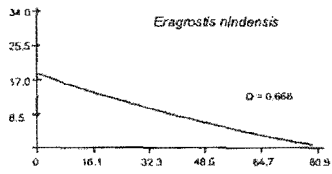


Fig 30(cont): The classification of individual species in Management Unit II according to their response to different levels of utilization

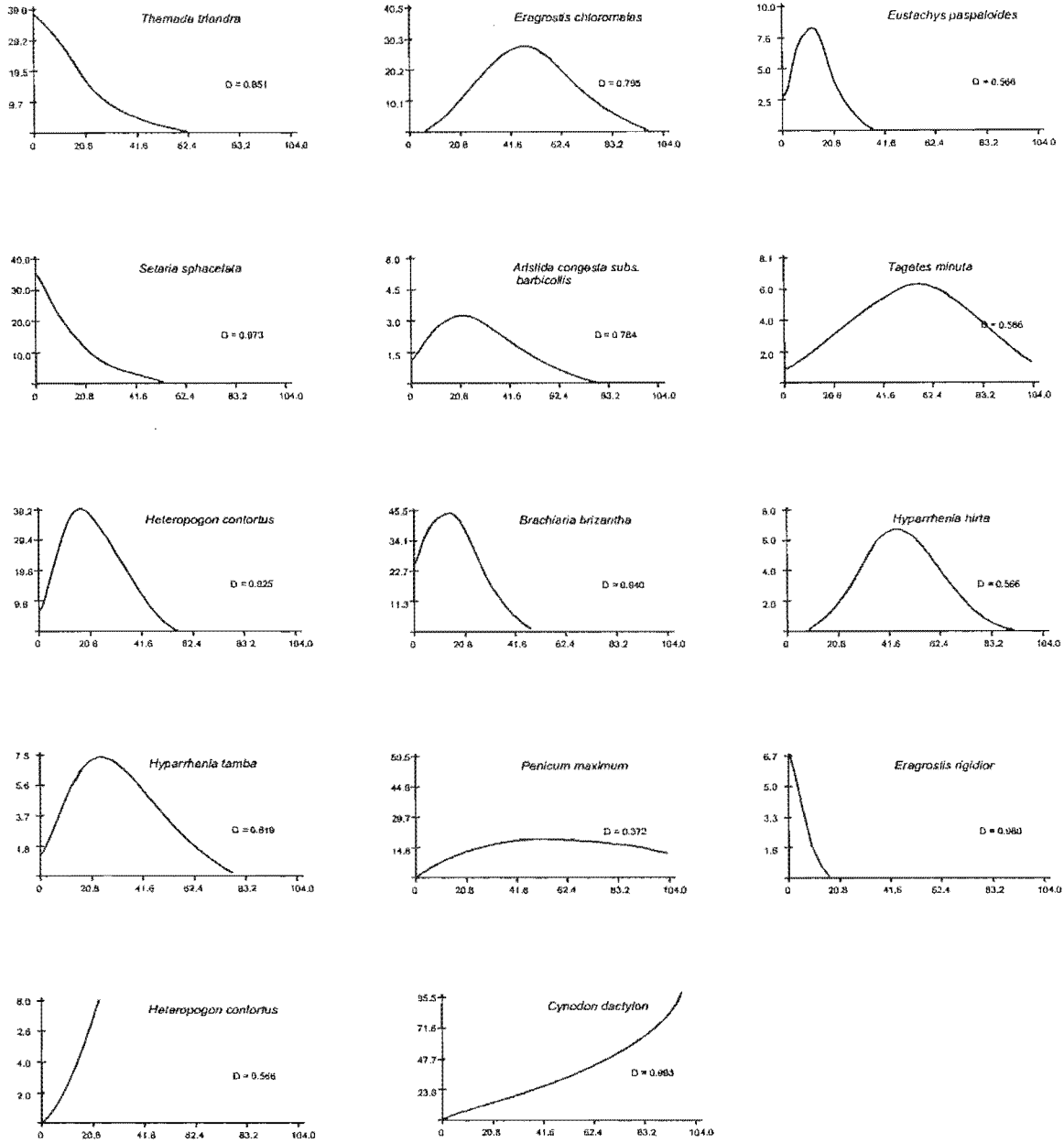


Fig 31: The classification of individual species in Management Unit III according to their response to different levels of utilization

## DESCRIPTION OF THE DEGRADATION GRADIENT FOR THE MANAGEMENT UNITS AS A BASIS FOR INTERPRETATION OF MONITORING RESULTS

The degradation gradients will act as basis for an objective interpretation of results obtained during the monitoring of the condition of the vegetation in the different units. The abundance value of the different key species which was identified for the different management units will be used to describe the changes taking place along the degradation gradient.

The X-axis is subjectively divided into five utilization categories, providing a guideline to management to interpret the condition of a site according to its position along the degradation gradient. The five utilization categories are (Jordaan 1997):

- lightly utilized
- lightly to moderately utilized
- moderately utilized to moderately over-utilized
- moderately to seriously over-utilized
- seriously over-utilized.

The degradation gradient in each management unit were evaluated according to the ecological objectives of the reserve: (Chapter 2)

- Presence of the different categories of herbaceous species, which are an indication of the stability of the whole system, and the
- occurrence of erosion in the more utilized sectors of the degradation gradient, both which will influence the quality and amount of effluent from this catchment.
- The amount of plant species present in each utilization sector and the
- general ability of that unit to sustain wildlife in its various forms,

which relates to the objective of promoting and sustaining biological diversity on the reserve.

### **MANAGEMENT UNIT I - *Selaginella dregei* - *Oldenlandia herbacea* Open Shrubland**

The results of the CPCA ordination for Management Unit I are displayed in Figure 32. The sites associated with more utilized veld is positioned to the right of the ordination, while those associated with less utilized veld is situated to the left of the ordination. The under-utilized sector of the degradation gradient is characterise by a diversity of herbaceous species. Species diversity decreases significantly along the degradation gradient.

*Setaria sphacelata*, *Tristachya rehmannii* and *Themeda triandra* dominate the species composition in the under-utilized sector of the degradation gradient. In this management unit these species decrease along the degradation gradient, but increases in abundance when the veld is not utilized. These species are classified as Increaser I species (Janse van Rensburg 1987; Jordaan 1997), species that increase in abundance when the veld is under-utilized. The high abundance of species such as *Themeda triandra* and *Setaria sphacelata* in the unutilized sector of the degradation gradient was also found by Bosch & Kellner (1991).

