GRADIENT ANALYSIS OF BOTTOMLAND VEGETATION IN THREE LAND TYPES OF THE HIGHVELD REGION

Andrew Charles Beckerling, BSc. (Agric)

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CONTENTS Page No.

ABSTRACT

The need for improved management and a better ecological understanding of the veld in South Africa cannot be over emphasised. The influence of grazing on the veld species composition and veld condition in general is especially important and the contract research undertaken by the Potchefstroom University for C.H.E. deals with this aspect for the Highveld region of South Africa. The study forms part of this research. The study area is the bottomlands (terrain unit 5) of three landtypes in the Highveld region namely, Bb25, Ca6 and Bc25. A total of 95 sites (30 x 30m each) were evaluated. Special attention was given to sites with varying environmental characteristics and differences due to grazing. A nearest plant survey (200 points) using a wheel-point apparatus was carried out. At each point observation, the nearest plant was identified, the distance to the nearest plant was measured and the diameter of tufted grass species was measured. A soil sample (0-30cm) was also collected in the middle of each site and analised for calcium, magnesium, sodium, organic matter, phosphate and pH.

Direct and indirect gradient analysis procedures were used to identify species responses to grazing and soil related gradients. Multiple regression and Principle Components

Analysis were used to model these responses and to identify the important soil factors. The results of these approaches are discussed separately and also summarised in the form of habitats with the associated community organisation and change due to grazing.

The results showed that two important gradients influence species composition in the bottomlands, namely drainage and grazing. Drainage is essentially a function of the soil, slope and the position of the site in the landscape. It was also evident that grazing interacted with the habitat, and/or caused changes to the habitat. This observation suggests that the grazing gradient can be named a grazing/habitat interaction gradient. Soil base status and soil sodium level were linked to this interaction and this in turn was linked to the parent material. Overgrazing increased the aridity of the site and this was attributed to the increased run off and donga formation in overgrazed areas. The point to tuft and tuft diameter measurements indicate that basal cover changes from large widely spaced tufts in undergrazed sites to small closely spaced tufts in overgrazed sites. The species modeling procedure did show some success with those species that had linear rather than strong curvilinear responses, and with those species that were abundant. The habitat and associated community organisation and change described by the model were closely related to field observations. The fact that certain

species differ in their reaction to grazing with changing habitat was emphasised in this part of the study. The conclusions drawn from this study emphasise the influence of habitat on both management objectives, and the response of species to grazing. The possibility of using multidimensional response surfaces to understand a species response to multiple factors is suggested.

OPSOMMING

Dit is algemeen bekend dat die veld se toestand in Suid Afrika swak is, en slegs deur beter bestuur kan die veld verbeter word. Daarom is dit belangrik om te weet watter rol die weidende dier of die spesiesamestelling en die veldtoestand het. Die studie is in samewerking met die Dept. Plantkunde (PU vir CHO) se navorsing oor die onderwerp gedoen. Hierdie navorsing is in die waterbane (terreineenheid 5) van drie landtipes, naamlik Bb25, Ca6 en Bc25 gedoen. 'n Totaal van 95 monsterpersele (30m x 30m) is vir die opname gebruik. Die spesiesamestelling (d.m.v. die naaste plant metode), die pol deursnit en pol tot punt afstand is genoteer. 'n Grondmonster (0-30cm) is in elke perseel versamel en vir deeltjiegrootte, Na, Ca, Mg, organiese materiaal, pH en P ontleed. Direkte en indirekte gradient analises is vir data ontleding gebruik. Meervoudige regressie en Hoof Komponente Analise prosedures is vir spesie modellering gebruik. Hieruit is die verskillende habitatte en die verwante plantgemeenskappe en verandering as gevolg van beweiding geidentifiseer.

Uit die resultate blyk dit dat veral twee omgewingsfaktore, naamlik beweiding en dreinering, 'n rol in spesiesamestellingverandering speel. Die interaksie tussen beweiding en habitat was duidelik. Die beweidinggradiënt kan daarom eerder 'n beweiding/habitat gradiënt genoem word.

Die moedermateriaal, basestatus en Na-inhoud van die grond word aan hierdie gradiënt gekoppel. Oorbeweiding lei tot uitdroging van die habitat as gevolg van verhoogde waterafloop en soms donga vorming. Die punt tot pol en pol deursnit metings het getoon dat daar nie net 'n moontlike afname in bedekking is nie maar ook 'n verandering in die tipe bedekking. In oorbeweide persele is die polle klein en na aan -mekaar gespasieer. In onderbenutte persele is die polle groot en verder uit mekaar geplaas. Die spesiemodelleringsprosedure het redelike resultate vir spesies wat meer algemeen voorkom getoon. Die habitat en verwante plant gemeenskap en verandering as gevolg van beweiding wat deur die model besluit word, is nou gekoppel aan waarnemings in die veld. Die feit dat sekere spesies verskillend reageer op beweiding in verskillende habitatte is in hierdie deel van die studie beklemtoon. Die gevolgtrekkings van die studie beklemtoon die probleme met betrekking tot die toestand en bestuur van veld, asook die beginsels vir die bestuur van waterbane in die Hoëveld Landboustreek.

INTRODUCTION

Stock farming in the Highveld region has recently become increasingly important as a result of the decrease in profit made on annual maize production. A problem associated with this, is the inevitable increase in the number of livestock on farms in this region. This factor and the general low standard of fodder flow planning of farmers could and already has resulted in the veld being used as a scapegoat when other feed sources are exhausted. Added to this is the low regard that the farmer has for the veld as a feed source, even though the animals spend 6 - 8 months of the year on the veld, which results in little or no capital outlay for correct utilisation of this natural resource. Water points are far too few and fencing is often inadequate or incorrect.

This state of affairs is not always the fault of the farmer, but also a result of the lack of knowledge with regards to grazing management and the interaction between abiotic factors and the grazing animal. The purpose of this study is to add to this knowledge and specifically to determine the important environmental gradients of bottomland vegetation in three land types of the Highveld region. It is envisaged that this information could be used as an aid in the development of planning and management strategies in the Highveld region.

In the past the division of veld into camps was primarily aimed at obtaining an eight camp system, for example, and little attention was given to the creation of relatively homogeneous areas with regards to the important environmental parameters of that area. Recently the emphasis is being placed on these "natural boundaries" for veld planning. The following questions can be asked about this approach.

* What are the important environmental parameters to be considered in each region?

* Is there a relationship between these parameters and species composition?

* What is the interaction between the grazing animal and these parameters - ie. are these parameters related to area selection?

These are the key questions that this study will attempt to answer for the bottomlands of the three land types considered in this study.

This research forms part of a contract research project undertaken by the PU for CHE (Bosch, 1988). A similar study of the other terrain units was done by Janse van Rensburg (1987). This author also conducted surveys in the bottomlands, but the axes obtained from the ordination techniques used could not be interpreted. This study was therefore also undertaken to solve this problem.

Acocks (1975) and Louw (1951) both recognise the fact that the bottomlands are the most severely overgrazed areas in the landscape. They also emphasise the implications of this problem in terms of water production and water quality. Janse van Rensburg (1987) points out the complex nature of the bottomlands. Sediment movement, grazing, and flooding all influence the species composition. It is therefore important that the bottomlands are ecologically understood so that management strategies can be developed to improve the present situation.

The complex ecology of these areas and the obvious need to protect these areas against injudicious management and degradation motivate further study and understanding of the bottomlands.

CHAPTER 1 : STUDY AREA

The description of the study area is divided into the three land types. More detail will also be given to some aspects of the bottomlands in the results and discussion. This will especially be so for the soil/vegetation relationships found during the study. These land types are also positioned in two different climate zones. This was done deliberately so that the effect of the climate, essentially effective rainfall, could also be studied.

1.1 Land type Bb25

1.1.1 Position

This land type occurs west and northwest of Harrismith in the Orange Free State, South Africa. It has a total area of 172440 ha. The area falls in five 1 : 50 000 topocadastral sheets (2829AA, 2829AC, 2828BB, 2828BD and 2828BA) (Bruce, Schoeman, Eloff & Snyman (in press)). 2829AA and 2828BB were used for survey purposes.

1.1.2 Geology and soils

The geology of this land type is predominantly Tarkastad mudstone and sandstone. Narrow dolerite sills can occur. Very small outliers of Molteno grit and sandstone also occur in the south west of this land type (Bruce, et al (in press)).

The soils of the bottomlands (terrain unit 5) are made up of primarily duplex and alluvial soils. The duplex soils are mostly of the Escourt (Es16, Es13) and Bonheim (Bo31, Bo41) forms. The alluvial soils consist of the Dundee (Du10) and Oakleaf (Oa36) forms. Soils of the Willowbrook (Wo20, Wo21) form are also found in wet low lying sites (Bruce, et al (in press)).

1.1.3 Terrain form

The terrain form is moderately mountainous with sandstone scarp faces that typify this land type. The midslopes are often steep with large boulders of sandstone. The midslopes (terrain unit 3) make up a large proportion of this terrain with the pediment slopes (terrain unit 4) and the water courses (terrain unit 5) often being very narrow (Fig 1.1).

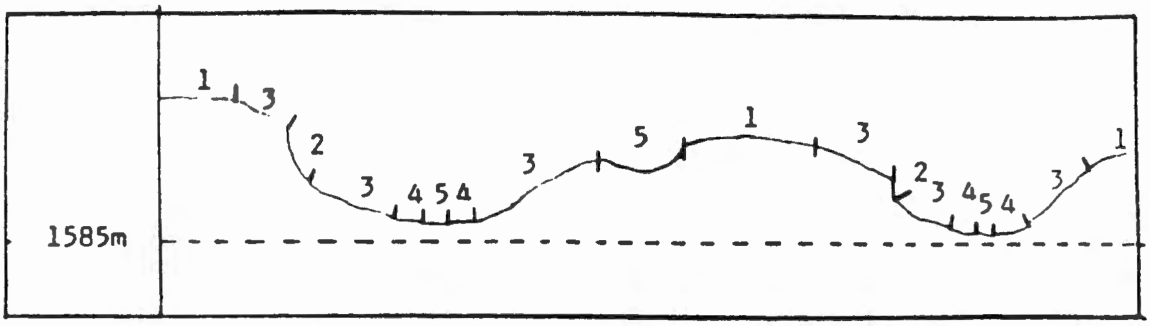


Figure 1.1 The terrain form of land type Bb25 with the height above sea level (Bruce et al, (in press)).

1.1.4 Climate

The average annual rainfall for this land type is 622 mm (S.I.R.I., 1988). This figure, and all the other climatic data for this land type, is taken from Harrismith. The rain falls mainly in the summer months but rain in winter is not uncommon (Fig 1.2).

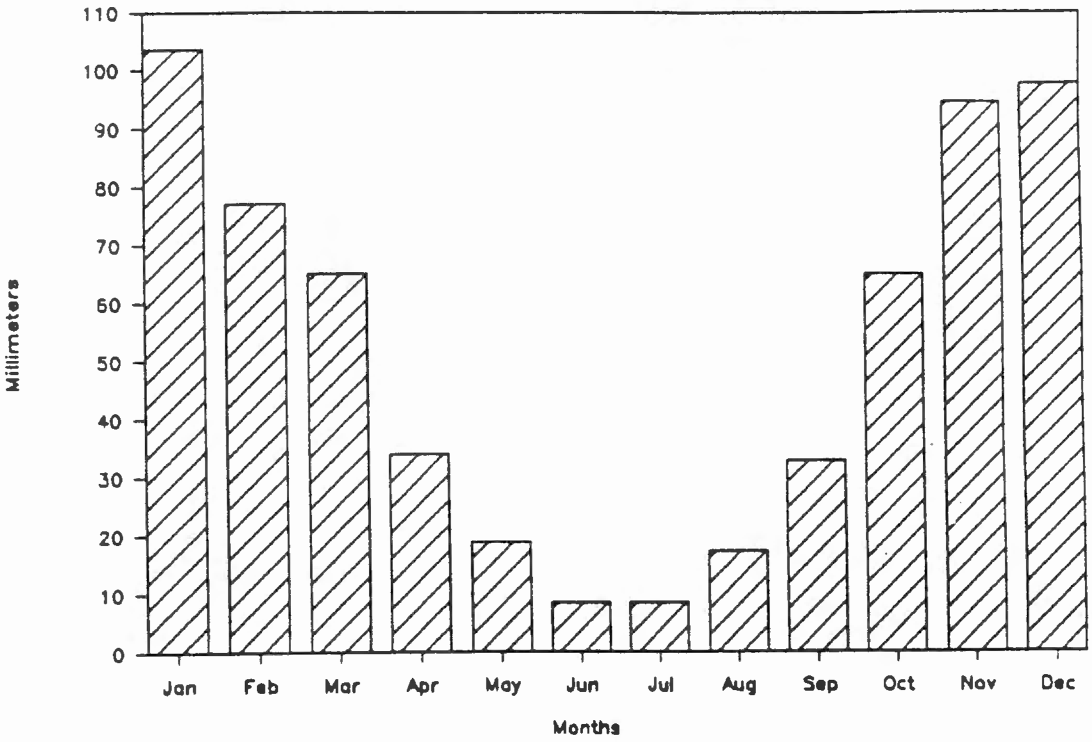


Figure 1.2 The rainfall distribution for the Harrismith area (S.I.R.I., 1988).

Hail is frequent in summer (October - March) and snow usually occurs in the winter months (May - August).

The average summer temperature is 20°C and maximum temperatures of 30°C are not uncommon (S.I.R.I., 1988). The average winter temperature is 10°C and minimum temperatures of -12°C have been measured. Frost is also frequent and can be very heavy in low lying areas.

1.1.5 Vegetation

Acocks (1975) classified the vegetation in this area as a climatic climax grassland. The vegetation is classed as a transition from the Highland Sourveld to the Cymbopogon - Themeda veld. The grass species which are abundant in this land type are Themeda triandra, Tristachya leucothrix, Eragrostis spp, Cymbopogon plurinodis and Elionurus muticus. Scheepers (1975) noted that old lands were also an important part of this vegetation especially on the mid- and pediment slopes. These areas are dominated by Eragrostis chloromelas and Eragrostis plana. The effect of the grazing animal is also profound in certain areas and the presence of karroo shrubs in certain sites is evidence of the degradation that has occurred in parts of this land type.

1.2 Land type Ca6

1.2.1 Position

This land type occurs in the Reitz area of the Orange Free State, South Africa, and has a total area of 421 200 ha. The area falls in eleven 1: 50 000 topocadastral sheets (2728CA, 2728CB, 2728DA, 2728DB, 2728CC, 2728CD, 2728DC, 2728DD, 2828AA, 2828Ab, 2828BA) (Land Type Survey Staff, 1984). Only three of these sheets were used for survey purposes (2728CA, 2728CB, 2728CC).

1.2.2 Geology and soils

Land type Ca6 is predominantly made up of Beaufort mudstone, shale, sandstone and grit. There are dolerite sills in places and occasional dolerite dykes. Very small outliers of Molteno sandstone and grit can be found in the far south of this land type (Land Type Survey Staff, 1984). The soils found in the bottomlands are mostly duplex type soils with Escourt (Es33, Es13, Es16, Es36, Es14), Kroonstad (Kd13, Kd16, Kd14), Valsrivier (Va31, Va41) and Swartland (Sw31, Sw41) soil forms being the predominant types. Soils of the Rensburg (Rg20), Willowbrook (Wo21), Katspruit (Ka20), Dundee (Du10) and Oakleaf (Oa36, Oa46) soil forms are found in the watercourses (Land Type Survey Staff, 1984).

1.2.3 Terrain form

The topography is rolling hills with a notable absence of scarp faces (Fig 1.3). The midslopes and crests (terrain unit 1) make up a large proportion of this terrain.

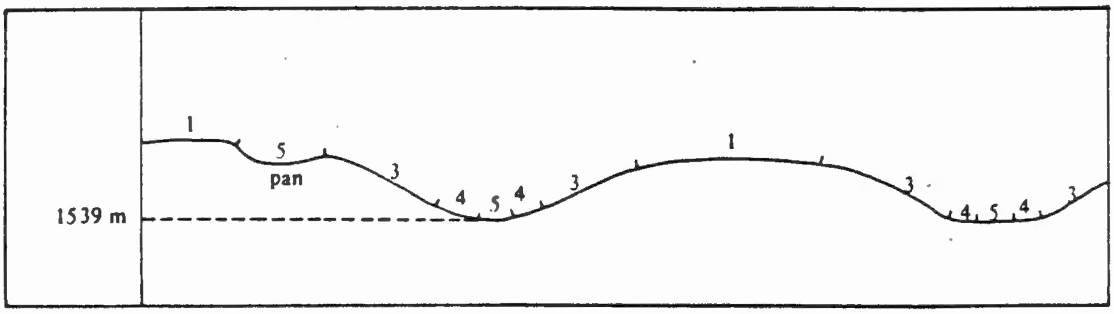


Figure 1.3 The terrain form of land type Ca6 (Land Type Survey Staff, 1984).

1.2.4 Climate

The average annual rainfall for this land type is 678 mm (taken from the rainfall for Reitz) (S.I.R.I., 1988). Most of the rain falls in the summer months (Fig 1.4).