The lightly and moderately utilized sector is dominated by *Aristida junciformis*, *Loudetia simplex*, *Melinis nerviglumis*, *Aristida transvaalensis*, *Triraphis andropogonoides* and *Eragrostis nindensis*. These species all prefer poor sandy soils associated with shallow rocky slopes (van Oudtshoorn 1992) of the Magaliesberg. These species decreases in abundance along the degradation gradient and have been classified as Decreaser-species (Janse van Rensburg 1987; Jordaan 1997).

Species diversity decreases significantly along the degradation gradient in this management unit (Figure 33). Except for the non-responsive species (D-stats < 0.5) *Brachiaria serratta*, *Diheteropogon amplexans*, *Melinis repens*, *Cymbopogon*



*validus* and *Triraphis andropogonoides* the species composition in the moderately utilized, moderately seriously over-utilized and seriously over-utilized sectors of the degradation gradient is limited to the forb *Coleocloa setifera*. This species is markedly absent in the under-utilized sector of the degradation gradient. It is classified as an Increaser IV, a species that do not occur in well-managed veld, and increases in abundance when the vegetation is seriously over-utilized.

Figure 33 displays the relation between the number of plant species in the sample plots and its position along the degradation gradient. In this management unit plant species diversity seems to be significant higher in the under-utilized sector of the degradation gradient than in the lightly- to severely-utilized sectors. This corresponds with the findings by Foran (1976) in the Dry tall Grassveld, Moist tall grassveld and the Mistbelt.

Figure 34 shows the ordination of the sample plots, indicating the amount of erosion. No significant erosion were recorded in this management unit. This is due to the large areas of open bedrock and shallow soils underlying this management unit and *Coleocloa setifera*, being a densely tufted perennial (van Wyk & Malan 1988), is seemingly able to colonize and stabilized bare areas of bedrock effectively.



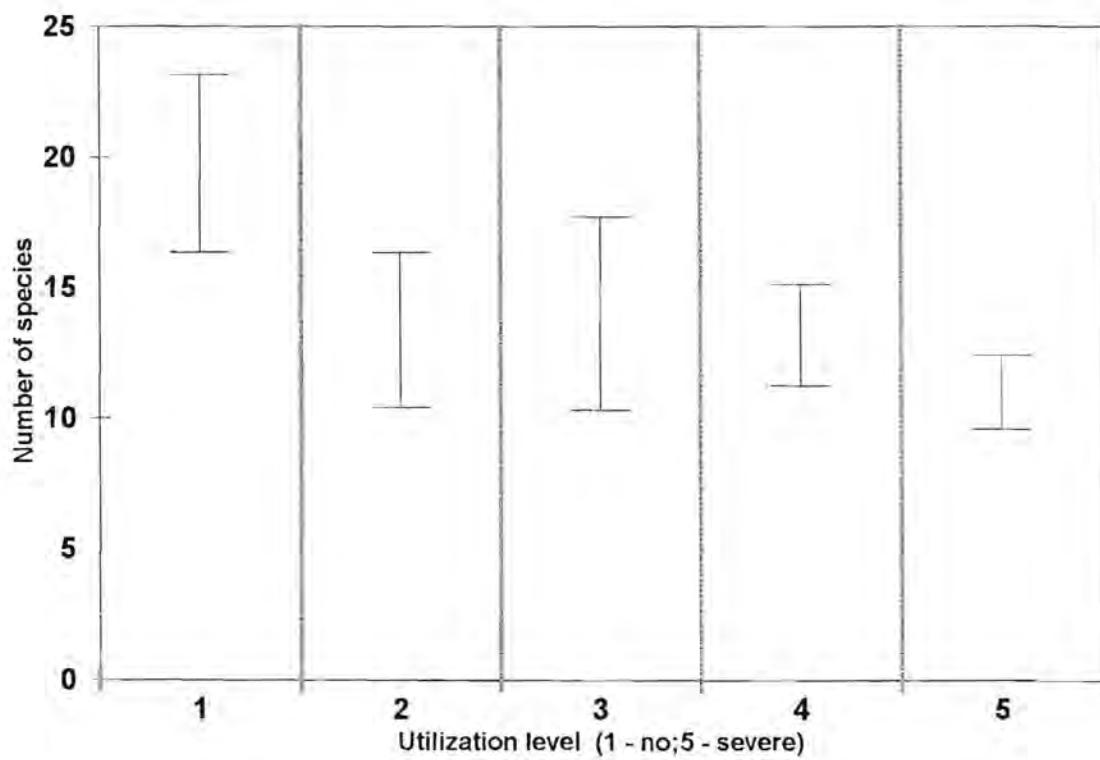


Figure 33: The total number of plant species encountered in each utilization class along the degradation gradient in Management unit 1.

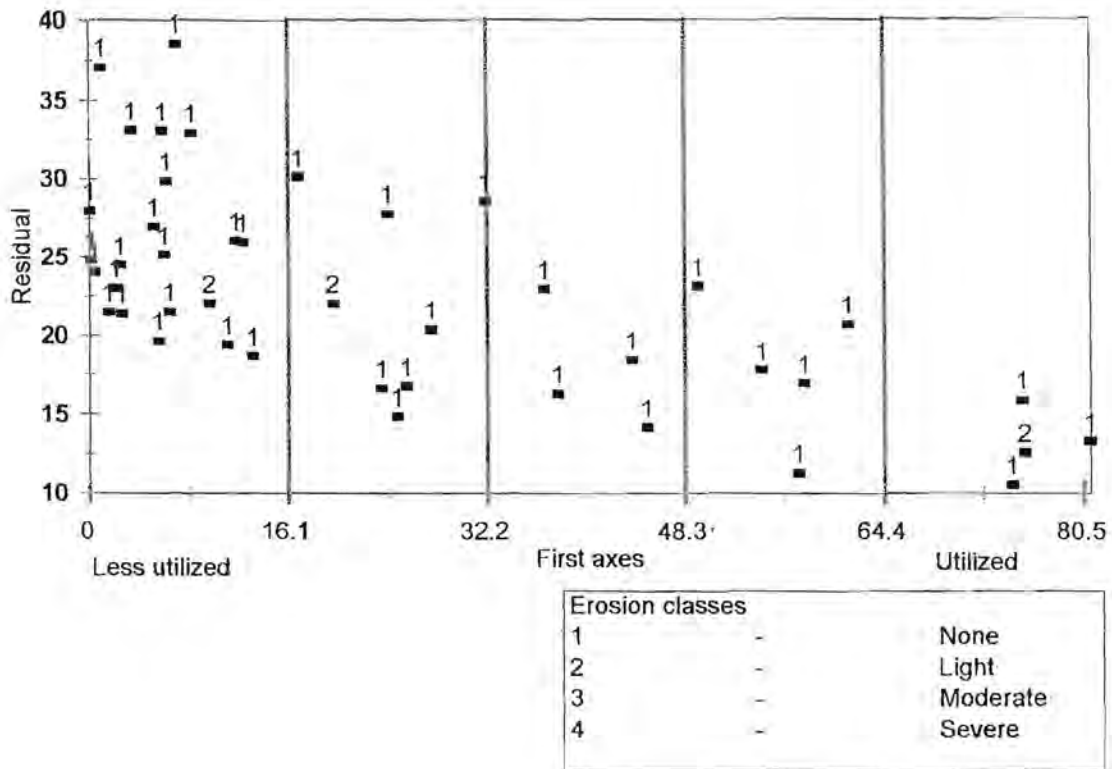


Figure 34: Ordination results of the CPCA ordination of the sites in management unit 1, indicating the amount of erosion in each site.



## MANAGEMENT UNIT 2 - *Becium obovatum* - *Elionurus muticus* Tall Grassland

The results of the CPCA ordination for management unit 2 are represented in figure 35.

The sites associated with more utilized veld is positioned to the right of the ordination, while those associated with less utilized veld is situated to the left of the ordination.

*Themeda triandra* is a very distinct perennial species through-out this gradient. It is abundant in the unutilized sector of this vegetation unit, but decreases consistently in abundance to low frequencies in the utilized sector of the gradient. *Eragrostis chloromelas* and *Tristachya leucotrix*, both tufted perennial grasses, depicted similar response to increased levels of utilization, although these two species occurred at lower frequencies. These three species were classified as decrease species. *Digitaria eriantha* and *Bewisia biflora* also reacted similar, but occurred in frequencies of less than 5% and can therefore not be regarded as a significant indicator to the process of gradual retrogression or secondary succession in this unit (Jordaan 1997) *Triraphis andropogonoides* displayed a decrease in abundance with increased levels of utilization, but was only present in three sample plots and are therefore discarded as an indicator.

*Setaria sphacelata* displayed the same downward trend, but disappears faster than *Themeda triandra* when utilization levels are increased. These species are classified as Increase 1 species. *Asclepias aurea* is also confined to the less utilized sectors of the gradient.

A number of unpalatable species increases in abundance along the vegetation gradient as utilization levels increases. Certain species such as *Bulbostylis*

*burchellii*, *Eragrostis racemosa*, *Indigofera melinoides* and *Cyperus rupestris* show a gradual increase (Increaser 2 species) , while other species such as *Loudetia simplex* and *Cymbopogon plurinodes* only appear in the moderate to severely utilized sectors of the gradient (Increaser 4 species). *Hermannia depressa* displays an intermediate reaction and are classified as an Increaser 3 species. This increase in abundance of unpalatable species associated with moderate to severe overgrazing was also found by Bosch & Kellner (1991) and can be attributed to the fact that unpalatable grasses are only lightly grazed and therefore stimulated and palatable perennial species are severely grazed (Trollope 1981).

Although species such as *Aristida transvaalensis*, *Schizachyrium sanguineum*, *Diheteropogon amplexans*, *Eragrostis curvula*, *Brachiaria serrata*, *Elionurus muticus*, *Trachypogon spicatus*, *Cassia comosa* and *Melinis repens* occurred in meaningful numbers, (frequency > 5%), they did not show a significant response to changes in vegetation due to different levels of utilization (D-stats < 0.5).

Figure 36 indicates the relationship between the number of plant species and the level of utilization in this management unit. No significant relationship exist between the level of utilization and the number of plant species recorded in the sample plots, but species seems to disappear when the veld is not utilized. This was found by Foran (1976) in the Highland Sourveld.

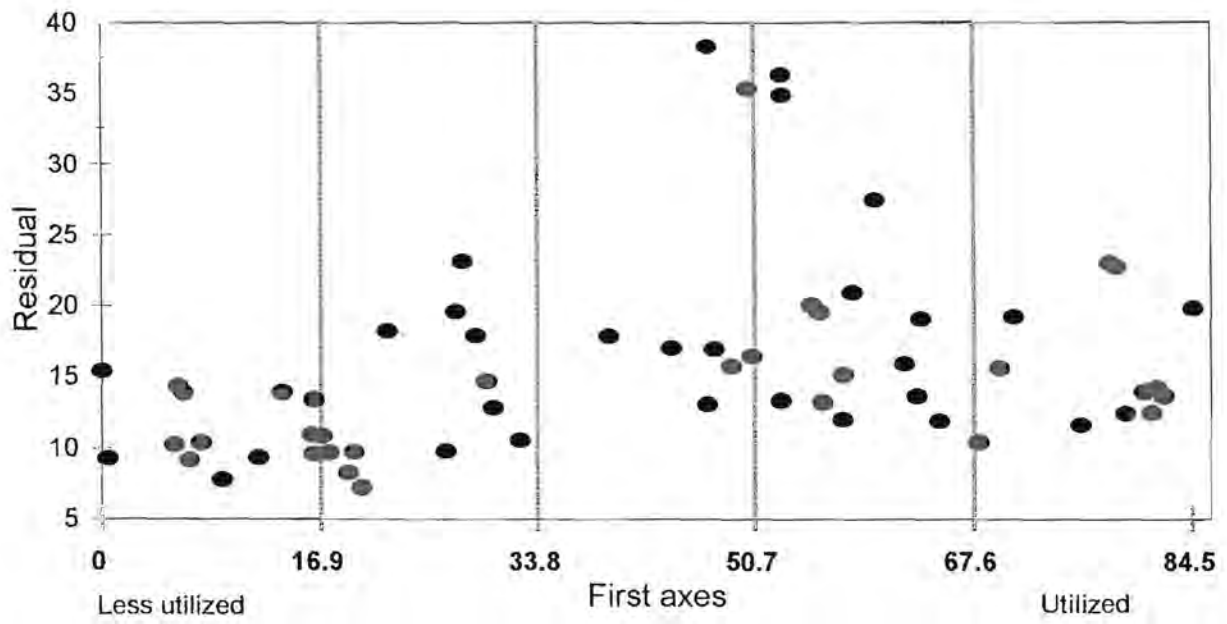


Figure 35: Ordination results of the CPCA ordination of the sites in management unit 2.