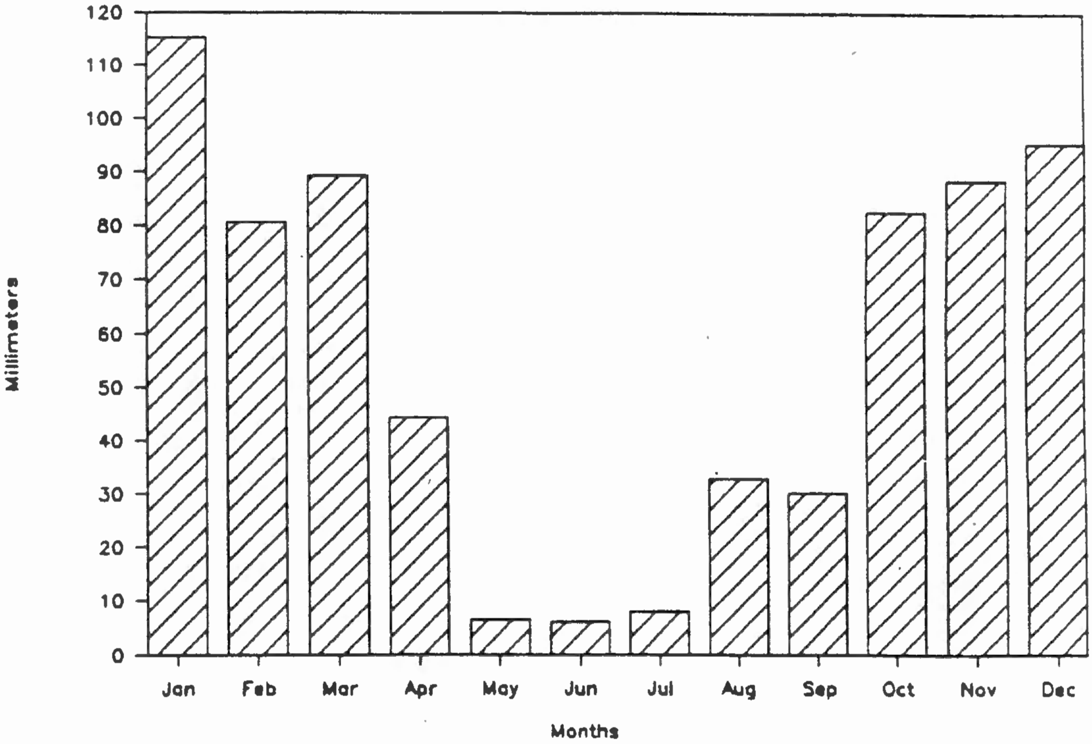


Figure 1.4 The rainfall distribution for Reitz (S.I.R.I.,1988).

Hail is common in the summer months and snow can occur in winter. The average summer maximum temperature is 26^{0}C and the average annual minimum for the summer is 11^{0}C (S.I.R.I.,1988). The average maximum temperature for winter is 17^{0}C and the average minimum for winter is -1^{0}C. Frost is frequent in winter and can be very heavy in low lying areas.

1.2.5 Vegetation

Acocks (1975) classified the area as a grassveld and named it Cymbopogon - Themeda veld. The dominant grasses are Themeda triandra, Elionurus muticus, *Cymbopogon plurinodis* and a large number of *Eragrostis spp*. *Eragrostis curvula* is particularly abundant because of over grazing and old lands that are left fallow. The extensive cultivation in this area has resulted in an increased volume of water and sediment occurring in terrain unit 5, and the resulting effects on the vegetation will be discussed.

1.3 Land type Bc25

1.3.1 Position

The Bc25 land type occurs in the Potchefstroom area of the Western Transvaal, South Africa. It has a total area of 107 220 ha. The area falls in five 1: 50 000 topocadastral sheets (2829AA, 2829AC, 2828BB, 2828BD and 2828BA) (Land Type Survey Staff, 1984). Two of these sheets were used for survey purposes, namely 2829AA and 2828BB.

1.3.2 Geology and soils

Land type Bc25 is predominantly Diabase and Hekpoort lava. There is also shale of the Pretoria group with Ecca shale and sandstone occurring in the south. The quartzite usually forms crests and scarps. The footslopes are usually on diabase, lava, shale or slate (Bruce & Schoeman, 1984).

The soils of the bottomlands are a combination of Valsrivier (Va40, Va41 and Va31), Swartland (Sw41 and Sw31), Rensburg (Rg20), Willowbrook (Wo21), and Arcadia (Ar20) soil forms. There are small areas with soils of the Dundee (Du10) soil form (Land Type Survey Staff, 1984). The soils are mostly mesotrophic and eutrophic with the B and C horizons frequently being calcareous.

1.3.3 Terrain form

This land type is generally rolling country, however the pediment slopes are usually long, merging with the watercourses (Fig 1.5).

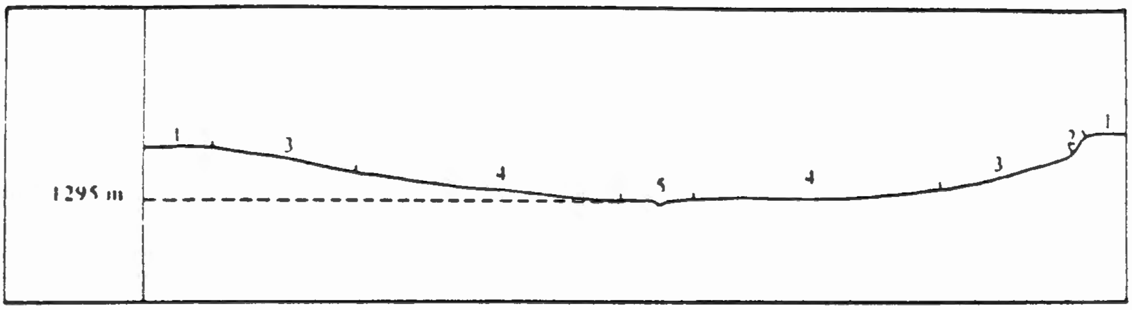


Fig 1.5 The terrain form of land type Bc25 (Land Type Survey Staff, 1984).

There is the occasional rock outcrop of quartzite and koppies do occur.

1.3.4 Climate

This land type has an average annual rainfall of 626 mm (taken from the rainfall for Potchefstroom) (S.I.R.I., 1988). Almost all the rain falls in the summer in the form of heavy thunderstorms (Fig 1.6). Severe mid-summer droughts are a general feature and this factor of unreliable rainfall differentiates this land type from the other two under consideration.

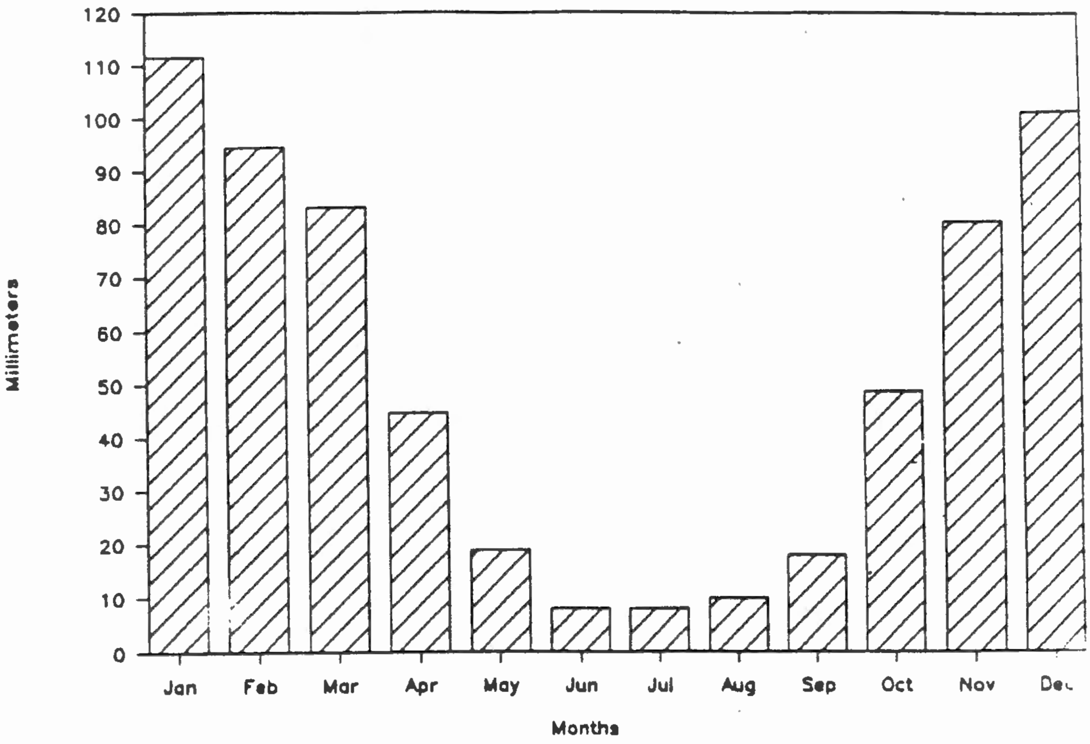


Figure 1.6 The rainfall distribution for Potchefstroom (S.I.R.I., 1988).

Hail does occur in the summer but snow is very rare in the winter.

The average maximum temperature for the summer is 28°C and the average minimum for the same period is 14°C (S.I.R.I.,1988). The average minimum for the winter is 3°C with the lowest recorded minimum being - 11°C. The average maximum temperature for the winter months is 19°C. Frost is frequent from May until the end of August especially in the low lying areas.

1.3.5 Vegetation

Although this area is classified by Acocks (1975) as being part of the dry *Cymbopogon* - *Themeda* veld there is a tree and shrub component that resembles the Bankenveld which borders this area (Acocks, 1975). The abundant grass species are *Setaria flabellata*, *Themeda triandra* and *Cymbopogon plurinodis*. *Acacia karroo* is sometimes abundant on the footslopes and *Acacia caffra* is often associated with the scarp and midslopes. *Euclea crispa* and *Grewia flava* are two shrub species that are abundant in places.

CHAPTER 2 MATERIALS AND METHODS

This chapter explains the procedures that were followed in the field for data collection. The greater part also deals with the two measurements, namely tuft diameter and point to tuft distance, that were included in the data collection procedure. These measurements were included in the study to serve as aids in explaining trends in the data, and to explain certain aspects of the sward structure and cover.

2.1 Field work

Approximately thirty sites were selected in each land type. A total of ninety - five sites were selected in total. These sites were deliberately chosen with respect to differences in condition due to various environmental factors, especially grazing. Each site was approximately 900 m^2, and sometimes long and narrow, parallel to the drainage channel, so that it was as homogeneous as possible.

Two hundred points were systematically selected in each site using the wheel - point apparatus. At each point species name (nearest plant), distance from the point to the base of the nearest plant (live, rooted material), and tuft diameter of important tufted species were recorded. A soil sample was also taken in the middle of the site. Soil type and other parameters such as the presence of a donga, were also recorded.

The sites were marked on the 1 : 50 000 topocadastral sheets that were used for survey purposes for each area. A grid reference was also given to each site to the nearest second for the purpose of further reference or studies that might be carried out on that site. Soil survey maps and land type survey maps were also used as aids to determine soil types that occurred in each site. Problems were found in this respect as soil complexes were often encountered in the field.

2.2 Soil analysis

The following analyses were carried out on the soil samples that were taken in the middle of each site.

1. Phosphate

The Bray 2 extraction method as described by Olsen & Dean (1965) was used as a basis for this analysis except that 0.1N HCl was used in place of 0.025N HCl.

2. Exchangeable cations (Ca, Mg, K, Na)

The ammonium acetate saturation technique as described by Jackson (1962) and Chapman (1965) was used for this analysis.

3. Organic matter

This analysis was done according to the Walkley-Black method as described by Jackson (1962) and Allison (1965).

4. Particle size analysis

The pipette method was used for this analysis as described by Day (1965).

5. pH

This was measured with a PHM 28d Radiometer pH meter. The suspension was 1 : 2.5 of soil : 1N KCl.

2.3 Cover estimates

2.3.1 Introduction

The criticism of the estimation of basal cover with the wheel - point by Mentis (1983) and many other workers has lead to a gap in a method to estimate basal cover of tufted grass species. The importance of having some cover estimate to evaluate veld condition is emphasised by Fourie, Redelinghuis and Opperman (1984), du Toit & Aucamp (1985) and Tainton (1981), who all note that species composition alone is sometimes not enough for correct veld evaluation. The search then for a measurement or measurements that could be used to estimate basal cover should continue. This is the reason why tuft diameter and point to tuft distance were included in this study.

2.3.2 The theoretical relationships

The theoretical relationship between point-tuft distance, tuft diameter and basal cover can be derived from work done by Laycock & Batcheler (1975) who studied the relationship between tuft density and the distance from the point to the centre of the nearest tuft in a grassland situation. One of the formulas used in this study to calculate tuft density from the mean of the point-tuft distance is

$D = 0.25/(r)^2$

where D = density in plants/m^2

r = the mean of all the measurements of the distance from the point to the centre of the nearest tuft in meters.

However, r can be divided into two separate measurements, namely the distance from the point to the base of the nearest tuft, which will be given the symbol (s), plus the tuft radius,which will be given the symbol (t) (Fig 2.1)

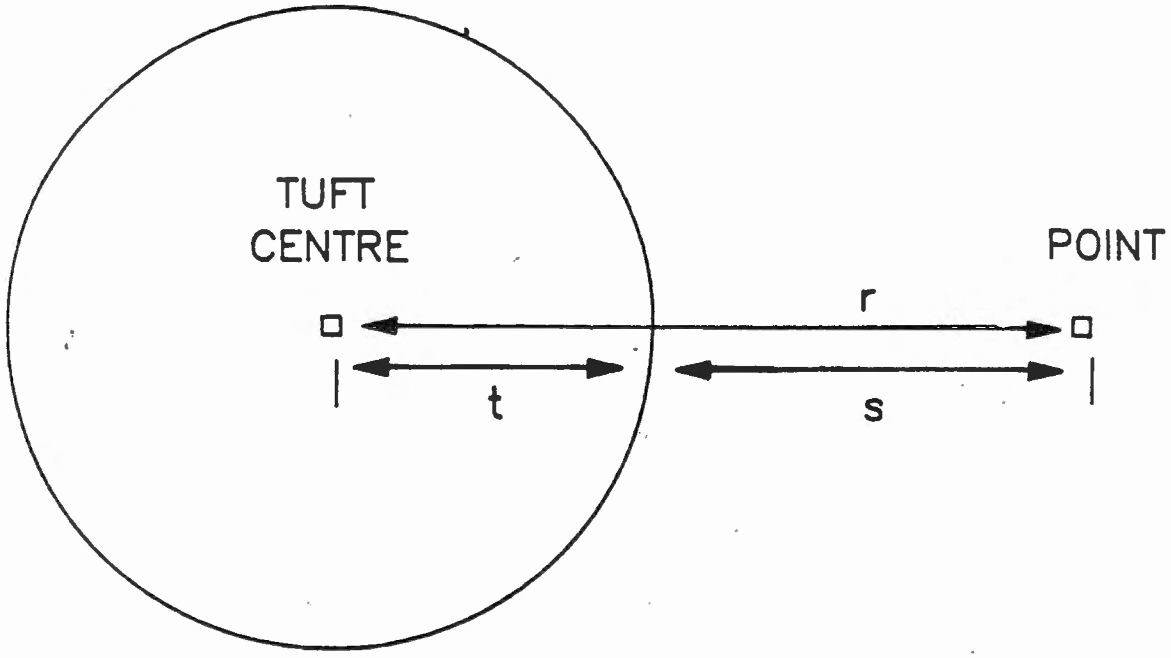


Figure 2.1 A sketch showing the division of the measurement, distance from point to the centre of the nearest tuft, into two separate measurements, namely distance from the point to the base of the tuft(s), plus the tuft radius(t).

In an equation then, $r = s + t$

then $D = 0.25/(s + t)^2$

From this equation one can derive the relationship between D and s for constant t (Fig 2.2). Note that in the figures the tuft diameter (TD) has been used instead of the tuft radius (t).

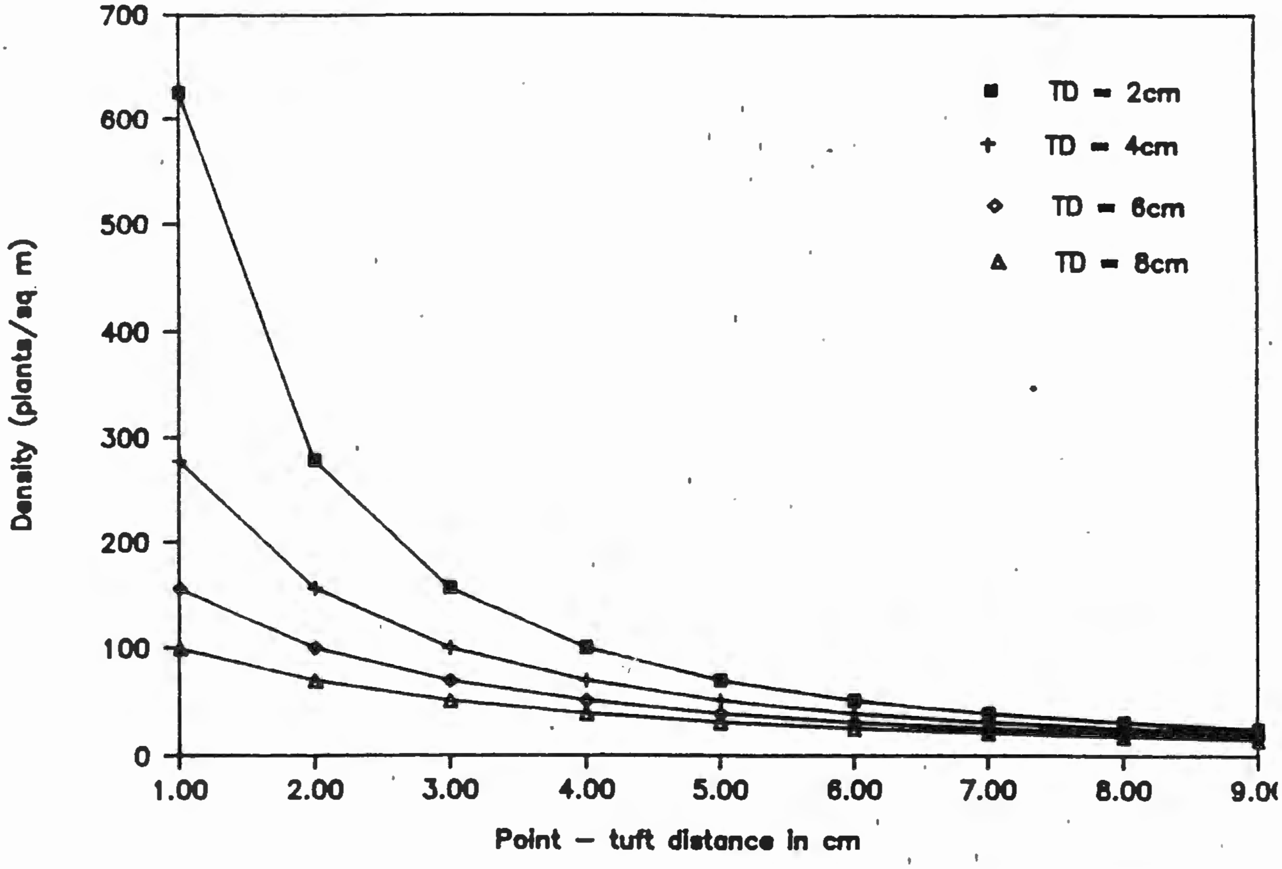


Figure 2.2 The relationship between density for constant tuft diameter (TD) and for constant distance from the point to the base of the nearest root of a tuft.