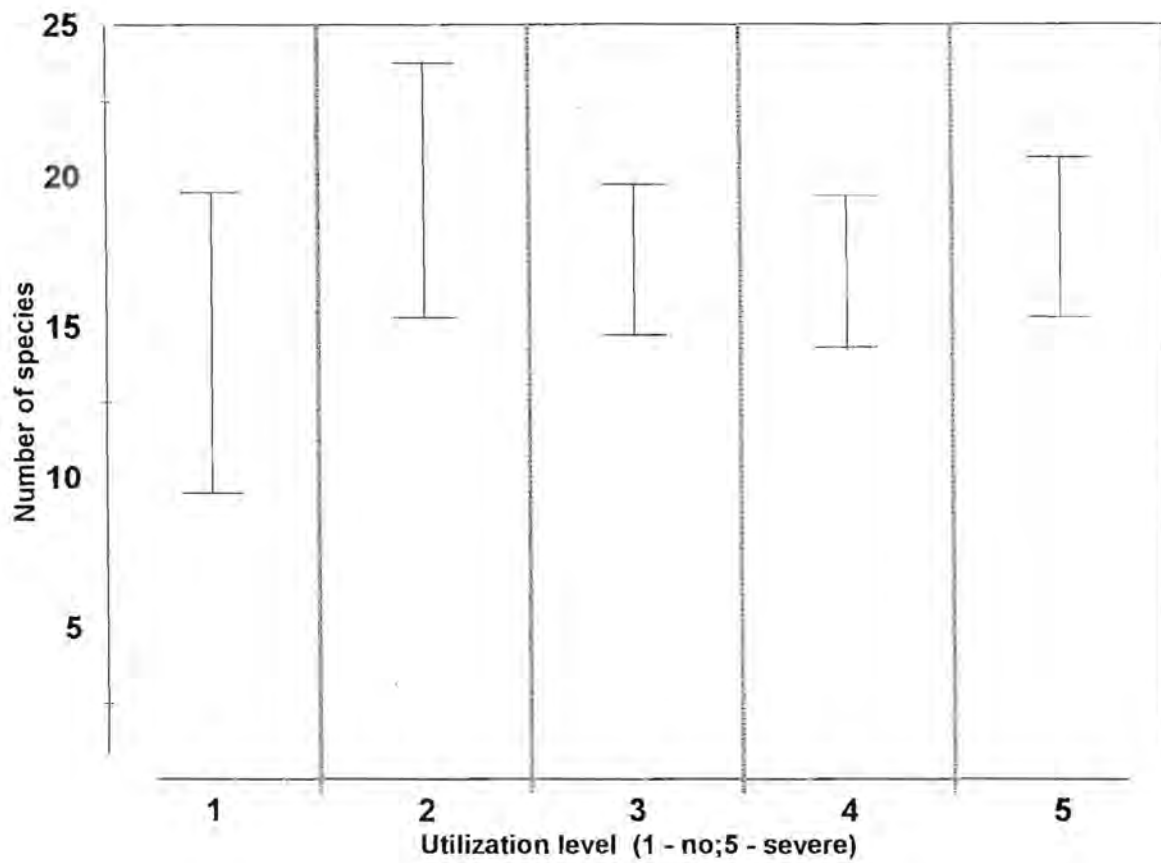


Figure 36 The number of plant species in the different utilization classes along the degradation gradient in management unit 2

Figure 37 displays the arrangement of sample sites in this management unit along the degradation gradient with the degree of erosion found in each site. No significant erosion were detected in the under-utilized, lightly utilized and moderately utilized sectors of the gradient. Fourteen percent of the sites in the moderately seriously over-utilized sector revealed light (Scaled 2; 1=none and 4=severe) erosion. Thirty six percent of the sites in the seriously over-utilized sector of the degradation gradient are moderately eroded (Scaled 3; 1=none and 4=severe). Light erosion were recorded in 18% of the sites in this sector. Further degradation along this gradient will encourage excessive erosion in this management unit, which will impact negatively on the objective of ensuring controlled and high quality runoff. In this regard the seriously over-utilized sector of the degradation gradient needs to be avoided in the management of this unit.



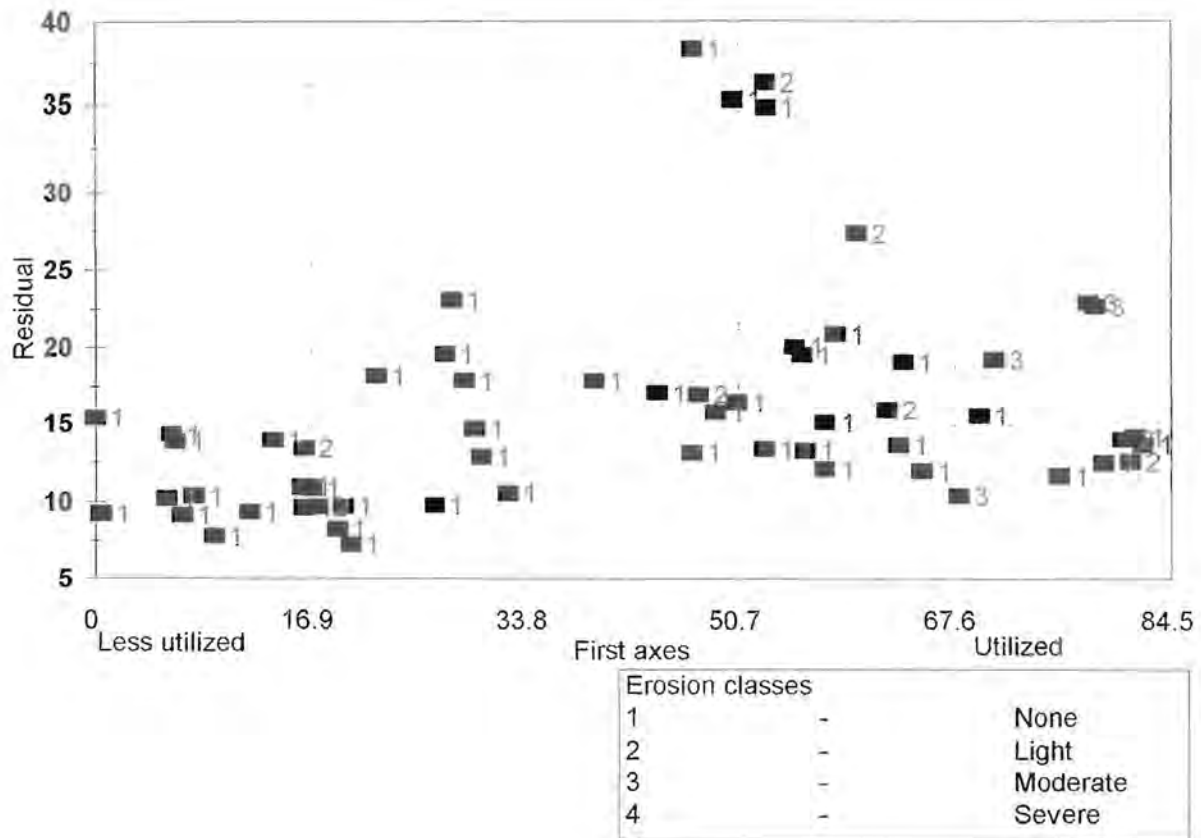


Figure 37: Ordination results of the CPCA ordination of the sites in management unit 2, indicating the amount of erosion in each site.

### MANAGEMENT UNIT 3 - *Ziziphus mucronata* - *Rhus leptodictya* Closed Woodland

The CPCA ordination for this management unit is depicted in Figure 38. The sites associated with more utilized veld is positioned to the right of the ordination, while those associated with less utilized veld is situated to the left of the ordination.

The under-utilized sector in this management unit, which is underlaid by deep alluvial soils, are, as in the other management units, characterized by a high abundance of *Themeda triandra* (also found by Nel *et al.* 1993) and *Setaria sphacelata*. These two species displayed similar responses in all three major habitat groupings on the reserve, being abundant in under-utilized veld and inconspicuous in severely utilized areas. These two species respond inconsistent in findings by Jordaan (1997). She categorize *Themeda triandra* as a Decreaser in all but one land type (Land type 6018 - situated in the northern variation of the Cymbopogon-Themeda Veld (Acocks No 48B) where it responded as an Increaser II. The response of *Setaria sphacelata* along the degradation gradient in her study was much more inconsistent, from not present in significant numbers in certain land types, to reacting as an Increaser II in Land types 6042 (underlaid by mudstone and sandstone) and 6024 (underlaid by mudstone, shale and sandstone) and a Decreaser-species in land types 6018 and 6002 (flat landscape on shallow soils underlaid by dolomite and chert). In this management unit both species react as Decreaser-species. This sector is further characterised by the presence of other palatable species. *Brachiaria brizantha*, *Eustachys paspaloides*, *Hyparrhenia tamba*, *Hyparrhenia hirta* and *Heteropogon contortus* (Nel *et al.* 1993) are prominent in this sector of the degradation gradient, decreasing in abundance as the veld is progressively more utilized. The categorization of *Hyparrhenia hirta* as an Increaser II agrees with the results of Jordaan (1997), who classified it as a Decreaser-species on deeper soils.

Two species, *Trachypogon spicatus* and *Eragrostis rigidior*, are abundant in the under-utilized sector of the degradation gradient, but do not appear in the moderately to severely utilized sectors of the gradient. Although *Trachypogon*

*spicatus* is regarded as an Increaser 1 (Bosch & Janse van Rensburg 1987; van Oudsthoorn 1992; Smith 1992), *Eragrostis rigidior* is generally considered to be an Increaser 2 or 3 (Pauw 1988; van Oudsthoorn 1992; Schulze 1992;). In this management unit this species is strongly associated with the under-utilized sector of the degradation gradient, responding as an Increaser I as utilization levels are increased.

The lightly-utilized to moderately-severe utilized sectors of the degradation gradient are characterised by the presence of less palatable herbaceous species. *Eragrostis chloromelas* and *Pogonarthria squarrosa* dominates the species composition in these sectors. Other conspicuous species in these sectors of the degradation gradient are *Aristida congesta* var. *barbicollis* and *Tagetes minuta*. These species are all classified as Increaser II species (Jordaan 1997), species that increases in abundances when the veld is moderately to moderate-severely utilized. The grouping of *Eragrostis chloromelas* in this category corresponds with the findings by Nel *et al.* (1993) in the Springbok Flats Turf Thornveld, and Jordaan (1997) who classified it similarly for sand soils and as an Increaser III on shallow sand soils. Various authors categorize *Aristida congesta* var. *barbicollis* ( Bosch 1989; van Oudtshoorn 1991; Nel *et al.* 1993; Jordaan 1997;) and *Pogonarthria squarrosa* (van Oudtshoorn 1991; Jordaan 1997) as either Increaser II or Increaser III-species. *Tagetes minuta*, a forb associated with disturbed areas (van Wyk & Malan 1988), also responds as an Increaser II species in this management unit.

The moderate-severely utilized to severely over-utilized sectors of the degradation gradient are dominated by *Cynodon dactylon*, a species known to colonises areas that suffered from overgrazing (Gibbs-Russell *et al.* 1991). In the severely over-utilized sector, this species accounted for more than 90% of the composition, with species such as *Eragrostis chloromelas*, *Panicum maximum* and *Mariscus congesta* contributing for the rest.

Figure 39 indicates the relationship between the number of plant species and the level of utilization in this management unit. A significant difference exist between

the number of species in the less utilized sectors of the degradation gradient and the species numbers recorded for the severely over-utilized sectors. Maximum species diversity is obtained when the veld is lightly utilized, but species seems to disappear when the veld is severely over-utilized. This was also found by Foran (1976) in the Highland Sourveld.

Figure 40 depicted the arrangement of sample sites in this management unit along the degradation gradient with the degree of erosion in each of them. No significant erosion were detected in the under-utilized and lightly utilized sectors of the gradient. In the moderately utilized sector of the degradation gradient 33.3% of the sites (n=6) revealed light (Scaled 2; 1=none and 4=severe) erosion, with the same percentage showing moderate erosion. Forty-four percent of the sites (n=9) in the moderately seriously over-utilized were lightly eroded. The extreme degraded site on the degradation gradient were moderately eroded. Although only two sites represent the seriously over-utilized sector of the degradation gradient, erosion was detected in both sites. Allowing the condition of the vegetation in this management unit to deteriorate to the level of severely over-utilized sector is in conflict with the set objectives of ensuring controlled and high quality runoff. In this regard the seriously over-utilized sector of the degradation gradient needs to be avoided in the management of this unit.