If one calculates the area of a tuft for the average tuft diameter, and multiplies this by the density for a given situation, then this gives the theoretical basal cover in m^2 of tuft per m^2 of ground. This can then be converted into a percentage and therefore give the basal cover percentage. In an equation this would be

$$\text{Basal cover \%} = 3.14\ D\ t^2 \times 100\ \%$$

This equation can then be used to show the relationship between basal cover percentage and s for constant t (Fig 2.3).

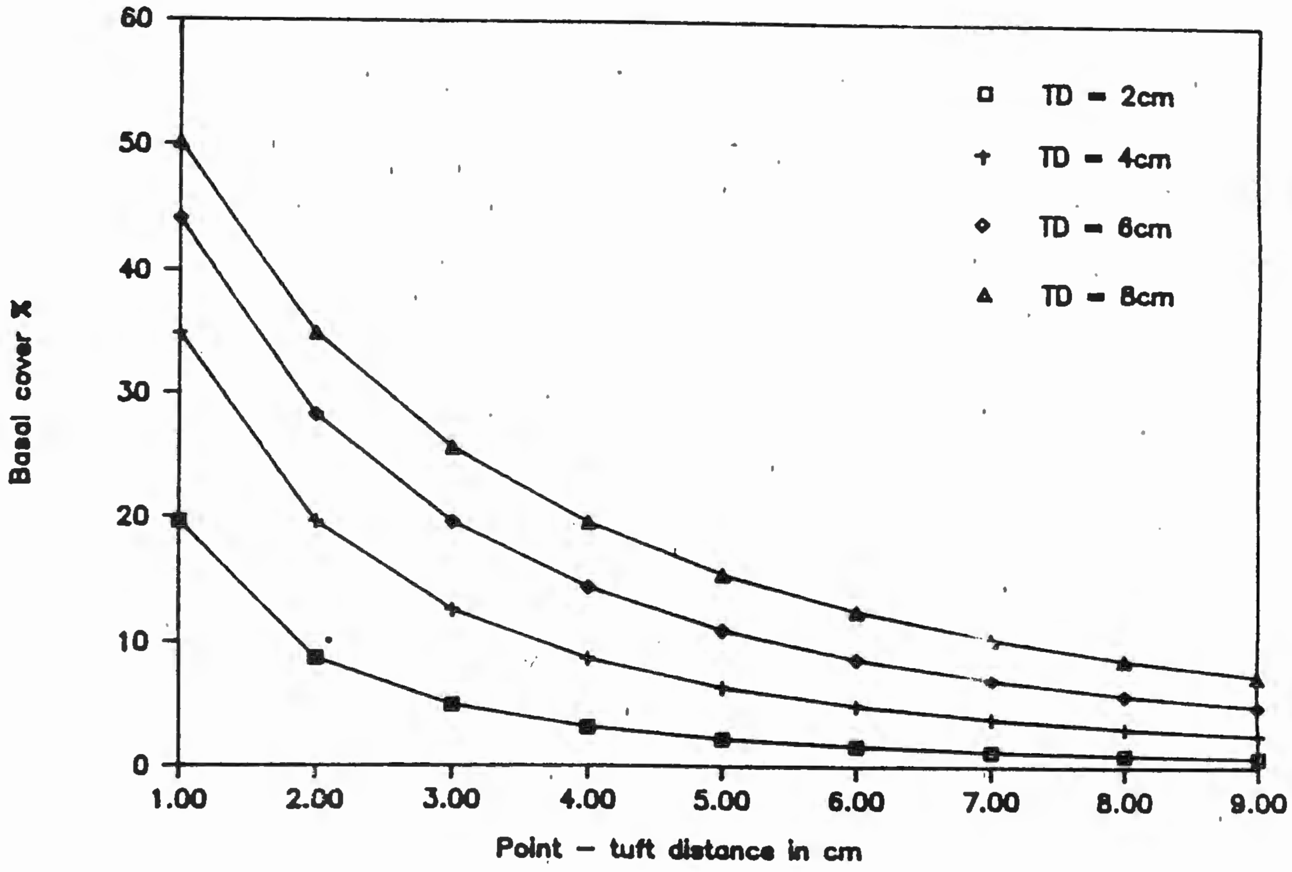


Figure 2.3 The relationship between basal cover percentage and s for constant tuft diameter (TD).

The logarithmic nature of this relationship is clearly evident and this results in two factors.

1. Where the point to tuft distance is small (< 6cm) then for small changes in this measurement there can be large changes in basal cover percentage (Laycock & Batcheler 1975). However this can be problematic where the error for the estimate of the point-tuft distance is large.

2. Where the point-tuft distance is large (>9cm) then basal cover becomes insensitive compared to the point-tuft measurement in showing changes in cover especially when the tuft diameter is small.

The obvious potential that these measurements show for the estimation of basal cover motivated further testing for the precision and the repeatability of these measurements in the field.

2.3.3 Procedure

Two sites (30m x 15m each) were selected with visually different veld condition. Site 1 was more overgrazed and trampled than site 2, and as a result had far more Aristida congesta subsp barbicollis than site 2. These sites are situated on the Noyons Experimental Farm, Potchefstroom, in land type Bc25 (Land Type Survey Staff, 1984). Both sites have soils from the Hutton 36 soil series with andesite as the underlying parent material. The soil depth in both sites ranges from 200 - 400 mm and the slope is 2 %.

Three replications of 100 points each were taken by four different workers on each site. The points were systematically located with a wheel-point apparatus. The various measurements, as explained, were taken at each point. The statistical package, Genstat V (Alvey, 1984) was used for the analysis of variance of the means of the point-tuft and tuft diameter measurements. The results of this test are presented in chapter 4.

CHAPTER 3 DATA ANALYSIS

This chapter explains the various steps that were taken to extract all the meaningful information from the various types of data that were collected.

3.1 Species composition data

The species composition data for each sample was placed in a two way, species x samples matrix, with species percentage abundance as the body of the table. Decorana, which is a fortran programme for Detrended Correspondence Analysis (DCA) and Reciprocal Averaging (RA) (Hill, 1979) were used for the data analysis. DCA was primarily used as this analysis has been found to be the most reliable and robust form of ordination with various types of data (Gauch, 1982). The reason for this is that there is no arch distortion of the first axis which prevents an undesireable and systematic relationship between the first and second axis (Gauch, 1982). This ordination technique also prevents compression of the samples at the ends of the axes, which can be problematic with RA, especially when the data has a high beta diversity (Gauch, 1982) The matrices for the three land types were ordinated together, and from this result decisions were made with respect to further analyses.

3.2 Edaphic data

The results of the soil analyses were placed in a two way, samples x environmental factors matrix. A standarsised Principal Components Analysis (PCA) was then used to analyse this matrix. The PCA is part of the ORDIFLEX computer programme (Gauch, 1977), which has a number of ordination techniques as options. The primary aim of this analysis was to summarise the data into a few axes and to eliminate the problem of multicollinearity. This approach was recommended by Gauch (pers comm.).

3.3 Relating the species composition data with the environmental factors

This step of the data analysis was approached in a number of different ways. The reason why different techniques were used is because these techniques complement rather than contradict one another. More trends and meaningful information are therefore extracted from the data.

3.3.1 Direct gradient analysis

Direct Gradient Analysis (DGA) involves a staight forward graphing procedure of plotting the relative abundance for each species against a measured parameter. This was done for all the soil components. Only meaningful trends are included in the results.

3.3.2 Hybrid ordination

This technique is extremely powerful in that it integrates the resulting axes from the DCA and the environmental parameters. This is done by using the sample scores from the DCA as weights for a weighted averages ordination of the samples by environment factors matrix. The resulting three sets of scores, the sample scores, the species scores and the environmental factors scores, are then graphed using the same scale, and this result can then be interpreted. The procedure is explained in detail by Gauch (1982).

3.4 The tuft diameter and point-tuft distance data

Average tuft diameters were used as data labels for the samples in the species space of the DCA. This was only done for abundant species. The same was done for the average point to tuft measurements.

3.5 Modeling species trends

REGPAC (Galpin, 1981), a linear multiple regression package, was used to establish models for important species with regards to the environmental gradients and edaphic factors. The dependent variables are the species percentages and the independent variables are the samples scores of the PCA axes and the sample scores of the DCA axes. The objective of this procedure is to identify relationships between the soil factors (PCA axes) and the other environmental factors which are derived from the DCA axes. The relationships and interactions that are identified are then reflected in the important habitat types and the associated community organisation and change. Chapter 7 and 8 are therefore products of the same results.

3.6 Identification of the important habitat types and the associated community organisation and change.

This information was obtained from the results of all the ordination techniques and the multiple regression. The original data was also studied to confirm trends that were identified in these results. This chapter is essentially a summary of the most important habitats and species trends that were obtained from the data analysis.

CHAPTER 4 : RESULTS OF THE COVER ESTIMATES EVALUATION

The results of this evaluation are divided into the various data types.

4.1 Species composition

Species composition showed some differences between workers in both sites (Table 4.1). Worker three, for example, recorded less Aristida congesta subsp barbicollis in site 1 than the other workers.

Table 4.1 Species compositions of the two sites for the four different workers.

	Site 1					Site 2				
Species	W1	W2	W3	W4	X	W1	W2	W3	W4	X
Themeda triandra	10	12	6	9	9	9	6	3	6	6
Heteropogon contortus	7	3	6	5	5	6	6	5	3	5
Eustachys paspaloides	0	0	0	0	0	4	3	2	3	3
Panicum coloratum	0	1	2	1	1	2	5	8	9	6
Cymbopogon plurinodis	6	5	7	6	6	7	9	10	8	8
Digitaria argyrograpta	2	1	3	3	2	7	5	8	8	7
Setaria flabbellata	8	5	10	5	7	23	22	26	25	24
Elionurus muticus	12	11	16	12	13	8	8	10	6	8
Rhynchelytrum repens	2	3	1	2	2	0	0	0	0	0
Rhynchelytrum setifolium	0	0	0	0	0	0	1	0	1	0
Cynodon dactylon	0	0	0	0	0	0	0	0	0	0
Chloris virgata	0	0	0	0	0	0	0	0	0	0
Trichoneura grandiglumis	1	1	0	1	1	0	1	1	0	0
Triraphis andropogonoides	0	0	1	0	0	0	0	0	0	0
Tragus berteronianus	11	15	14	10	12	6	9	5	9	7
Aristida congesta subsp. barbicollis	38	36	28	41	36	23	20	21	21	21
Herbs/Sedges	2	3	4	4	3	1	1	2	2	2
Brachiaria serrata	2	1	2	0	1	0	0	0	0	0
Microchloa caffra	0	0	0	0	0	0	0	0	1	0
Eragrostis chloromelas	0	0	0	0	0	2	1	0	0	1
Digitaria eriantha	1	0	0	0	0	0	3	0	0	1
Eragrostis curvula	0	0	0	0	0	0	0	0	0	0
Eragrostis plana	0	0	0	0	0	0	0	0	0	0
Eragrostis lehmanniana	0	0	0	0	0	0	0	0	0	0
TOTAL	100	100	100	100	100	100	100	100	100	100

Note: W=Worker, X=average

This table also indicates that site 1 was in fact overgrazed, as was visually noted, and this is corroborated by the presence of more Aristida congesta subsp barbicollis in site 1 than in site 2, which is associated with overgrazed conditions (Bosch & Janse van Rensburg, 1987).

4.2 Point-tuft distance (s) and the tuft diameter (t).

In the analysis of the means of s, sites were highly significant (P<.01) and workers were significant (P<.05) (Table 4.2).

Table 4.2 Mean (M), standard errors (SE) and least significant differences (LSD) of point - tuft distances for the two sites and the different workers.

	Workers				
Sites	1	2	3	4	M
1	6.57	4.10	3.77	5.63	5.02
2	3.57	4.40	2.73	3.83	3.63
M	5.07	4.25	3.25	4.73	4.33

		LSD	
	SE	5%	1%
Body of table	0.43	1.31	1.82
Workers	0.31	0.93	1.29
Sites	0.22	0.66	0.91

Worker three tended to consistently measure less than the other workers. This consistency amongst all the workers throughout the data collection resulted in no interactions with workers and also resulted in very little variation due to replications. The replications only accounted for 1.33% of the variation in this ANOVA (Table 4.3).

Table 4.3 The analysis of variance of the means of s for the four workers.

Source of variation	DF	SS	SS%	MS	VR	F PROB.
Replicates	2	.53	1.33	.26		
Sites	1	11.48	28.87	11.48	20.42	<.001
Workers	3	11.27	28.34	3.76	6.68	0.005
Sites x Workers	3	8.61	21.66	2.87	5.11	.014
Residual	14	7.87	19.80	0.56		
Total	21	39.23	98.67	1.87		
Grand total	23	39.77	100.00			

This would also be an indication that the sampling intensity was sufficient for this measurement, and that the measurements are highly repeatable within workers. The significant result between workers suggests that one would have to be careful in comparing results between workers.

The highly significant difference ($P<.01$) between site 1 (5.02 cm) and site 2 (3.63 cm) for the point to tuft measurement could be explained by the bare patches which occurred in site 1. Such a measurement would therefore help in demonstrating the effect of overgrazing and trampling. Although these differences are small, Fig 2.2 shows that this small change could represent a large reduction in basal cover percentage.

In the analysis of the mean diameters of tufted species, species, sites and workers were all highly significant ($P<.01$) (Table 4.4 & 4.5)

Table 4.4 Mean diameters of the two sites, standard errors (SE) and least significant differences(LSD) of five tufted species recorded by the four different workers.

Species	Workers 1	2	3	4	Mean
H. contortus	6.92	7.50	7.78	10.52	8.18
S. flabbellata	2.87	3.18	2.03	3.67	2.94
C. plurinodis	7.95	7.53	7.13	11.97	8.65
E. muticus	6.32	5.95	6.10	8.57	6.73
A. congesta	5.85	6.02	5.68	6.60	6.04
Mean	5.98	6.04	5.75	8.26	

	SE	LSD 5%	LSD 1%
Body of table	0.70	1.97	2.62
Species	0.35	0.98	1.31
Workers	0.31	0.88	1.17

The highly significant difference between workers is mainly attributed to the over measurements of worker 4.

The average diameter for tufted species in site 1 was highly significantly smaller than in site 2. Although this average has little meaning it reflected the trend found in all the species (Table 4.4).

Table 4.5 Mean diameters recorded by the four workers, standard errors (SE) and least significant differences(LSD) of five tufted species for the two sites.

Species	Sites 1	2	Mean
H. contortus	7.70	8.66	8.18
S. flabbellata	2.73	3.14	2.94
C. plurinodis	7.20	10.09	8.65
E. muticus	6.45	7.02	6.73
A. congesta	5.75	6.33	6.04
Mean	5.97	7.05	

	SE	LSD 5%	1%
Body of table	0.49	1.39	1.85
Species	0.22	0.62	0.83
Sites	0.35	0.98	1.31

This could be accounted for by the reduction in the size of the tufts due to the physical effects of grazing and trampling that occurred in site 1 and/or the lifespan of individual tufts could be shorter in site 1. The fact that tuft diameter decreased, and distance from the point to the base of the nearest tuft increased, shows that there is a marked decrease in basal cover (Fig 2.2).

The highly significant differences found between species diameters also introduced the question:

"What is one percent of a species in a nearest plant survey?"

It is quite clear from the results that one percent of Setaria flabbellata, for example, is approximately a tuft with a basal diameter of 2.5cm. Whereas a tuft of Heteropogon contortus is approximately a tuft of 8cm. This is clearly not the same, especially when one considers the contribution that each tuft makes to the basal area. These measurements could therefore be used for the conversion of percentage abundance to basal cover of each species.

4.3 Conclusions

The fact that clear trends exist in the data indicates that these measurements could serve as a valuable aid in explaining treatment effects and growth habits of various tufted grass species in different habitats. The need to measure both point-tuft distance and tuft diameter to estimate basal cover has problems. Firstly, the error in measuring these two distances is multiplied in the equation to estimate basl cover. Secondly, the tuft diameter is often difficult to determine and define which results in differences between workers. The question must be asked however if run-off, sward stability and veld condition as a whole, is correlated with basal cover and/or inter tuft spacing. For example, a sward with large tufts and large inter tuft spaces could have exactly the same basal cover as a sward with small tufts and small inter tuft spaces (Fig 2.2). The run-off and stability of these two situations would be completely different (Tainton, 1981). Therefore basal cover per se could not be used to distinguish between these two situations, but rather inter tuft distances and/or tuft diameter. This example demonstrates that these measurements used independently could be more informative than an estimate of basal cover.

This simple technique for giving an index of spacing of grass tufts and tuft diameter does show some potential. The measurements do have shortcomings, especially where tufts are not well defined. Although these problems do exist, it is also evident that the measurements could be used to aid in explaining changes in the sward cover, especially where they can be correlated with treatments and environmental gradients (Chapter 6). It is also evident that this technique will be more useful in sparse rather than dense swards.

CHAPTER 5 : DIRECT GRADIENT ANALYSIS

This chapter contains all the meaningful results obtained from the DGA procedure. Discussion of these results will also be included. The trends that are shown in the graph have simply been drawn in by hand so that the trend is easily seen. Almost all the distributions were filled Gaussian and this is why regression analysis was not used. A regression done on this type of distribution results in a trend which passes through the middle of the cloud of points and usually shows little or no significance. The cause of the filled Gaussian distributions is the multidimensional data.

It must also be emphasised that the trends that are shown are not independent of other factors and this is the reason why the multivariate techniques are more relevant with this type of data (Chapter 6). All the data from the three different land types were used in this procedure, but the samples were given different labels for each land type so that possible interactions between the land types and the edaphic factors could be identified.