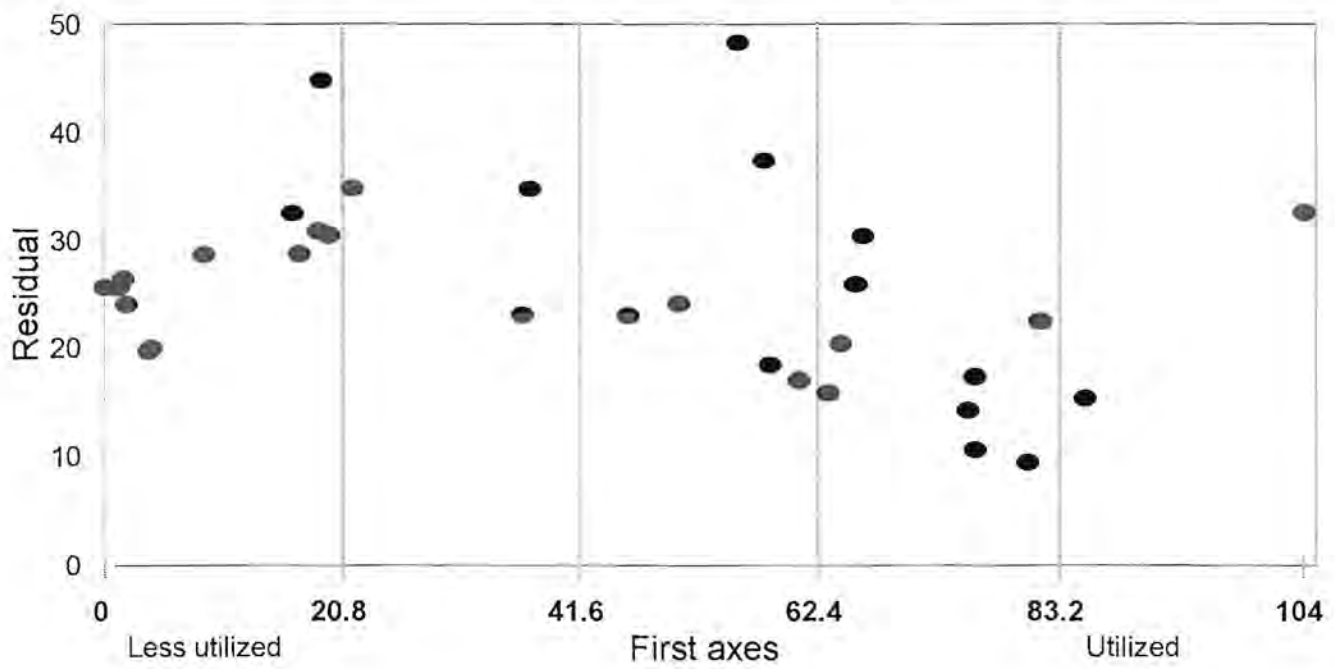


Figure 38: Ordination results of the CPCA ordination of the sites in management unit 3.



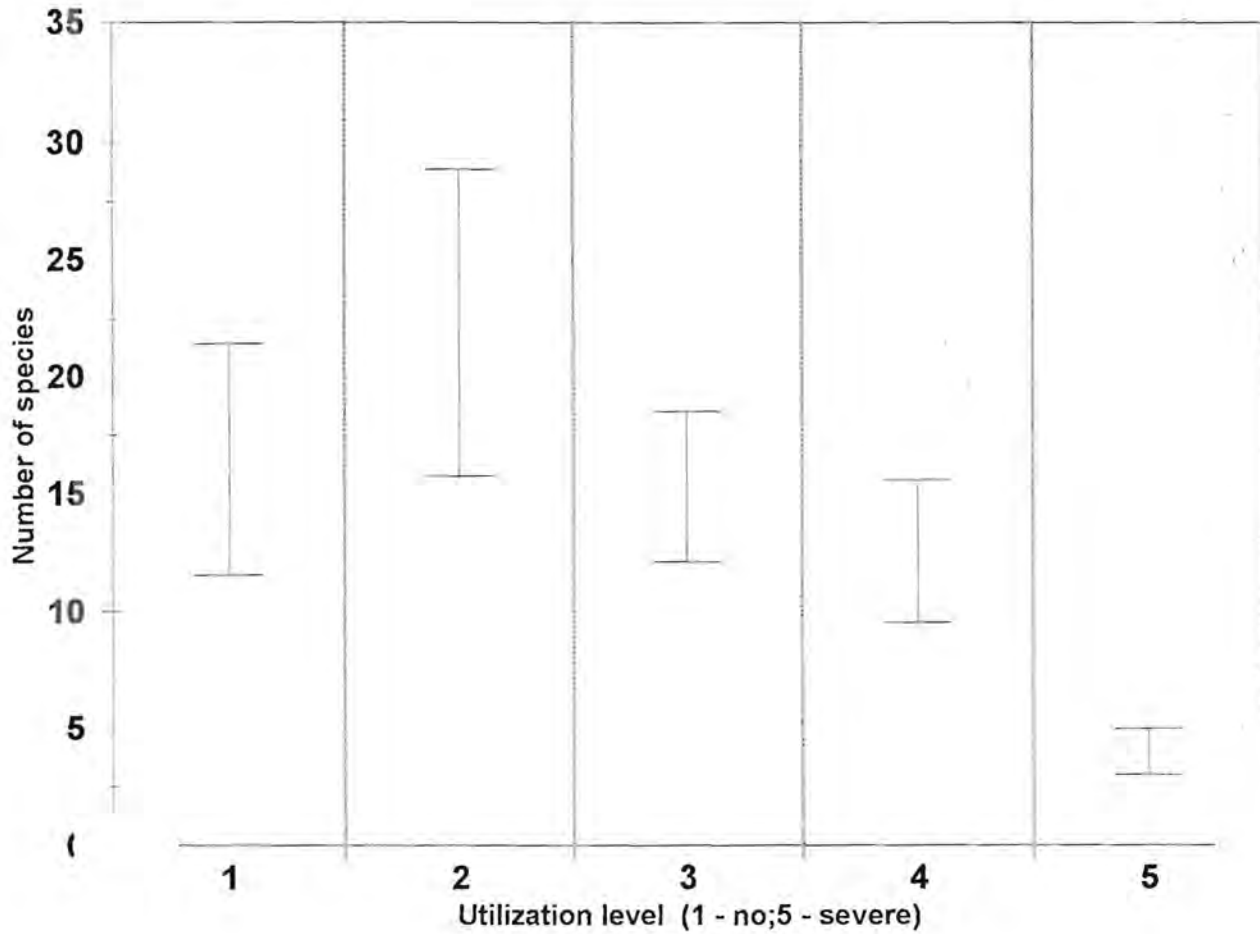


Figure 39 The number of plant species in the different utilization classes along the degradation gradient in management unit 3

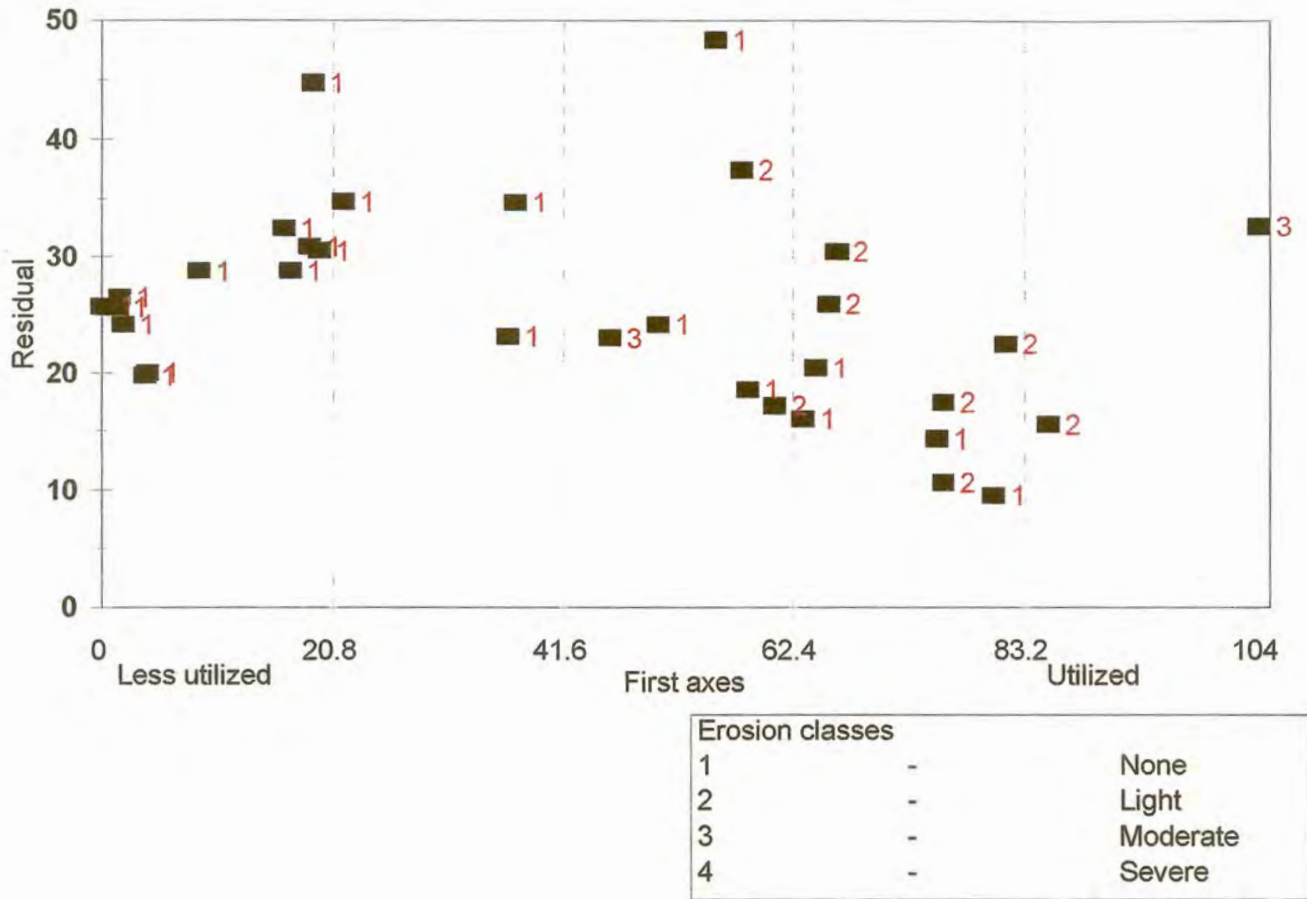


Figure 40: Ordination results of the CPCA ordination of the sites in management unit 3, indicating the amount of erosion in each site.

## **Application of degradation gradient analysis to monitor veld condition in Rustenburg Nature Reserve**

To determine the degree of success of a management strategy, critical parameters must be regularly surveyed and compared with pre-determined goals. The only mechanism to enable a manager to measure the degree to which goals are being achieved, is by regular surveillance and comparing it against pre-determined goals. Without this it is impossible to judge the success of management strategies. Through a process of adaptive management, the management of the reserve can be altered or re-evaluated if proven not to produced the desired effect. Through this process objectives are frequently re-evaluated and refined, which will result in cost-effective management.

An understanding of the process of degradation provides information to interpret the impact of management strategies on the vegetation. This information can be used as a basis for evaluating the impact of a specific management strategy on veld composition and trends (Bosch 1989).

The degradation gradients developed for each of the three management units will be used as a basis for interpreting change in plants species composition over time. These degradation gradients outline the main attribute affecting the achievement of ecological objectives in each of the management units, *viz.* ability of the system to ensure sustained flow of quality water, which is depicted by the ecological status of the veld, species diversity and erosion.

### **Inserting new samples in the degradation gradient for monitoring purposes**

A new sample can be entered onto the degradation gradient in the following two ways (Jordaan 1997; Bosch & Kellner 1991; Bosch & Gauch 1991):

- The new sample is added to the original data set and the ordination is repeated. According to Bosch & Gauch (1991) this method has two principal disadvantages:
  - It requires much more computation, and
  - the ordinations positions of the old data is shifted for each new sample, complicating the ecological interpretation of the data
  
- Alternatively, and more functional, is that the existing ordination of the data sets of the different vegetation units is retained as is. New samples are brought into the same ordination and the position of the plot on the gradient will provide an indication of the condition of the veld in which the samples were taken. This will enable comparisons between sites (Jordaan 1997).

This second option of including new samples into a stored ordination and retaining the original ordination as it is was used in this study. The ISPD package possesses an option to compare successive veld condition assessments on the same degradation graph using this option. This procedure are fully described in Bosch & Kellner (1991) and Bosch & Gauch (1991).

Although the general habitat conditions for each management unit seem homogenous, the residual values of the CENTRALIZED PRINCIPAL COMPONENT ANALYSES ordination indicate variation in these units. If a new site is inserted into the ordination, it's residual value is calculated (Bosch & Kellner 1991) which provides an indication of its fit in the degradation gradient. A new sample (monitoring site) is regarded appropriate for this model if its residual value is less than half of the Euclidean length of the first axis. ISPD has the ability to incorporated new sites which falls outside the degradation gradient boundaries, without changing the ordination result (Jordaan 1997). In developing a reliable model to assist in the interpretation of ecological monitoring, it is essential that habitat variation inside a management unit be minimised and that focus be placed



around the elements that causes change.

### ***Methods***

Five monitoring sites were visually selected for each of Management Units 1 and 2 (Jordaan 1997). As a result of the variation in Management Unit 3, 10 sites were selected in this unit. An attempt was made to include veld in different successional stages. These sites were permanently marked and their coordinates were determined by means of a Global Positioning System. These sites were surveyed as described earlier in this chapter and the results of each sample were inserted into the data sets through the screen input option in ISPD. The site was accepted as representative if its residual value were less than half of the Euclidean length of the first axis.

The results of the analysis indicates that the residual value of all five sites in Management Unit 1 are less than the Maximum Acceptable Residual value, which is half of the Euclidean length of the first axis. This indicates that they are representative of the vegetation in the management unit. The five sites are evenly distributed along the degradation gradient.