5.1 Soil pH

Pennisetum sphacelatum, Fingerhuthia sesleriaeformis and Cynodon dactylon all increased with increasing soil pH but Cynodon dactylon did show a sensitivity to pH levels above 7 (Fig 5.1).

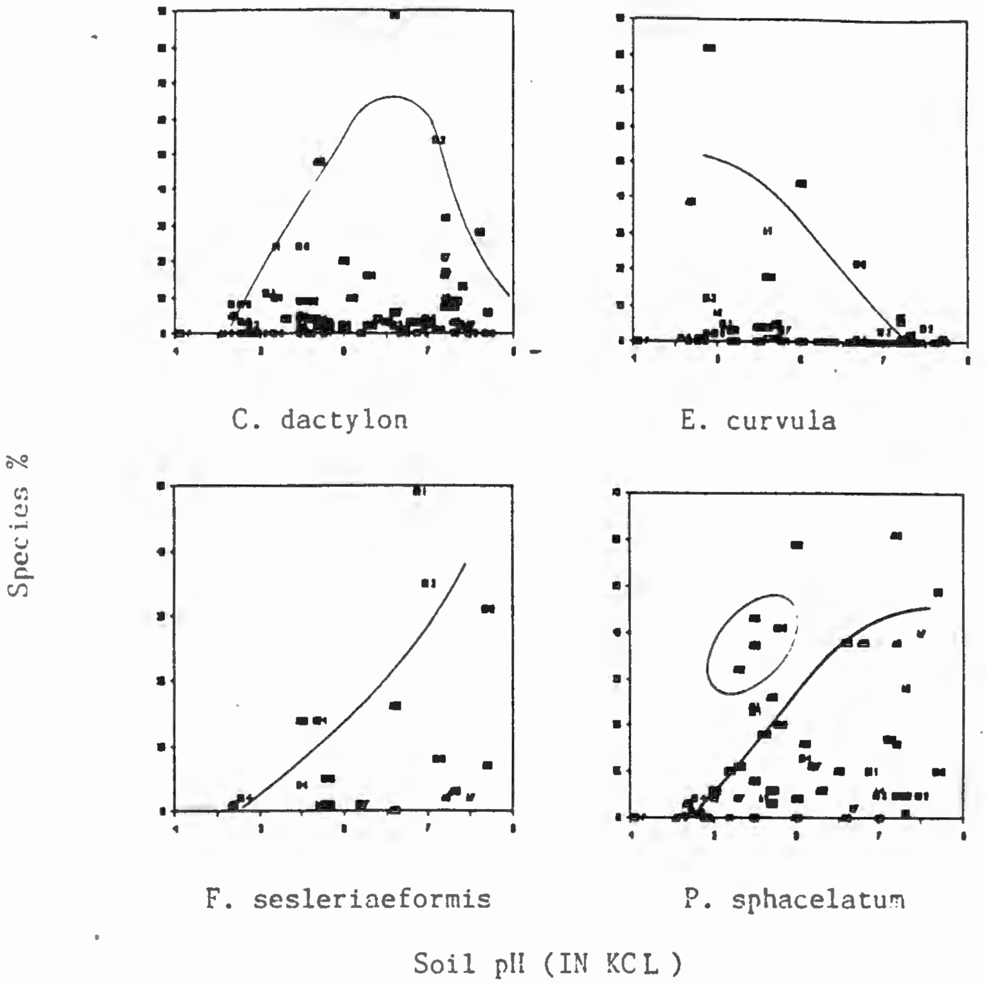


Figure 5.1 The trends shown by Cynodon dactylon, Eragrostis curvula, Fingerhuthia sesleriaeformis and Pennisetum sphacelatum to changing soil pH.

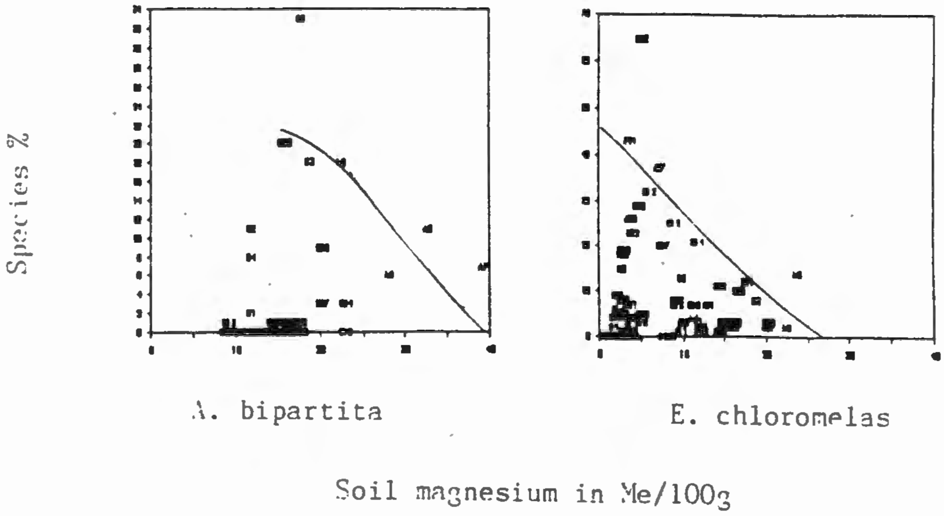
Roberts (1971) did not find the same trend with regards to Pennisetum sphacelatum. The trend identified by Roberts (1971) is questionable because the species showed a similar trend with calcium, which is positively correlated with pH.

Eragrostis curvula was most abundant where soil pH was less than 6 (Fig 5.1). This decline in Eragrostis

<u>curvula's</u> abundance with increasing soil pH supports the fact that <u>Eragrostis</u> <u>curvula</u> is a well suited pasture species where soil acidity is a problem (Tainton, 1981).

5.2 Magnesium (Mg)

Only two species showed trends with changing Mg levels. <u>Eragrostis</u> <u>chloromelas</u> decreased in relative abundance with increasing Mg levels (Fig 5.2). <u>Aristida</u> <u>bipartita</u> was abundant at moderate Mg levels, but rare at both low and high Mg levels. This species did show an affinity for heavy black vertic soils which are often a result of dolerite, especially in the Bb25 and Ca6 land types. This rock type is also rich in Mg, which perhaps supports this trend. Roberts (1971) also found a positive association between this species and dolerite.



A. bipartita

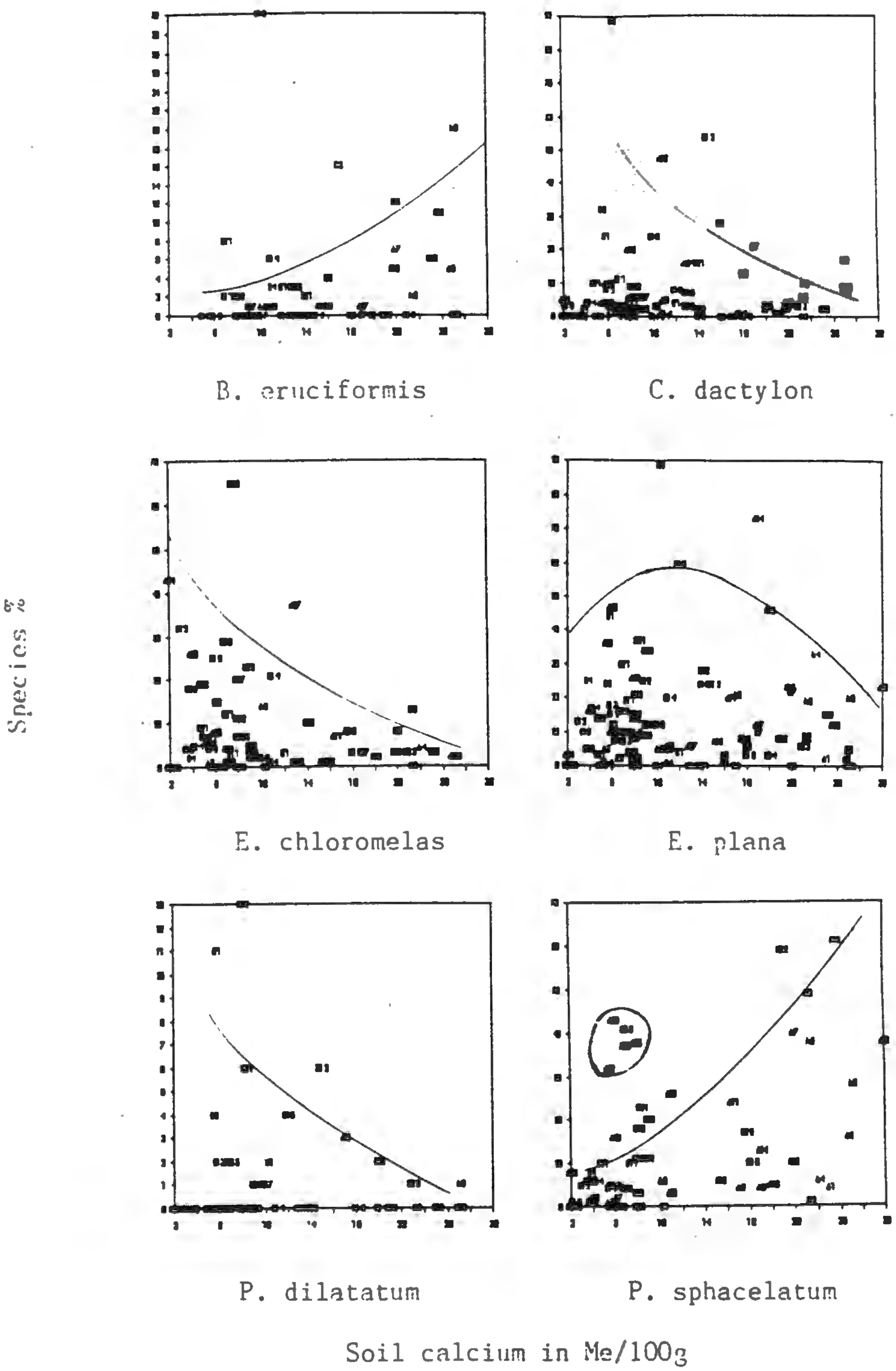
E. chloromelas

Figure 5.2 The response of <u>Aristida</u> <u>bipartita</u> and <u>Eragrostis</u> <u>chloromelas</u>, to changing soil magnesium levels.

5.3 Calcium (Ca)

Pennisetum sphacelatum increased with increasing calcium in the soil. There were five samples that deviated from this trend (Fig 5.3). This deviation can probably be explained by the calcerous B horizons of the soils on these sites. This is important because it demonstrates that the roots of the sward are able to penetrate these horizons and extract nutrients that were not in abundance in the A horizon. The soils that are typical of this situation are the eutrophic duplex soils (Estcourt and Valsrivier forms). This does have practical implications because pastures which are established on these soil types can benefit from the high nutrient status of the B horizons.

Brachiaria eruciformis and Pennisetum sphacelatum have a strong positive association with the soil calcium content, and the trend could be linked to the trend that the species show to soil clay percentage. The slight negative correlation between Cynodon dactylon and Eragrostis plana with soil calcium, is possibly linked to the fact that these species become more palatable where the soil has a high base status.



B. eruciformis

C. dactylon

E. chloromelas

E. plana

P. dilatatum

P. sphacelatum

Figure 5.3 The trends of Brachiaria eruciformis, Cynodon dactylon, Eragrostis chloromelas, Eragrostis plana, Paspalum dilatatum and Pennisetum sphacelatum for changing calcium levels in the soil.

Paspalum dilatatum and Eragrostis chloromelas both decrease in relative abundance with increasing calcium in the soil. The trend of Eragrostis chloromelas is stongly supported by an experiment done by Wiltshire (1980) who noted that Eragrostis chloromelas was sensitive to soils with a high base status. This author also found that in some instances it was almost impossible to establish this species on these types of soils. The particular soil in question in this experiment was of a dolerite origin which was also found to increase the base status of soils in the land types that were studied.

5.4 Sodium (Na)

Aristida bipartita and Andropogon appendiculatus decreased in abundance with increasing sodium levels (Fig 5.4). What was evident in the field is that Aristida bipartita was abundant where calcium nodules were abundant in the soil. However it would appear from this trend that where sodium was part of these cations then Aristida bipartita decreased in abundance.

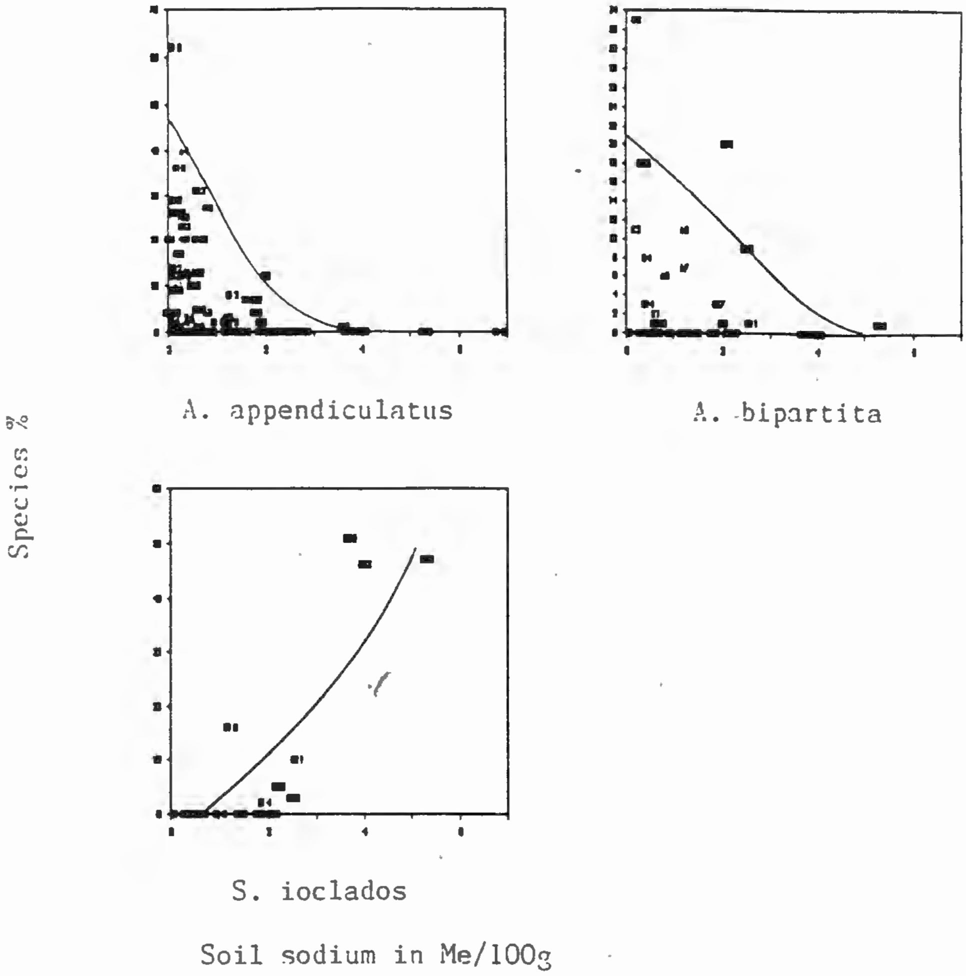
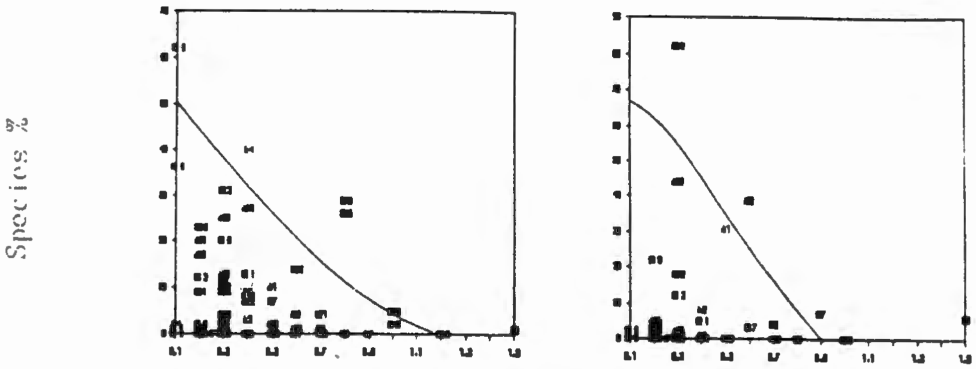


Figure 5.4 The trends of <u>Andropogon</u> <u>appendiculatus</u>, <u>Aristida</u> <u>bipartita</u> and <u>Sporobolus</u> <u>ioclados</u> with changing sodium levels in the soil.

<u>Sporobolus</u> <u>ioclados</u> showed a marked increase in abundance where Na levels were high (Fig 5.4). This species was also associated with extremely overgrazed sites in the Bc25 land type and areas that had pan characteristics, which would support this trend. There is also a possible interaction between grazing and the Na level in the soil. This interaction is explained in more detail in chapter 5.

5.5 Potassium (K)

Only <u>Andropogon appendiculatus</u> and <u>Eragrostis curvula</u> showed any trend with changing potassium levels in the soil. These species both decreased in abundance where potassium levels were high (Fig 5.5).



A. appendiculatus

E. curvula

Soil potassium in Me/100g

Figure 5.5 The response of <u>Andropogon appendiculatus</u> and <u>Eragrostis curvula</u> to different potassium levels in the soil.

5.6 Phosphate (P)

Both <u>Eragrostis chloromelas</u> and <u>Andropogon appendiculatus</u> show a decrease in abundance with increasing soil phosphate (Fig 5.6).

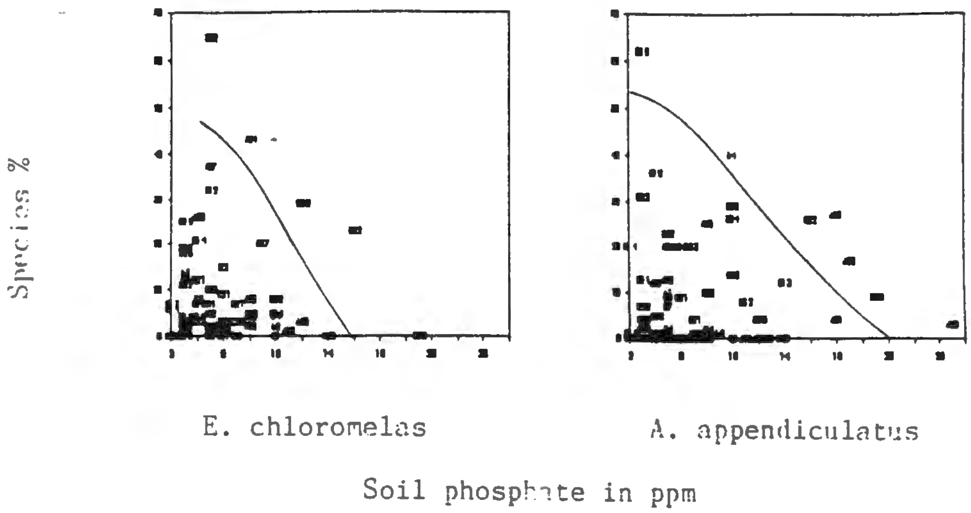


Figure 5.6 The response of Eragrostis chloromelas and Andropogon appendiculatus to soil phosphate.

These species were more abundant in the dystrophic and mesotrophic soil types, which would support this trend, as phosphate availability tends to be lower in these soil types compared to the eutrophic soils (Sanchez 1976).

One would expect more species to show a trend with changing soil phosphate, because of the importance of phosphate in the physiology of the plant. The possible cause of this lack of trends is the influence that other soil factors, such as the abundance of calcium and magnesium, have on the availability of phosphate for the plant (Sanchez, 1976).

5.7 Soil clay percentage

Five species showed trends with changing soil clay percentage (Fig 5.7).

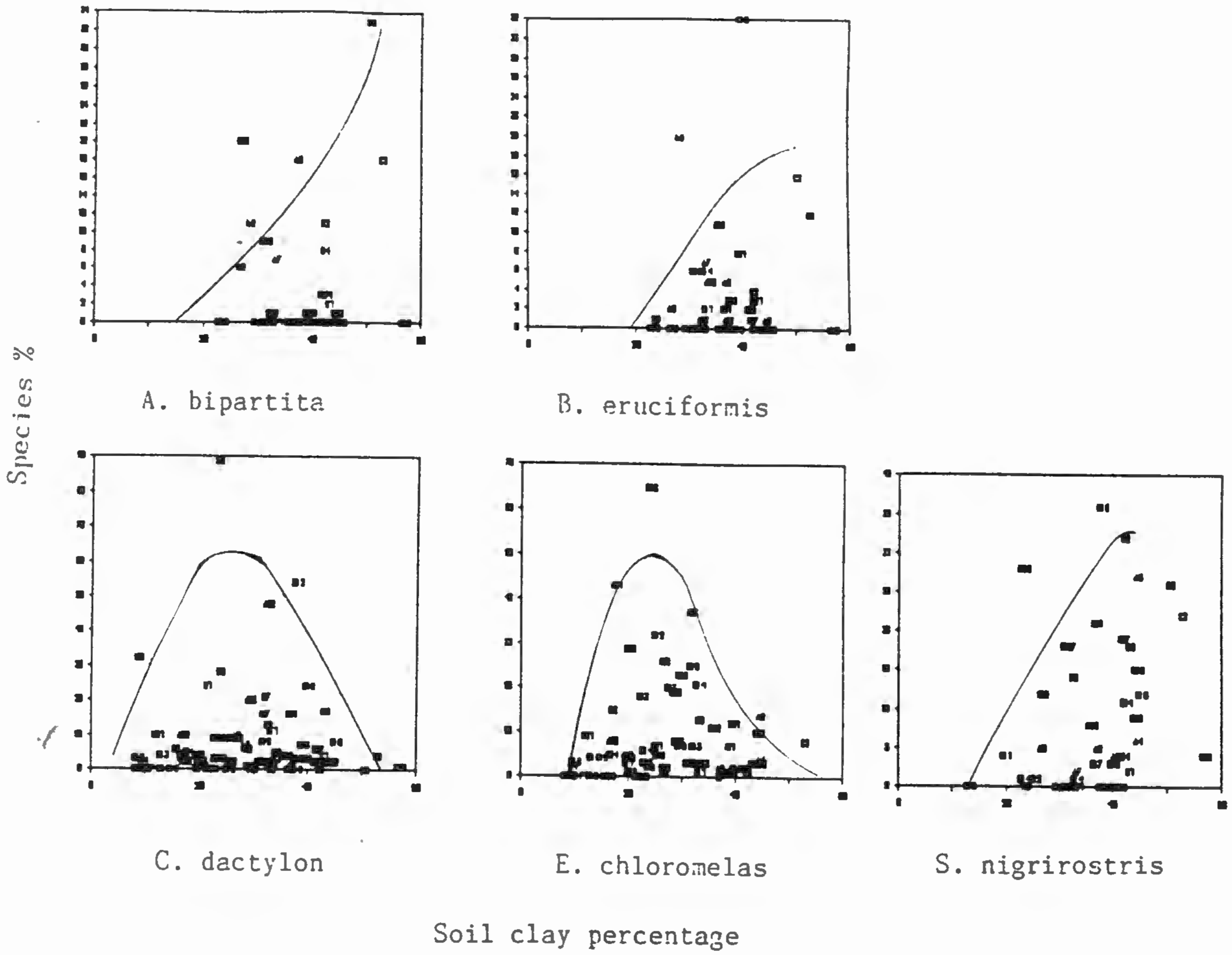


Figure 5.7 The response of Aristida bipartita, Brachiaria eruciformis, Cynodon dactylon, Eragrostis chloromelas and Setaria nigrirostris to changing soil clay percentage.

Aristida bipartita, Brachiaria eruciformis and Setaria nigrirostris all increase in abundance with increasing clay percentage. Setaria nigrirostris was predominantly found in the Bc25 land type in moist positions on Rensburg and Arcadia soil forms. This species can be regarded as the most characteristic species for these soil types in land type Bc25. Chippandall (1955) notes that this species is abundant on wet black turf soils. The trend supports this finding but it should be emphasised that the species prefers a wet position and not a dry turf.

Aristida bipartita was found in similar sites to that of Setaria nigrirostris, but tended to prefer the raised, drier areas. Scheepers (1975) found that Brachiaria eruciformis was associated with heavy black soils and could be linked to the trend shown with soil calcium.

Cynodon dactylon and Eragrostis chloromelas decrease in abundance at both high and low clay percentages. Cynodon dactylon showed a similar trend with soil calcium, which to a certain degree, is correlated with soil clay percentage. Eragrostis chloromelas also showed a decrease in abundance with increasing soil calcium. This finding contradicts the finding of Scheepers (1975), but is supported by the work done by Wiltshire (1980).

5.8 Conclusions

It is clear from the results of the DGA that species are not only linked to one factor, but their abundance is rather a complex interaction of a number of factors. Although this is the general rule (Gauch, 1982), there are some species which do have good indicator value for certain edaphic factors and these species can be useful when doing field work. The biggest problem with DGA is that there is no real way of expressing these trends with a mathematical function because regression analysis on this type of data does not give good results, as pointed out in the introduction to this chapter.

CHAPTER 6 : INDIRECT GRADIENT ANALYSIS

In this chapter the mechanisms and interactions of the gradients identified are discussed. The resulting changes in species compositions as a result of these gradients will not be included in any detail but this will be dealt with separately in chapter 7.

The essential difference between this indirect approach for determining important environmental gradients, and the DGA approach, is that the environmental gradients are indirectly and objectively obtained from the ordination of the species abundances for the various samples, whereas, for the DGA approach, it is hoped that the species will show trends for the various parameters which were measured (Gauch, 1982). The problem with this indirect approach is that the axes obtained from the ordination only become environmental gradients when they are interpreted as such. Gauch (1982) points out that these gradients are often complex interactions, and therefore interpretation is often difficult, compared with the more simple interpretation of the DGA. There are, however, four aids for this interpretation:

1. Existing knowledge of the species. Note that the trends from the DGA were also used.

2. The characteristics of the sample sites. This was essentially summarised in the PCA of the soil factors and in the hybrid ordination.

3. Field observations.

4. Point to tuft distances and tuft diameters were also plotted against these axes to aid in the interpretation. Only significant trends will be discussed.

All these aids were used simultaneously to obtain meaningful interpretations of the axes in the DCA's. Species used as examples in the discussions, although often rare species, were considered to be reliable indicator species.

6.1 The DCA of the Bb25, Ca6 and Bc25 land types combined.

In the description of the study area it is clear that these land types can be separated with respect to the abiotic factors. Studying the samples ordination of axis 1 and axis 2 (Fig 6.1) it is possible to separate land type Bc25 from the other land types, because most of the samples that were taken in this land type occur to the right of the graph. However, the other two land types show no pattern.

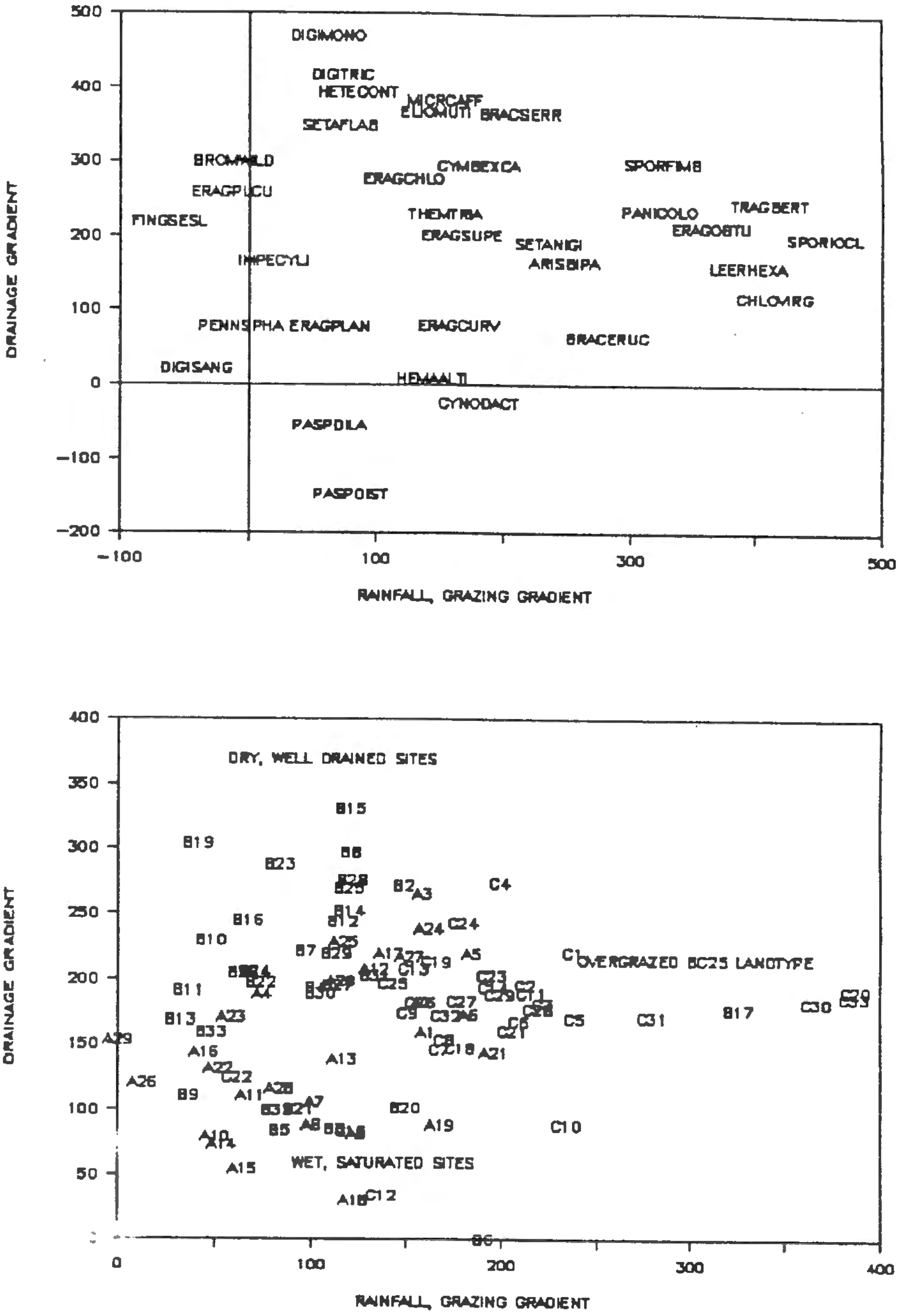


Figure 6.1 The species (above) and the samples (below) ordination for axis 1 and axis 2 for all three land types. A = the Ca6 land type and B and C the Bb25 and Bc25 land type respectively.

The reason for this is that there were a number of species namely, <u>Themeda triandra</u>, <u>Eragrostis plana</u> and <u>Cynodon dactylon</u>, that were abundant in all three land types. These species often made up a large proportion of the total species composition, and this resulted in the samples from different land types having high similarities. This is probably why Acocks (1975) considered all of these areas to fall into variations of the Cymbopogon - Themeda veld. There were, however, species that characterised the Bc25 land type. These are the species which occur on the right of the species ordination (Fig 6.1), namely Sporobolus ioclados, Tragus berteronianus and Eragrostis obtusa. What is interesting about all these species is that they are associated with overgrazed sites (Trollope, 1986) and are also xerophytic. This is the primary reason why the X axis, (axis 1) was considered to be a rainfall/grazing gradient. This can be supported by Snyman (1986), who showed that overgrazing can indirectly enhance the aridity of the site because there is a reduction in cover (basal and/or canopy), which results in less infiltration of rainfall and more run - off. So the effect of moisture and grazing on a site can be confounded.

Species which characterised the Bb25 and the Ca6 land types are found on the far left of the species ordination (Fig 6.1) namely Fingerhuthia sesleraeformis, Pennisetum sphacelatum, and Eragrostis planiculmis. All these species are hygrophilous and probably cannot tolerate moisture stress, and this is why they did not occur in land type Bc25, where drying out of the bottomlands is a common occurrence during droughts.

The second axis of the ordination can be explained by soil drainage. Those species which prefer well drained soils are situated at the top of the species ordination (Brachiaria serrata and Digitaria tricholonoides being good examples) and those that prefer saturated water logged soils are situated at the bottom of the species ordination (for example Paspalum dilatatum and Paspalum distichum). The gradients will be explained in more detail in the separate ordinations. It was on the basis of this result that the division of these land types was done for further ordinations.

6.2 The DCA and hybrid ordination of land types Bb25 and Ca6 combined.

The result of this analysis will be divided into the two axes that could be interpreted as environmental gradients.

6.2.1 Axis 1

This axis is interpreted as a drainage gradient and is very similar to the drainage regime gradient described by Dix & Smeins (1967) (cited by Gauch (1982)) and the moisture gradient described by Edgell (1971). The presence of hygrophilous species, such as Leersia hexandra, Hemarthria altissima, Eragrostis planiculmis and Imperatra cylindrica (Chippandal, 1955) on the far right of the DCA ordination (Fig 6.2), and the presence of species which prefer well drained sites, namely Digitaria monodactyla, Harpochloa falx, and Microchloa caffra (Scheepers , 1975) on the left of this axis, is the first support for this interpretation. It was also clear from the samples ordination that wet and water logged sites occurred to the right, and drier well drained sites occurred to the left of the ordination.

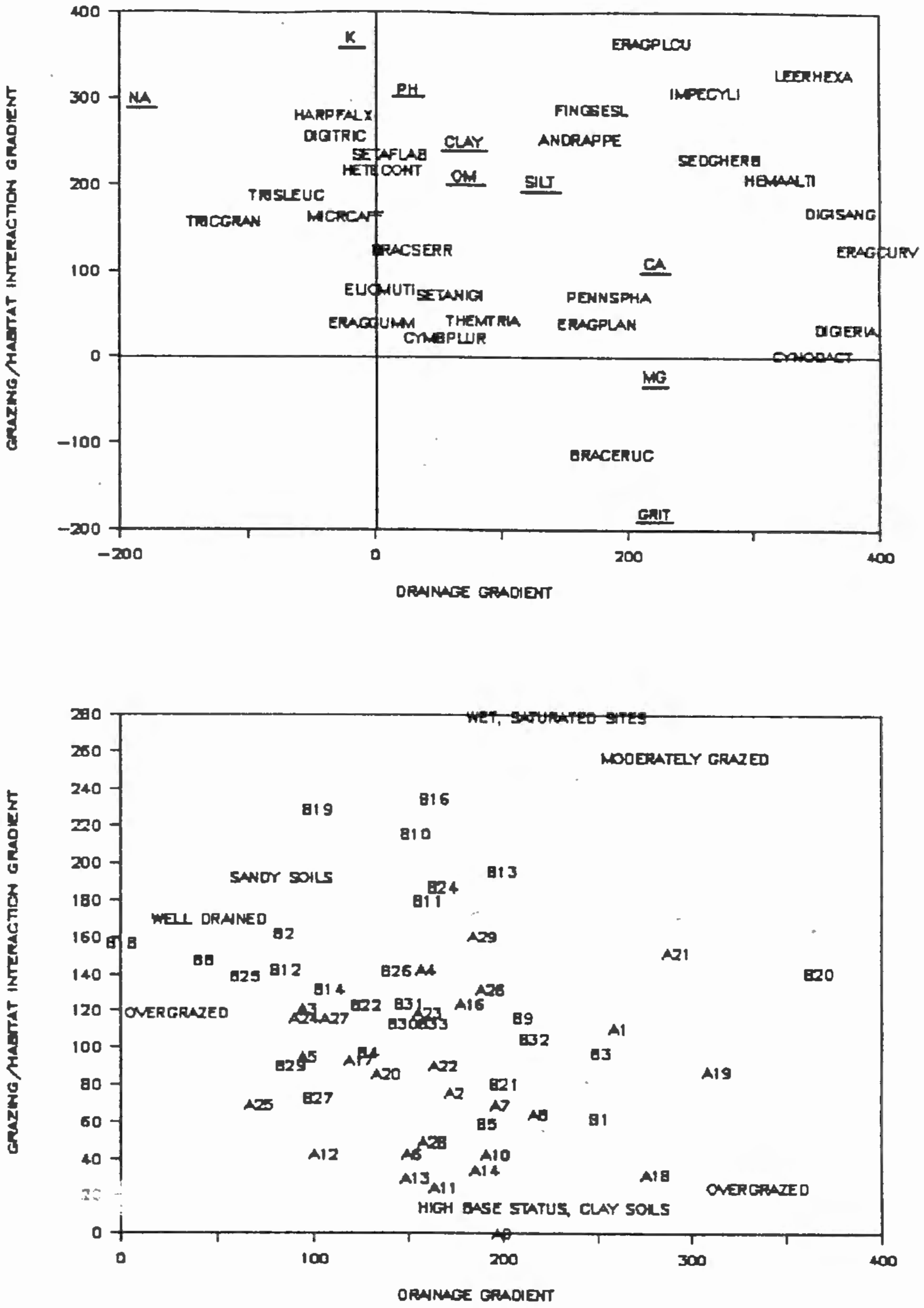


Figure 6.2 The result of the DCA and hybrid ordination of samples that occurred in the Bb25 and Ca6 land types. The hybrid and species ordination has been graphed together (top) and the samples ordination is separate (bottom).