In management unit 2, the residual value of four sites are less than the acceptable value. The residual value of the fifth site is unacceptably high and can therefore not be considered for this gradient.

The residual value of three sites in management unit 3 are more than the maximum acceptable value and can not be fitted into the constructed models. The residual value of the remaining seven sites are within the acceptable maximum value.

Figure 41, 42 & 43 depicts the positions of new sites that was entered into the ordination to test the validity of each model, and to evaluate the appropriateness of the sites that was selected inside each management unit.



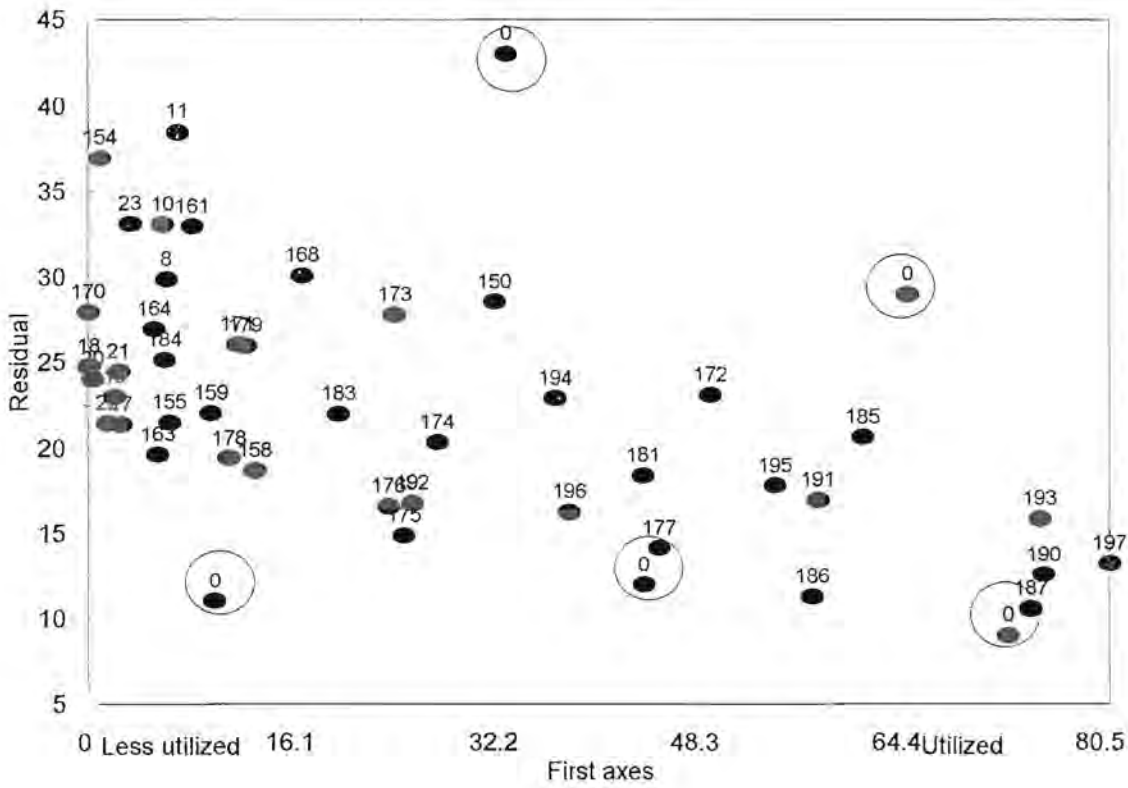


Figure 41 : Positioning of selected monitoring sites on the degradation gradient of the management unit 1

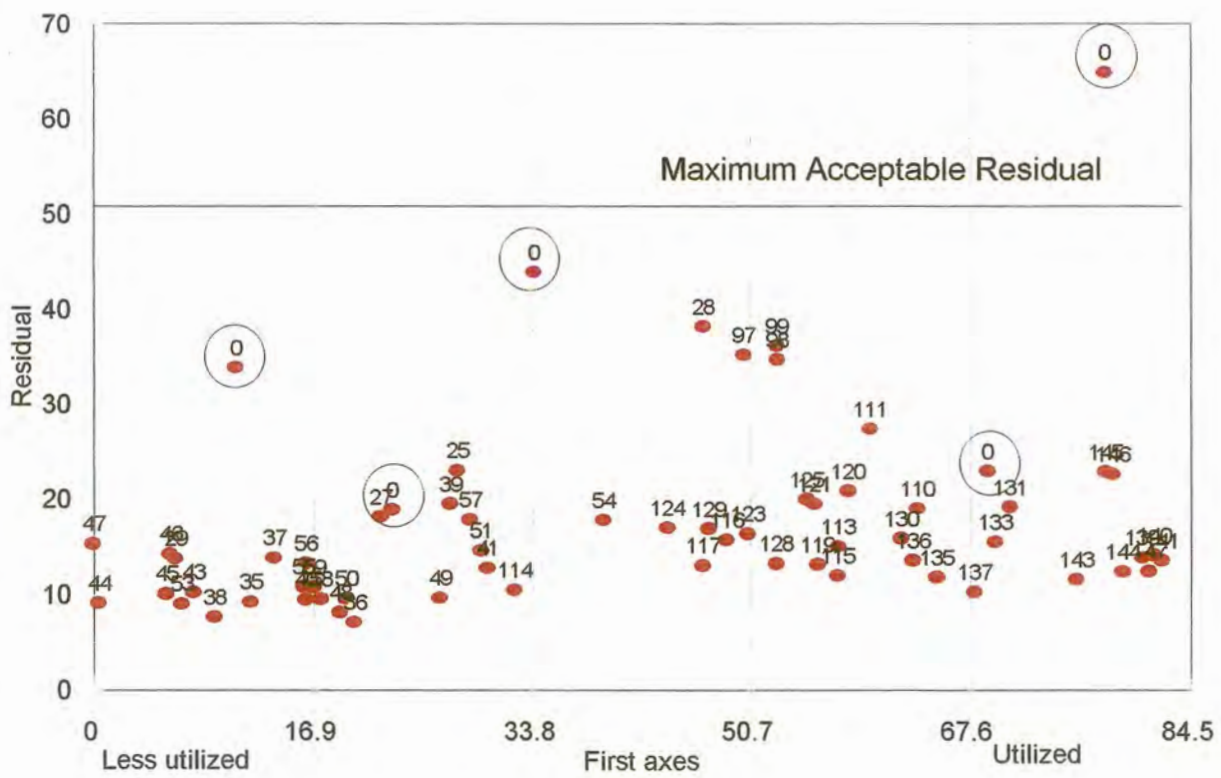


Figure 42: Positioning of selected monitoring sites on the degradation gradient of the management unit 2