The association of silt, calcium, magnesium, organic matter, clay and pH with these wet sites can be explained by the accumulation of minerals, and the finer soil fractions in the wetter sites. A high pH is also often associated with wet, saturated conditions due to the anaerobic conditions. This results in the reduction of oxidised ions which in turn causes the release of hyroxil ions, increasing the pH (Sanchez, 1976). The strong association of the wet sites with soil phosphate, is possibly due to the movement of phosphate fertilisers from the cultivated lands into these bottomland areas. The position of sodium cannot be fully explained, but it is perhaps indicative of a fluctuating moisture status which is common in duplex soils. The latter were common in samples in this part of the ordination. It is also important to note that the Tarkastad mudstones are particularly rich in this element (Stavrakis, 1979), and often give rise to this soil type, and this would therefore support this explanation.

The drainage gradient is in effect a product of three important abiotic factors:

1. The position of the site in the landscape.

Although the study was restricted to the bottomland situations (terrain unit 5) there were variations with respect to this factor (Fig 6.3). These variations directly affected the moisture status of a site and therefore the species composition.

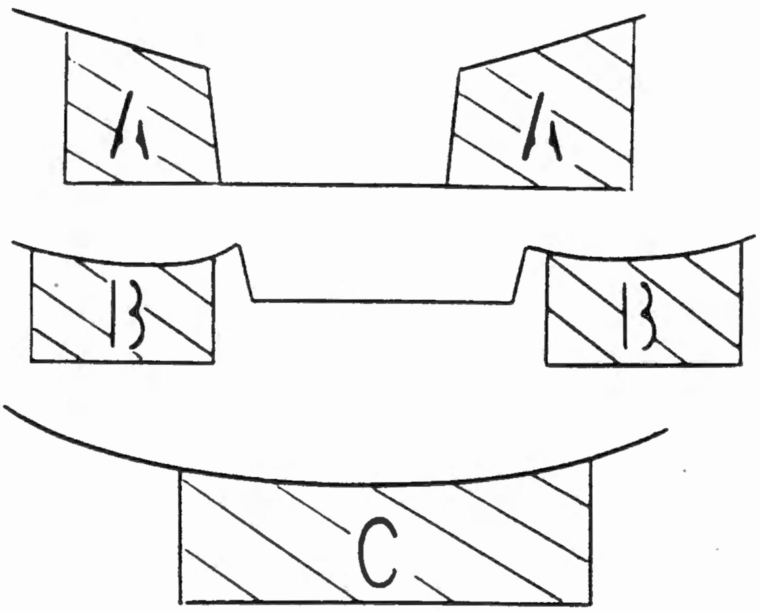


Figure 6.3 The three typical types of situations that can be found in land types Bb25 and Ca6.

The sites in situation "A" are well drained as a result of the deep drainage channel and the slope of the banks of the drainage channel. These sites are therefore mostly found on the left of the ordination. Sites in situation "B" are poorly drained and undergo fairly frequent flooding. These sites are found in the middle and to the right of the ordination. Sites in situation "C" are almost permanently wet and this is a typical "vlei" situation. These sites occurred to the right and sometimes in the middle of the ordination. Although one can get variations of the three types of situations and they can to a certain degree occur together, it is clear that position in the landscape is vital to the eventual drainage of a site and therefore deterministic of the species composition.

2. Soil structure.

As was pointed out in the description of the study area, various soil types are found in the bottomlands and these variations also influence the drainage status of a site. The deep sandy alluvial soils, although moist, are well drained, and Themeda triandra was often abundant on this soil type. Themeda triandra showed no tolerance to saturated soil conditions and would therefore only occur where flooding is infrequent. On the other hand soils with grey, saturated B horizons (Rg & Wo) were clearly associated with the hygrophilous species.

3. Slope

There are two types of slope to be considered. Firstly, the slope of the drainage channel and secondly, the slope of the banks of the drainage channel. Their effect on the drainage is simply that increasing slope increases the drainage of a site.

The above mentioned three factors, often interacting with one another, result in the eventual moisture and/or drainage status of the site. This forms the most important gradient influencing the species composition of a site in the bottomlands of the two land types under consideration. This gradient is also important in other topographical positions as suggested by Janse van Rensburg (1987), Roberts (1971) and Bosch (1985). A practical consideration of this interpretation is the drastic increase in the drainage of a bottomland caused by erosion, which would result in a marked increase in the abundance of species that occur on the left of the gradient, and a decrease in abundance of the species that occur on the right of the gradient. Another example is the increase in moisture status caused by run-off from ploughed lands and roads. It is clear, therefore, that water movement into and out of a site must always be considered when trying to predict or interpret the species composition of a site.

6.2.2 Axis 2

Axis 2 of the DCA was interpreted as a grazing gradient. This gradient does not only represent the effect of defoliation on the vegetation, but also the physical disturbance of the soil surface by trampling and the deposition of urine and excreta by the grazing animal. The magnitude of this effect of the gradient increases from the top of the ordination to the bottom of the ordination (Fig 6.4). Support for this interpretation is derived from both the position of samples and species in the ordination. Firstly samples that were visually overgrazed occurred at the bottom of the ordination and samples that were considered to be in a better condition were found at the top of the ordination. Species also commonly found in abundance in overgrazed sites, for example Cynodon dactylon, Brachiaria eruciformis, Aristida junciformis, and Eragrostis gummiflua, were found towards the bottom of the ordination and those species associated with veld in a good condition, for example Andropogon appendiculatus and Digitaria tricholanoides, were found at the top of the ordination.

Secondly it is evident from the hybrid ordination that magnesium and grit would appear to be associated with overgrazed, wet sites. It was also found in the DGA that species in the lower right half of the ordination also tended to be more abundant where soil calcium and/or magnesium levels were high. In other words, it would appear that sites with a high base status were more frequently overgrazed than sites with a low base status. This apparent interaction of the grazing animal with the edaphic factors was identified by Roberts et al (1972), who also suggested that the palatability of a grass plant can change with changing habitat. Tainton (1981) also recognises the importance of habitat type for the calculation of the grazing capacity, as a topographic factor and a soil erodibility factor are included in the formula that is recommended for calculating grazing capacity. Janse van Rensburg (1987) goes so far as to say that the ecological status of a species, ie. whether it is an increaser or decreaser, should be given for each habitat type, because the reaction of a species to grazing can differ for different habitats.

It is obvious, therefore, that it is important not only to identify, but also to understand, the mechanisms involved in these interactions. The problem is that there are two possible causes of this trend that cannot be separated in this study, namely:

1. The preference shown by animals for sites with a high base status could result in these areas being overgrazed, in comparison to sites with a low base status. Edgell (1971) also identified this preference shown by grazing animals for sites that had soils with a high base status.

2. Sites with a high base status could show a greater sensitivity to the same level of grazing as other sites, and therefore appear to be overgrazed, as there is more rapid change in species composition, because of rapid degradation of the soil's physical properties.

Although these mechanisms of veld degradation could not be separated because there was no quantification of the grazing gradient, the habitats which showed this trend were identified.

These interactions also question the definition of the grazing gradient. This is because the gradient is not only a result of grazing and the associated factors, but also a result of habitat resilience or sensitivity to grazing, and/or animal preference for certain habitats. Therefore this gradient could rather be termed a habitat/ grazing interaction gradient. In other words, for a single habitat type, one could identify a grazing gradient, but when different habitats are combined then the gradient becomes a habitat/grazing interaction gradient.

6.2.3 Conclusions

Two environmental gradients, namely the drainage and the habitat/grazing interaction gradient, are the main factors influencing the species composition of the Bb25 and Ca6 land types. These gradients are by no means independent of one another, because the habitat is a result of drainage, and the this habitat interacts with the grazing animal. It is therefore important that the impact of management on soil drainage, and the management tools to prevent certain sensitive and/or selected areas from being overgrazed, should be given attention. Certain aspects which need particular consideration are:

1. Control of run-off from cultivated lands.

2. Fencing of camps using soil type as a guideline.

The fact that point to tuft distances and tuft diameters could not be related to these gradients, especially the grazing gradient, was attributed to the following factors:

1. The point to tuft measurement was generally very small (< 2 cm), and this is problematic as pointed out in the technique study. The simple fact that it is

so low, would also suggest that grazing does not cause a marked reduction in basal cover in these bottomlands. However the visual reduction in canopy cover was extreme.

2. The tuft diameter measurements were extremely difficult to determine in these bottomland areas, because the canopy cover was often high, and this resulted in considerable guess work as to where the tuft began and ended. This resulted in few identifiable trends, as the error was large.

6.3 The DCA and hybrid ordination of the Bc25 land type.

The results from this land type will also be divided into the two axes that could be interpreted as environmental gradients (Fig 6.4).

6.3.1 Axis 1

The interpretation of this axis is based on the position of samples and species in the ordination.

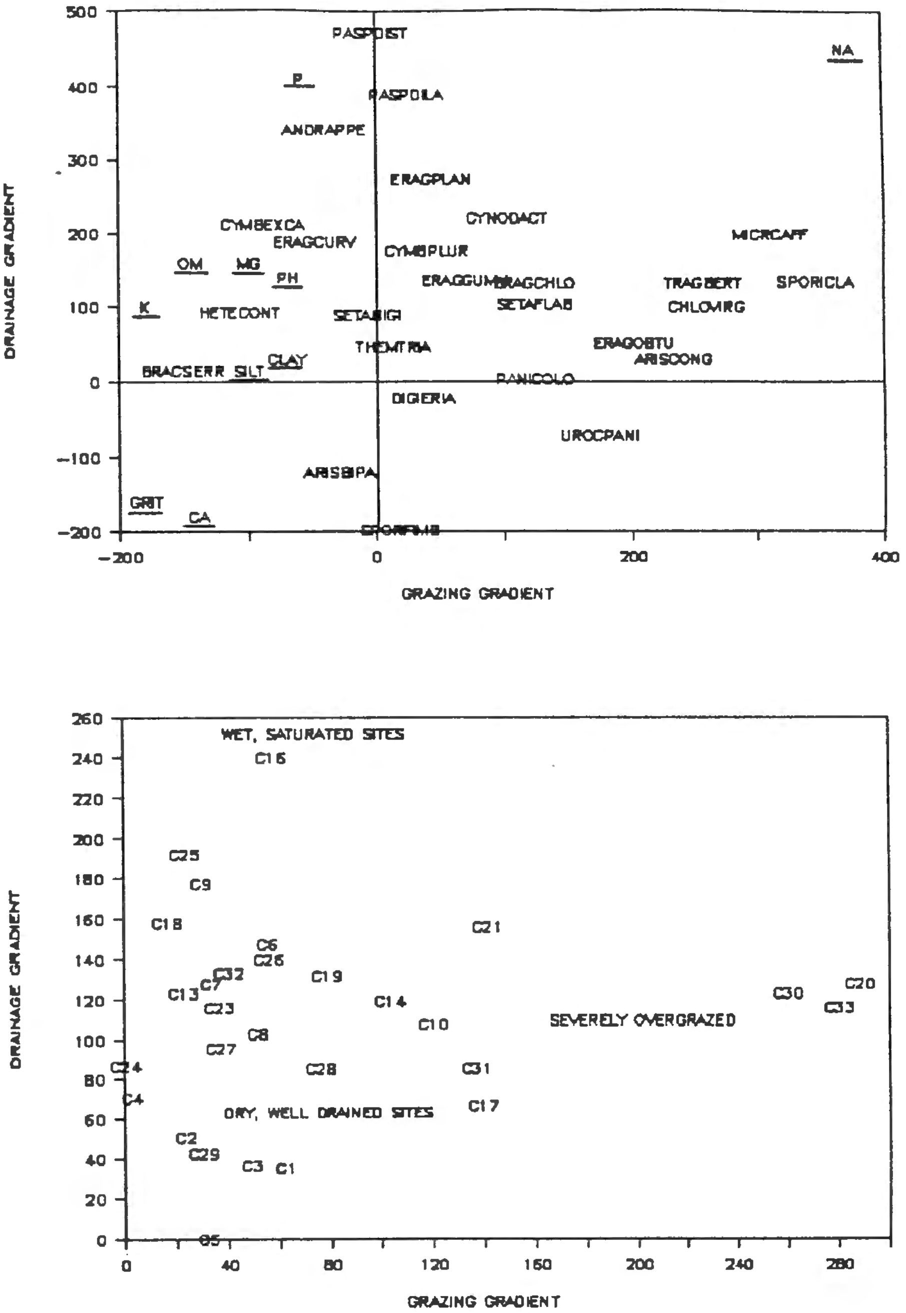


Figure 6.4 The result of the DCA and the hybrid ordination for the samples that occurred in the Bc 25 land type. The species and hybrid ordination have been graphed together (top) and the samples ordination is separate (bottom).

Overgrazed, highly disturbed samples occurred on the right of the ordination, and sites that were considered to be in a better condition occurred on the left, and in the middle, of the ordination. The distribution of the species also supported this interpretation. A number of annual species that are associated with overgrazed and disturbed sites occurred on the right of the ordination. These were Tragus berteronianus, Chloris virgata, Brachiaria eruciformis and Urochloa panicoides (Trollope, 1986). However, the three perennial species that also occurred in this position, namely Eragrostis obtusa, Sporobolus ioclados and Microchloa caffra (Trollope, 1986), are also very good indicators of overgrazing. Acacia karroo also increased in abundance in overgrazed sites, especially where the soil had stone in the B horizon, and where the drainage channel was deep. This would suggest that this species cannot tolerate saturated soil moisture conditions. The impact of grazing in the bottomlands of this land type is catastrophic in many cases. This was also noted by Louw (1951) and Acocks (1975), who both considered the bottomland situations of this area to be totally degraded. The reason they gave for this, is that the streams and rivers are used as watering points, and therefore these areas are not only overgrazed, but also physically damaged by trampling.

The hybrid ordination also showed a strong association between overgrazed sites and the sodium level in the soil. The white appearance of the soil surface in certain overgrazed sites could be linked to this association. The reason for this association is possibly also due to the reduced moisture infiltration in overgrazed sites, which causes an increased precipitation of salts (eg. sodium compounds) on the soil surface. This would in turn increase the sodium levels in the topsoil.

What is also problematic is the fact that the high level of sodium in the topsoil will enhance the droughty nature of these heavy clay soils found in this land type, and therefore increase the stress on the plant, making it more sensitive to overgrazing. The sward as a whole would therefore be less productive. This shows the accumulative negative effect that overgrazing can indirectly have on the degradation of the veld. This build up of sodium in the topsoil could also be enhanced by drought and reduced by wet years. One would expect therefore a change in species composition following dry and wet years.

Elionurus muticus, Brachiaria serrata and Themeda triandra are abundant in moderately grazed veld. Elionurus muticus is considered a problem species that occurs in selectively grazed and overgrazed areas in the eastern areas of South Africa (Opperman, Roberts & Nel (1974)). It is however clear that this species does not show such a trend in this region, which supports the finding of Janse van Rensburg (1987).

6.3.2 Axis 2

Axis 2 of the DCA was interpreted as a drainage gradient. Eragrostis plana, Paspalum distichum, Paspalum dilatatum, Imperatra cylindrica and Andropogon appendiculatus are all associated with the wet sites that occurred at the top of the ordination diagrams. Sites with a better drainage occurred in the bottom left of the ordination. Species that were abundant in these sites were Heteropogon contortus, Brachiaria serrata and Elionurus muticus.

The various habitat types that were a product of this environmental gradient, are frequently found together in the same bottomland area (Fig 6.5). In other words, the bottomlands are often a complex of various habitats, and not uniform.

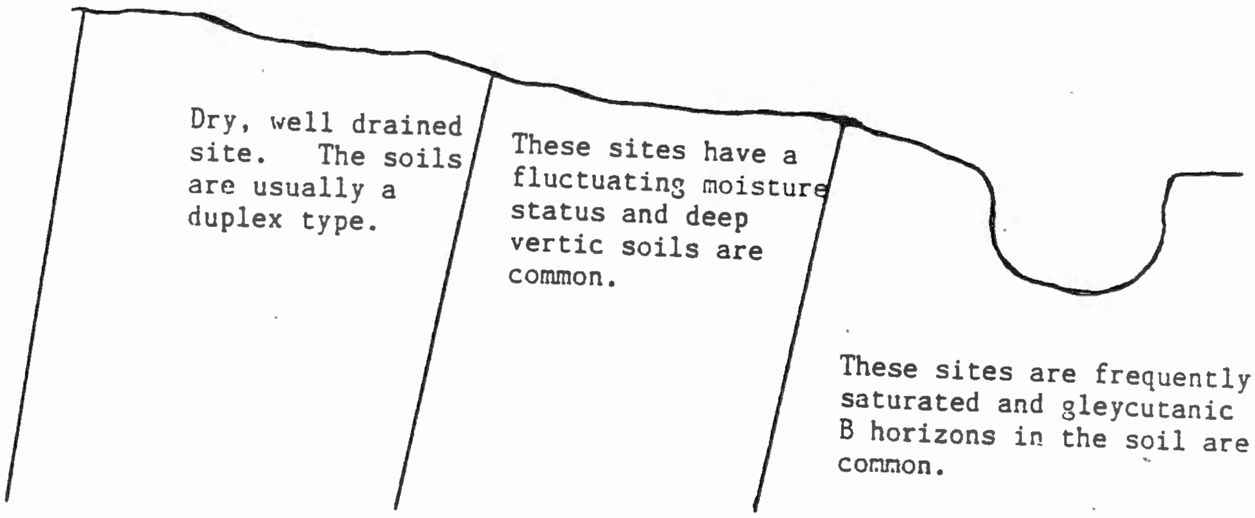


Figure 6.5 A sketch showing the complex of soils that can be found in the bottomlands of the Bc25 land type. Note that the sequence shown in the sketch is common but not the rule.

This is especially true in the bottomlands that were flat and wide. This patchwork of habitats can be problematic when trying to manage these bottomlands, because fencing of relatively homogeneous areas becomes difficult, and if done, the camps would become too small. However if this is not done the animals would tend to overgraze the dry, high base status sites. This "patchy" grazing was also observed during field work.

The distance from the point to the nearest tuft measurements were also used as data labels on the DCA ordination diagram(Fig 6.6).

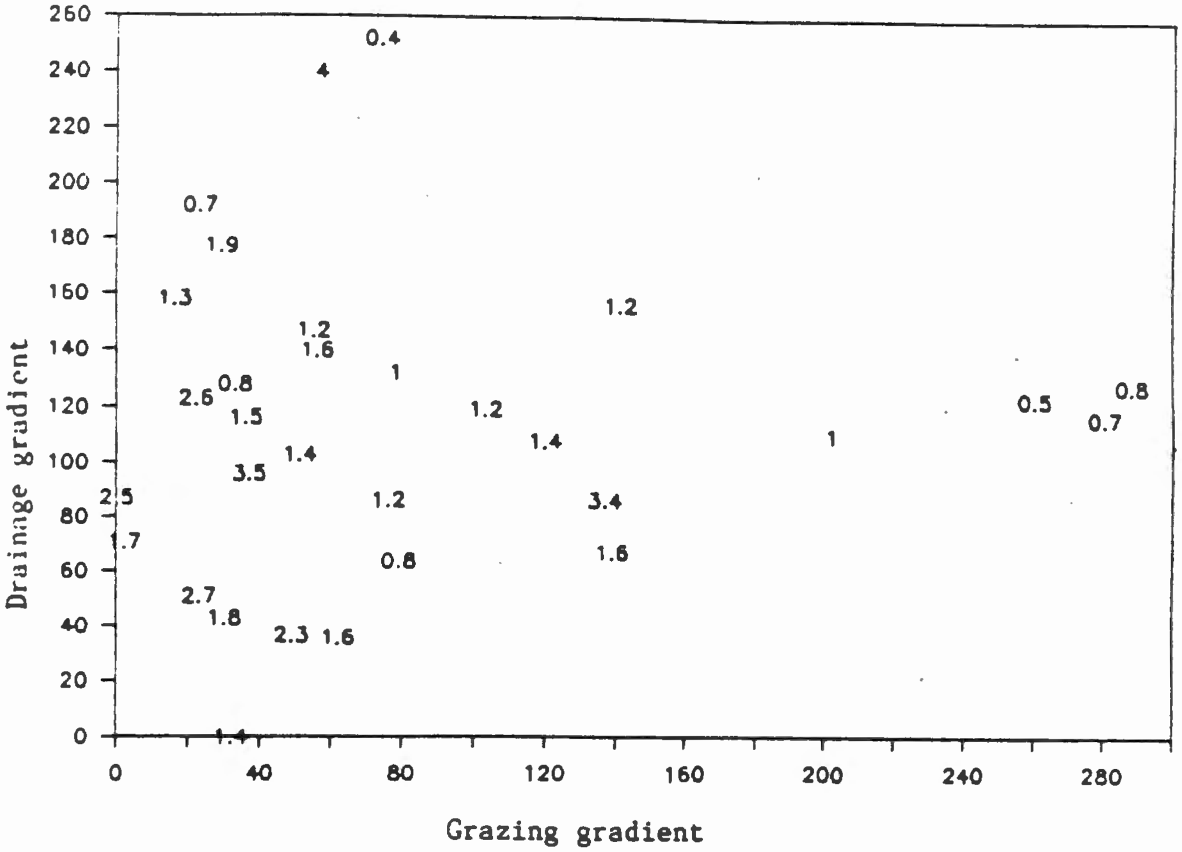


Figure 6.6 The samples ordination of the DCA with average distances from the point as sample labels.

The most interesting trend which arose, is that the distance from the point to the base of the nearest tuft, tended to be small in the overgrazed sites. The reason for this is difficult to explain in terms of changes in basal cover, but it can be explained in terms of changes in canopy cover. If the canopy cover of a tuft is removed by grazing, then the competition of that tuft for water, and its overshading of neighbouring tufts, will be reduced. Note that basal cover can remain the same (Fig 6.7).

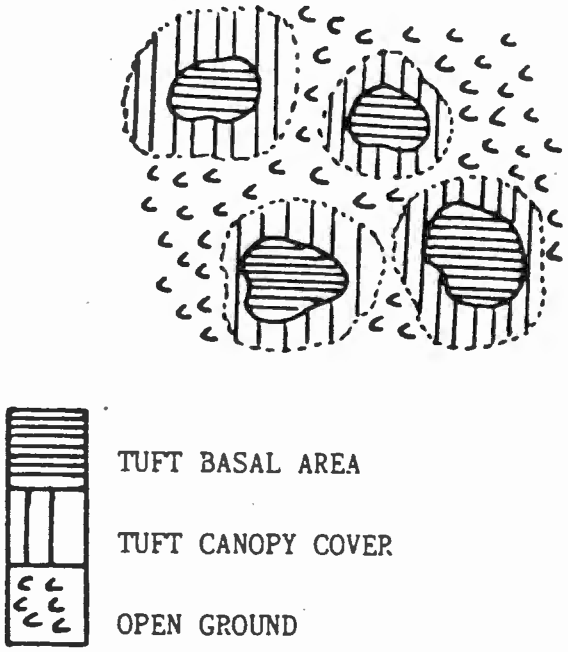


Figure 6.7 A schematical representation of the various cover components that are found in a grass sward.

If this removal of canopy cover is frequent, as would be the case where overgrazing was practiced, then there will be a greater possibility that tufts can establish nearer one another and hence reduce the tuft to tuft distance. In other words, in undergrazed sites the sward has a high canopy cover and large inter tuft spaces, but in an overgrazed site there is a low canopy cover but short inter tuft spaces. Tainton (1981) also made similar observations. This type of change in sward structure was frequently seen in the field, rather than a marked reduction in basal cover.

6.3.3 Conclusions

The catastrophic effect of overgrazing in the bottomlands of this land type was once again seen in this study. However, it was clear that these bottomlands are also destroyed by the dumping of refuse and by the mining activities in this area. The solution for this total destruction of the bottomlands is complex. Two practical recommendations are:

1. Watercourses should not be the only water points for grazing animals, but additional water points should be provided on the farms, and the bottomlands should be fenced into a separate camp.

2. There should be stricter control of dumping and mining activities in the bottomlands, especially when one considers the renewed interest in alluvial diamond mining.

CHAPTER 7: MODELING OF SPECIES TRENDS

The inadequacies of regression analysis done on species abundances for a single environmental parameter are explained by Mead (1971). Although smoothing the curves, as described by Gauch (1982) and by Walker (1988), would have helped in improving the statistical fit of the regression analysis, it would still not solve the problem of multiple gradients that all influence the species at the same time (Mead, 1971). Multiple regression solves this problem to a certain extent, and was recommended by Gauch (1988 pers comm). This approach also has statistical problems. For example, the independent variables, which were the sample scores of the DCA and PCA axes, are not independent of the dependent variables. This is problematic in the multiple regression procedure, because the estimates of error of the coefficients will be larger (Mead, 1971). This approach is, however, adopted for the modelling of species trends, because the results obtained often made ecological sense, and trends in the field were often identified in the trends given by the results of the multiple regression.

The equation for the multiple regression is in the form;

$$Y = \text{Intercept} + A(\text{DCA1}) + B(\text{DCA2}) + C(\text{PCA1}) + D(\text{PCA2})$$

where A,B,C and D are the coefficients, and the value in brackets is the sample score for the particular ordination and axis in question.

7.1 The result of the PCA of the soil factors in the Bb25 and Ca6 land types.

Three axes of the PCA accounted for 71 % of the variation of the soil factors (Table 7.1).

Table 7.1 The soil parameter scores for the first three axes and the percentage variance accounted for by each axis for the PCA of the Ca6 and Bb25 land types combined.

Soil parameter	Axis scores 1	 2	 3
pH	48	100	45
P	64	51	0
K	100	0	56
Ca	0	59	26
Mg	3	66	28
Na	99	88	100
Clay %	20	26	63
Silt %	7	38	50
Grit %	56	91	21
OM	8	25	36
Percentage variance	44	16	12

The interpretation of the axes was difficult and depended to a large degree on the trends seen in the sample scores, which could be linked to sample characteristics, and on the soil factor scores.

The first axis (43.7 % of the variation) was attributed to the type of cations found in the clay fraction, because sodium and potassium have high scores, and magnesium and calcium have low scores. This was linked to the basic soil types that were found in these land types. The sites with young alluvial soils tended to have high scores, but those sites with soils that had structured B horizons and vertic A horizons, had low scores.

The second axis (15.5 % of the variation) was considered to be indicative of the base status of the soil. Soil pH, sodium, calcium, and magnesium all had high scores. This axis is to a degree linked to the first axis, and also, perhaps, to the first axis of the DCA, as pH is also linked to the drainage of a site (Sanchez, 1976).

The third axis (11.8 % of the variation) was not considered to be important, but this axis could be a result of the geological differences found in these land types. The rock types with a high sodium content generally resulted in soils with a higher sodium content, which had a higher score than soils originating from rock types that had high levels of calcium and magnesium.

All three of these axes were included in the multiple regression.

7.2 The results of the multiple regressions for the Bb25 and Ca6 land types.

The multiple regression done on the more abundant species (Table 7.2) showed a large variation in results.

Table 7.2 The coefficients for the independent variables and the r^2 values and F statistic for the multiple regressions of each species in the Bb25 and Ca6 land types. * and ** indicates significance at the 5% and 1% levels respectively.

Specie	Intercept	DCA 1	DCA 2	PCA 1	PCA 2	PCA 3	F	P	R Squared
A. appendiculatus	9.33	-.01	.11**	-.06	-.05	-.18	5.57	<.01	.27
A. bipartita	2.81	0.0	0.0	-.04**	.03*	-.02	2.89	<.05	.13
A. congesta	2.95	0.0	0.0	-.01	-.02	0.0	0.74	NS	-.02
B. eruciformis	5.56	0.0	0.0	-.07**	.05**	-.04	10.65	<.01	.44
C. dactylon	-27.79	.10**	-.10**	.25**	.10	.22**	12.93	<.01	.50
C. plurinodis	2.14	0.0	0.0	-.02*	.01	.01	1.89	NS	.07
E. chloromelas	10.45	-.07**	-.01	.04	.01	.25**	8.91	<.01	.39
E. curvula	-9.02	.10**	.02	0.0	-.12	.03	5.46	<.01	.27
E. muticus	6.98	-.02**	-.01	.02	-.03	-.02	2.81	<.05	.13
E. plana	22.53	.02	-.12**	.09	.04	-.12	2.99	<.05	.14
E. planiculmis	-9.24	.02	.06**	-.04	.03	.05	4.02	<.01	.20
E. racemosa	2.01	-.01**	0.0	.01	-.02	0.0	3.60	<.01	.18
F. sesleriaformis	-6.49	.01	.06	-.02	.08	-.03	2.15	NS	.09
H. contortus	2.92	-.02**	.01	.03	-.01	-.02	4.22	<.01	.21
M. caffra	1.52	-.02**	.01	-.01	.02	.05*	6.01	<.01	.29
P. sphacelatum	28.00	.02	-.01	-.26**	.09	-.13	3.7	<.01	.18
S. flabellata	-1.64	-.04**	.03**	.02	.06	.09**	9.18	<.01	.40
T. triandra	49.45	-.10**	-.10**	.07	-.23**	-.07	6.70	<.01	.32

The abundant species tended to give better results than the rare species. For example, Themeda triandra, showed no trends in the DGA but it has an r^2 value of .32 and the F statistic is highly significant in the multiple regression. Tests done for the normality of the data showed no real deviations. The success of this result for a number of the species can perhaps be attributed to the low beta diversity of the data. This is seen in simulated data done by Gauch (1982) where the species trends in this type of data tend to be linear, rather than Gaussian.

The good results in the multiple regression procedure for the abundant species is important, because it is these species that will effect the production or grazing capacity of the grass sward. Although the rare species often have good indicator value for habitat type, as well as veld condition, these species have little influence on the production and grazing capacity of the grass sward. It is therefore not important to know the exact percentage of these species, but the presence or absence of these species would be sufficient.

7.3 The result of the PCA of the soil factors for the Bc25 land type.

The first four axes of the PCA accounted for 75.6 % of the variation (Table 7.3).

Table 7.3 The soil parameter scores for the first four axes and the percentage variance accounted for by each axis for the PCA of the Bc25 land type.

Soil parameter	Axis scores 1	2	3	4
pH	0	65	49	71
P	20	45	50	38
K	46	3	49	84
Ca	17	25	56	100
Mg	9	58	51	31
Na	49	100	63	31
Clay %	80	13	50	0
Silt %	44	38	100	94
Grit %	64	39	0	85
OM	100	0	68	40
Percentage variance	30	21	13	12

The methods used to interpret these axes was the same as in the PCA of the Bb25 and Ca6 land types. The first four axes were used in the multiple regression but the first two axes were considered more important.

The first axis (29.6 % of the variation) had high scores for soil organic matter and clay percentage, with the lowest scores being soil pH, calcium and magnesium. The samples with high scores usually had wet saturated soils with gleyed B horizons and samples in drier conditions had lower scores. This axis is therefore linked to the drainage of the site.

The second axis (21.3 % of the variation) was without doubt correlated with the first axis of the DCA. The sodium level in the soil is directly linked to this axis as seen in the high score for this factor. The sodium level was therefore indirectly linked to grazing. The possible reason for this association has already been explained (Chapter 6.3.1).

The third axis (13.3 % of the variation) could not really be explained but there was some indication that this axis was linked to the amount of stone in the A horizon. Samples with little stone having high scores, and samples with few stones had lower scores. Geological differences could perhaps account for these differences.

The fourth (11.5 % of the variation) and last axis that was included in the multiple regression was simply linked to the presence or absence of calcium nodules in the soil. This was explained by the high score of calcium in this axis, and it was also found that species which showed a positive trend with respect to calcium in the DGA, were abundant where the sample scores were high.

7.4 The results of the multiple regressions for the Bc25 land type.

The results of the multiple regressions showed a definite correlation (correlation coefficient = .48) between the first axis of the DCA and the second axis of the PCA. This supports the interpretation of the PCA axis, and also the finding in the hybrid ordination that overgrazed sites are often high in sodium. This result also suggests that the axis derived with ordination from the species abundance data and the soil data can be related, and are not as obtuse as Walker (1988) implies. The formulas given for the more abundant species (Table 7.4) once again showed that the results for the abundant species were better than for the rare species.

Table 7.4 The coefficients of the independent variables and the r^2 values and the F statistic for the multiple regressions of the species in the Bc25 land type. * and ** indicate significance at the 5% and 1% levels respectively.

Specie	Intercept	DCA 1	DCA 2	PCA 1	PCA 2	PCA 3	PCA 4	F	P	R Squared
A. appendiculatus	.24	0.0	0.0	.03	-.02	-.01	.01	.68	NS	.10
A. bipartita	21.49	-.02	-.09**	-.05	-.04	.04	-.08	5.02	<.01	.24
A. congesta	3.28	.06**	-.02	0.0	-.08	-.02	.06	1.15	NS	.25
B. eruciformis	9.98	.02	-.04	.02	-.07	0.0	-.03	.89	NS	.11
C. dactylon	4.98	.01	.10*	-.12	-.04	-.07	.08	1.76	NS	.79
C. excavatus	4.45	-.01	0.0	-.02	-.02	0.0	-.03	1.58	NS	-.07
C. plurinodis	-1.60	.01	.02	.01	-.03	-.03	.09**	2.09	NS	.13
D. eriantha	3.97	-.02	-.03	.08	.02	.01	-.03	1.36	NS	-.02
E. chloromelas	-4.32	-.02	0.0	.10	.10	.02	-.03	1.77	NS	.17
E. curvula	3.76	-.03	0.0	.02	.02	.02	-.06	0.65	NS	.44
E. muticus	2.9	-.01	.02	.04	-.02	-.06	.01	1.56	NS	.03
E. plana	-10.11	-.06**	.17**	.11*	-.05	.20**	-.14*	15.71	<.01	.10
H. contortus	1.46	-.01	0.0	.02	.01	-.03*	-.01	2.62	<.05	.07
P. coloratum	-.16	0.0	-.01	.04*	.02	-.01	.01	1.64	NS	-.07
S. ioclados	-.29	.14**	-.01	-.08	.09	-.02	-.10	20.81	<.01	.74
S. nigrirostris	22.11	-.04	-.02	-.11	-.10	.05	.06	2.69	<.05	.48
T. triandra	37.25	-.13**	-.12**	-.09	.21*	-.05	.11	5.81	<.01	.13

Tests done for the normality of the data once again showed no deviations. The results of this land type were not as good as the previous land types, and this is probably due to the fewer number of samples that were used for the analysis. It was also clear that some species showed different trends than in the other two land types, and this is explained in the following chapter. A problem which does arise is the confounding of grazing and soil sodium level. The implication is that habitat, and not only grazing, must be considered when interpreting species composition data. This is especially true when doing veld condition surveys.

7.5 Conclusions

Multiple regression most certainly shows potential for this type of data, especially for the abundant species. The simplicity of the equations for further modelling purposes makes this method of analysis attractive. The problem with this approach is that the dependent variables must be meaningful in terms of parameters that can be estimated in the field. This step is complicated as it depends on the interpretation of the axes of the DCA and the PCA.

CHAPTER 8 HABITAT TYPES AND THE ASSOCIATED COMMUNITY ORGANISATION AND CHANGE

This chapter is divided into the most prominent habitat types, which in effect are the product of the abiotic environmental gradients, that were identified in the land types. These are used as a basis to show the changes in species composition due to the changes in habitat, and within each habitat, due to grazing. These habitats can be described in terms of their abiotic characteristics and are equivalent to the ecotopes described by Mcvicar et al (1986). The reason why the plant community is not used as a basis for division, is simply because of the dynamic nature of the plant community. It must be emphasised that these habitats are not seen as independent units, but are rather integrated, and the definitions of the habitats are directly related to the abruptness of the environmental gradients which link them. The species compositions that are given in this chapter are determined by the results of the multiple regression and ordinations. The variation shown in the tables is the standard error of the multiple regressions at the 5% level. This chapter is therefore a summary of all the trends and information that was extracted from the data. It was also evident that the habitats and associated communities that were identified in the Bb25 and Ca6 land types were closely related to bottomland communities identified by Scheepers (1975).

8.1 The habitat types of the Bb25 and Ca6 land types.

8.1.1 Habitat 1

Description

The soil type is mostly young alluvial soils, however duplex soils that had a deep A horizon were also present. The ecotope is also frequently flooded and the subsoil is often saturated. The base status of the soils is often low.

Dynamics

The effect of grazing on the species composition of this ecotope (Table 8.1) is primarily reflected in the marked increase in _Cynodon dactylon_ and _Eragrostis plana_. _Themeda triandra_ also showed an increase in abundance in the overgrazed sites.

Table 8.1 The species composition change for various intensities of grazing in habitat 1 of the Bb25 and Ca6 land types.

Species	Grazing			SE (5%)
	Light	Moderate	Severe	
A. appendiculatus	17	8	0	20
A. bipartita	0	0	0	6
A. congesta	2	2	2	4
B. eruciformis	0	0	0	4
C. dactylon	22	30	50	20
C. plurinodis	1	1	1	3
E. chloromelas	5	6	8	20
E. curvula	35	33	29	22
E. muticus	0	0	0	7
E. plana	0	6	30	30
E. planiculmis	15	10	0	13
E. racemosa	0	0	0	3
F. sesleriaformis	9	4	0	16
H. contortus	0	0	0	7
M. caffra	1	0	0	6
P. sphacelatum	0	0	0	26
S. flabellata	5	2	0	10
T. triandra	0	0	15	24

The increase in abundance of Themeda triandra can possibly be explained by the drying out effect caused by overgrazing, which benefits Themeda triandra, because this species cannot tolerate saturated conditions.

8.1.2 Habitat 2

Description

The soil types in these sites are usually dystrophic and mesotrophic duplex soils. The B horizon has no calcium nodules. These sites are usually flooded in summer, and the drainage of the A horizon is usually good. These sites are frequently associated with the Tarkastad mudstones.

Dynamics

These habitats generally have a greater percentage of Themeda triandra, Elionurus muticus, and Setaria flabbellata than habitat 1 (Table 8.2).

Table 8.2 The species composition change for various intensities of grazing in habitat 2 of the Bb25 and Ca6 land type.

	Grazing			
Species	Light	Moderate	Severe	SE (5%)
A. appendiculatus	22	14	0	20
A. bipartita	0	0	0	6
A. congesta	2	2	2	4
B. eruciformis	0	0	0	4
C. dactylon	13	0	13	20
C. plurinodis	2	2	2	3
E. chloromelas	20	21	23	20
E. curvula	11	9	5	22
E. muticus	1	2	4	7
E. plana	0	0	20	30
E. planiculmis	12	7	0	13
E. racemosa	1	1	1	3
F. sesleriaformis	8	3	0	16
H. contortus	3	2	0	7
M. caffra	6	5	3	6
P. sphacelatum	4	4	6	26
S. flabellata	11	9	3	10
T. triandra	7	15	35	24

Eragrostis plana, and Cynodon dactylon are good indicators of overgrazing. Themeda triandra also increases in abundance with heavier grazing. This appears contradictory to the common belief that Themeda triandra is a decreaser species (Tainton, 1981 &

Trollope, 1986). However it was clearly evident in the field that _Themeda triandra_ had a high tolerance of grazing, especially in the moist and wet sites. This tolerance of heavy grazing by _Themeda triandra_ is also noted by Acocks (1975), who came to the conclusion that non-selective heavy grazing had less of a damaging effect than selective overgrazing. Although the tuft size did not show any pattern, it was observed that in many cases the tufts were prostrate and the leaves were small and narrow in overgrazed sites. The inflorescence was also often short in these sites. One would therefore not get a visual impression of the relatively high abundance of _Themeda triandra_.

8.1.3 Habitat 3

Description

The soil types of this ecotope are eutrophic vertic and duplex soils, although alluvial soils that originate from eutrophic duplex soils do sometimes occur. Calcium nodules are often present in the soil profile, and this characterises this ecotope. The drainage is poor and the B horizon is often gleyed with clear signs of wetness. This ecotope is often associated with the dolerite dykes and sills which occur in the Ca6 land type.

Dynamics

Pennisetum sphacelatum is abundant in this habitat compared with the other ecotopes, and _Brachiaria_ eruciformis is often a good indicator of the soil types associated with this habitat (Table 8.3). Scheepers (1975) also found that this annual grass species frequently occurred on these heavy black turf soils.

Table 8.3 The species composition change for various intensities of grazing in habitat 3 of the Bb25 and Ca6 land types.

Species	Grazing			SE (5%)
	Light	Moderate	Severe	
A. appendiculatus	18	9	0	20
A. bipartita	4	4	4	6
A. congesta	1	1	1	4
B. eruciformis	8	8	8	4
C. dactylon	7	15	35	20
C. plurinodis	4	4	4	3
E. chloromelas	2	3	5	20
E. curvula	23	21	17	22
E. muticus	0	0	0	7
E. plana	0	1	25	30
E. planiculmis	22	17	5	13
E. racemosa	0	0	0	3
F. sesleriaformis	19	14	2	16
H. contortus	0	0	0	7
M. caffra	3	2	0	6
P. sphacelatum	28	29	31	26
S. flabellata	9	6	0	10
T. triandra	0	0	0	24

Andropogon appendiculatus and Eragrostis curvula tend to be less abundant in this habitat type. Cynodon dactylon and Eragrostis plana are once again good indicators of overgrazing. These habitats were observed to be preferred by the grazing animal. However Pennisetum sphacelatum displayed a tolerance to overgrazing and was therefore still abundant in overgrazed sites.

8.1.4 Habitat 4

Description

The soil types in this habitat are eutrophic, vertic and duplex soils. The drainage of these sites is usually good owing to a deep drainage channel or the slope.

Dynamics

This habitat is often an ecotone. Species which are abundant on the adjoining terrain to the bottomlands are present, and these are Elionurus muticus, Setaria flabbellata and Heteropogon contortus, as well as species which are typical of the wet bottomlands eg. Pennisetum sphacelatum and Andropogon appendiculatus (Table 8.4).

Table 8.4 The species composition change for various intensities of grazing in habitat 4 of the Bb25 and Ca6 land types.

Species	Grazing Light	Moderate	Severe	SE (5%)
A. appendiculatus	23	15	0	20
A. bipartita	3	3	3	6
A. congesta	2	2	2	4
B. eruciformis	5	5	5	4
C. dactylon	0	0	0	20
C. plurinodis	3	3	3	3
E. chloromelas	19	28	30	20
E. curvula	5	0	0	22
E. muticus	0	2	4	7
E. plana	0	0	16	30
E. planiculmis	15	8	0	13
E. racemosa	0	2	2	3
F. sesleriaformis	13	7	0	16
H. contortus	1	3	1	7
M. caffra	7	8	6	6
P. sphacelatum	21	21	23	26
S. flabellata	13	14	8	10
T. triandra	0	12	32	24

Cynodon dactylon, Eragrostis plana and Themeda triandra all increase in abundance with overgrazing and Pennisetum sphacelatum, Andropogon appendiculatus and Fingerhuthia sesleriaformis decrease in abundance with overgrazing.

8.2 Habitat types of the Bc25 land type.

8.2.1 Habitat 1

Description

The soil in these land types usually has black melanic or vertic A horizons which vary in depth. The B horizon is usually saturated and grey, and yellow colours are dominant. There is usually grit or stone in the soil profile and calcium nodules are present. These sites are frequently flooded in the summer, and sometimes wet in the winter.

Dynamics

The abundance of *Eragrostis plana* in these sites is characteristic. *Setaria nigrirostris* is also often more abundant than indicated (Table 8.5).

Table 8.5 The species composition change for various intensities of grazing in habitat 1 of the Bc25 land type.

Species	Grazing			SE (5%)
	Light	Moderate	Severe	
A. appendiculatus	3	3	3	6
A. bipartita	0	0	0	12
A. congesta	0	3	15	16
B. eruciformis	0	1	5	13
C. dactylon	20	21	23	20
C. excavatus	2	1	0	4
C. plurinodis	6	7	9	7
D. eriantha	3	1	0	11
E. chloromelas	6	4	0	12
E. curvula	6	3	0	11
E. muticus	9	8	6	8
E. plana	63	57	45	14
H. contortus	1	0	0	3
P. coloratum	0	0	0	5
S. ioclados	0	0	27	13
S. nigrirostris	10	6	0	18
T. triandra	0	0	0	25

The absence of *Themeda triandra* is due to the saturated soil conditions. Indicator species of this habitat type are Paspalum distichum and Paspalum dilatatum. Eragrostis plana decreases with extreme overgrazing and therefore does not follow the same trend found in the Bb25 and Ca6 land types. This is possibly due to the interaction that the overgrazing has with the sodium and moisture status of the soil. Eragrostis plana cannot withstand arid conditions, and would therefore decrease in abundance where the site had a high percentage of sodium and had dried out as a result of severe overgrazing. Sporobolus ioclados is a good indicator of overgrazing.

8.2.2 Habitat 2

Description

This habitat has similar soil characteristics to that of habitat 1. Flooding is less frequent and the site is dry in winter. The B horizon shows signs of wetness at a deeper level.

Setaria nigrirostris and Eragrostis plana are once again abundant in this habitat but decrease in abundance with overgrazing (Table 8.6). Themeda triandra also decreasers in abundance with overgrazing, in contrast to the other land types. Sporobolus ioclados and Aristida congesta subsp barbicollis are both very good indicators of overgrazing.

Table 8.6 The species composition change for various intensities of grazing in habitat 2 of the Bc25 land type.

	Grazing			
Species	Light	Moderate	Severe	SE (5%)
A. appendiculatus	4	4	4	6
A. bipartita	0	0	0	12
A. congesta	3	9	21	16
B. eruciformis	2	4	8	13
C. dactylon	17	18	20	20
C. excavatus	0	0	0	4
C. plurinodis	10	11	13	7
D. eriantha	4	2	0	11
E. chloromelas	4	2	0	12
E. curvula	2	0	0	11
E. muticus	10	9	7	8
E. plana	29	23	11	14
H. contortus	2	1	0	3
P. coloratum	2	2	2	5
S. ioclados	0	0	24	13
S. nigrirostris	13	9	1	18
T. triandra	11	0	0	25

Cymbopogon plurinodis is generally considered as a species which is abundant in underutilised veld (Tainton, 1981). This trend was not found in these habitats, as *Cymbopogon plurinodis* showed a slight increase in abundance with overgrazing. This trend was confirmed by field observations.

8.2.3 Habitat 3

Description

The soils in this habitat are usually a complex of duplex and vertic soils. There is usually little indication of water saturation in the B horizon. Calcium nodules can be present. Flooding of this habitat can occur in summer, but there is good drainage as these habitats usually have a steeper slope than the other habitats, even though the difference is small.

Dynamics

The absence of Eragrostis plana is characteristic and the abundance of Themeda triandra in moderately grazed veld is typical of this habitat (Table 8.7).

Table 8.7 The species composition change for various intensities of grazing in habitat 3 of the Bc25 land type.

Species	Grazing Light	 Moderate	 Severe	SE (5%)
A. appendiculatus	0	0	0	6
A. bipartita	22	19	7	12
A. congesta	3	9	14	16
B. eruciformis	9	11	8	13
C. dactylon	2	3	4	20
C. excavatus	4	3	0	4
C. plurinodis	0	0	0	7
D. eriantha	4	2	0	11
E. chloromelas	0	0	0	12
E. curvula	4	1	0	11
E. muticus	0	0	0	8
E. plana	1	0	0	14
H. contortus	0	0	0	3
P. coloratum	0	0	2	5
S. ioclados	0	10	48	13
S. nigrirostris	27	23	3	18
T. triandra	36	23	20	25

This habitat is also an ecotone, in that it links the saturated bottomlands with the drier pediment slopes. Digitaria eriantha (usually the stoloniferous type and not the tufted type) was also sometimes abundant in this habitat. Aristida bipartita was particularly abundant in sites with a large number of calcium nodules, but because of this species sensitivity to sodium, as seen in the DGA, it was not abundant in extremely overgrazed sites.

8.3 Conclusion

In order to understand the response a species will have to grazing, there must be a clear understanding of the habitats influence on this response. Therefore, extrapolation of results from experiments done in controlled environments, or experiments done with limited habitat variation, is risky. This interaction also complicates interpretation of indirect gradient analysis procedures. The isolation of a single factor, like grazing, is difficult. The definition of gradients, should therefore, be done with caution.

CHAPTER 9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

The interaction between habitat and the grazing animal reflected in the vegetation response is a key issue in veld management, and three important principles can be derived from the results of this study:

1. The most important function of the bottomlands is the transport and provision of water, hence the importance of the drainage gradient. The management objectives of the bottomlands should therefore be aimed at a vegetation type that can hold the soil and can tolerate flooding. Forage production is secondary to this primary function, so the problem of <u>Eragrostis plana</u> in land types Ca6 and Bb25, which is perhaps not a good forage species but can serve well for the primary function of these areas, could be debated. Similarly, canopy cover should be maintained to slow down the flow of water to prevent gully erosion even though this will result in reduced forage production. Another implication of this principle is the selection of benchmarks for the bottomlands. Sites with vegetation that has maximum forage value should not be the prime objective, but rather sites that have a vegetation with high soil binding properties and flooding tolerance.

2. The grazing gradient is habitat specific. In other words, the response of a species to grazing, is dependent on the moisture, nutrient and climatic

conditions under which it grows. Therefore an ecological classification of species into Increaser and Decreaser groups is bound by a specific homogeneous habitat, and care must be taken with extrapolation. Examples of this are _Themeda triandra_ and _Eragrostis plana_ which change their ecological status in different land types (see Chapter 8). Janse van Rensburg (1987) has similar findings.

3. The impact of grazing on the bottomlands is not restricted to a species composition change only, but can also permanently change the nutrient and moisture status of a site, which in turn will influence a species response to grazing. The dynamics and domains of attraction of that vegetation would therefore be changed, and this is why Bosch (1988) has a multiple benchmark approach.

Some examples that illustrate this principle are;

* the drying out of a site caused by increased water run-off in sites where the grass cover (both canopy and basal) has been reduced by grazing. This can be temporary, but where donga formation, salt build up and topsoil loss has occurred, then the change can be permanent and the vegetation will move into a different domain of attraction and would therefore require a different benchmark.

* the increased nutrient status of the soils caused by urine and dung build up where animals congregate, and perhaps the long term effect of sodium and

phosphate rich licks that are given to animals in the veld. Both the increase in xerophytic conditions and nutrient status of the soils favour the Increaser II, species especially the Cynodon, Sporobolus, Eragrostis and Aristida spp, so a permanent shift in species composition towards an increased abundance of these species is predictable.

Division of veld into camps using soil type as a guideline is also verified by the results. Soil base status and the soil moisture status are considered to be the two most important factors to consider in this division. Areas with a high base status and a low moisture status can be regarded as sweet veld and should be grazed in winter or late summer. Areas with a low base status and a high moisture status can be regarded as sour veld, and should be grazed in spring and summer. This approach to the utilisation of the bottomlands will prevent the sweet veld, which often occurs on erodible soils, from being overgrazed and will ensure moderate utilisation of the sour veld.

Gradient analysis is most definitely not an end product, and the results of this study should be transformed into a form that veld managers can use. This is why these results will be included in the veld dynamics model developed by Bosch (1988).

9.2 Recommendations

The potential of this type of data collection and analysis is clearly evident from the results and conclusions of this study. However, improvements of the data collection and analysis procedures can be made.

1. Stratification of the study area into the various habitat types is essential, so that the gradients which are identified are not confounded with complex habitat interactions. This also implies that the essential abiotic factors should be recorded. Close co-operation with resource experts in the area is therefore recommended.

2. It was also evident from the point-tuft distance studies that basal cover is especially important in dry environments, but the emphasis should not only be on the absolute amount of cover but also on the type of cover, ie. tuft size and distribution, and note should also be taken of the canopy cover. Careful consideration should also be given to the interpretation of relative abundance data. Species that have small tufts, but are numerous are over-estimated and big tufts that are more spread out are under-estimated.

3. A high beta diversity in the data makes modeling of the species responses complex. A non linear multiple regression and/or stratification of the data, using some classification technique, will help to solve this problem. Stratification can however, reduce the understanding of the vegetation dynamics.

It was also apparent that Scheepers(1975) who worked in the same study area, using different techniques, had similar findings. The establishment of a data base and network of all the work that is being done by ecologists, is stongly recommended. Even although techniques might differ the results are usually complimentary and time and money would be saved if repitition is eradicated.

9.3 Future research

An in depth study on the use of the various ordination techniques in this type of data analysis is recommended. Special attention should be given to the stratification of data and the modeling of individual species response to multiple factors. Multi-dimensional response surfaces could be investigated.

Moisture and drainage tolerance of species, and the influence of base status and the sodium level in the soil on the physiology of key species, is important and should be investigated. The influence these factors have on production and palatability of species could also form part of this investigation. This in turn could be used to refine the estimation of carrying capacity and veld condition models.

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