

DEVELOPMENT OF DEGRADATION MODELS
FOR BOTSALANO GAME RESERVE

BY

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DISSERTATION

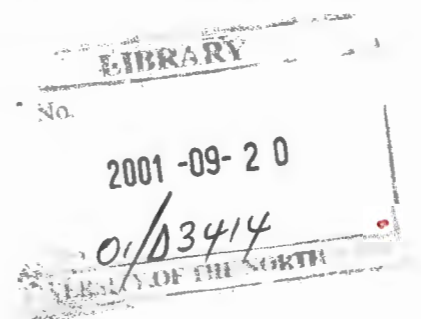
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DEDICATION

THIS WORK IS DEDICATED TO **MARAI SANE**,

MY COLLABORATOR

MY PHILOSOPHER

MY TRANQUILLISER

MY JOY

MY HUSBAND

AND OUR BELOVED SON AND DAUGHTER

MACHELI AND BOITUMELO

MOST BELOVED PARENTS

MOTSAMAI (Father)

'MATSELE (Mother)

RALETSAE (Father-in-law)

FOR THEIR INCEASANT ENCOURAGEMENT AND SUPPORT, AND ALSO THEIR
PATIENCE DURING MY FIELD WORK AT BOTSALANO AND LONG ABSENCE
FROM HOME.

ACKNOWLEDGEMENTS

My profound gratitude and sincere appreciation go to Ms. L. Thahane, who in supervising my work has continuously given generous support, encouraging comments and Mr. H.U.H. Syed for his suggestions.

My heartfelt gratitude goes to the Park Manager and the other park staff members for ensuring our safety while working in the Park. My sincere gratitude also go to Mr. David Phalatse who helped in the identification of the species. The members of my inclusive families both Sehlare's and Macheli's for their encouragement and best wishes. My husband Maraisane, as always a constant source of my 'courage' and my son, Macheli and my daughter, Boitumelo, sisters 'Mamohapi and her family, 'Matumelo and my brothers Pitso and Mohapi and my brother-in-law Lefu who have accepted with patience, tolerance and good humour the inroads the work has made on our family life, they have much more than my gratitude.

Lastly, may the souls of the following loved ones;

'MALEBOHANG BEATRICE SEHLARE (Mother)

'MAMOLIEHI ROSALINA MACHELI (Mother-in-law)

REST IN PEACE

ABSTRACT

In this study, sites were selected to deliberately represent the different levels of degradation in Botsalano Game Reserve which is situated 30Km north of Mafikeng in the Lehurutshe region, Northwest Province, and 350Km from Johannesburg. Sites were chosen closer to water points, near old kraals, and under big trees to represent highly degraded sites, open grassland for moderate degradation and closer to camp sites, fences and offices to represent less degraded.

Biomass, species composition and soil characteristics like soil colour, soil texture, cation exchange capacity and organic carbon percentages were compared for a total of 70 sites chosen. Integrated System for Plant Dynamics (ISPD) was used to construct the degradation models by using DCA and DMOC ordination techniques, degradation models which showed the position of different sites on the degradation gradient were constructed. Biomass and degradation were compared using Spearman's rank correlation coefficient which showed a negative correlation. Some species were also selected to be representative of either high, less or even moderately degraded areas. All the findings in this study show that some areas of the park need restoration especially those severely degraded areas, this can be done by re-seeding and protecting the areas by fences or de-stocking.

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CHAPTER ONE

INTRODUCTION

The study area falls within the Molopo ranching area which covers approximately four million hectares (Donaldson: 1969) . For efficient management of this ranching area, more precise assessment of the range condition and grazing capacity is necessary. Smith (1989), also agrees that if one fails to understand and know the condition of a range he is working with this cause some frustration and eventually lead into inadequacies. Information is therefore required to assist the range managers in knowing which areas of the park need more attention, being degraded and how the fertility in highly degraded areas can be restored. Early warning signs of improvements or deterioration need to be known and understood.

1.1 VALUE OF THE STUDY

Park Managers and nearby farmers may utilise the findings of the study in overcoming problems of overgrazing. Thorough information regarding the range and its condition is a precursor to good management of rangelands. Bosch and Booysen stated in their paper March: 1992 that a need existed to develop a comprehensive

system that would enable rangeland scientists to compile a data base for all existing relevant data that are required for the assessment of condition and grazing capacity in different homogenous grazing areas. A requirement was, that the system has to be developed in such a way that once the data base is completed, an assessment of the range condition and grazing capacity of any management unit in the area under consideration would be possible. It is therefore believed that the Park Managers will benefit from the results of this study which will in turn benefit the North West Province since the management of the park will have a clear picture as to which area of the park to concentrate on.

Overgrazing and trampling of the vegetation particularly in the semi-arid and arid regions can cause extensive denudation of the surface, resulting in severe erosion and a poor growth of mainly Ephemerals (Walker: 1974). This can therefore adversely affect the soils particularly loamy soils, because the infiltration rate of rain water is much lower in bare soils than in those soils which are mulched. Revegetation of such bare soils consequently is hampered seriously (Walker: 1974). The degeneration of range condition has become one of the most serious problems in the agriculture of developing countries.

The effects of overgrazing are sometimes associated with domestic livestock, such as cattle, and particularly sheep and goats (Shaw: 1975, Acocks: 1953, Phillips: 1956-57, Volk: 1966, Scott: 1967, Myre: 1970, Werger :1973, 1974). Basically, this is one of the reasons why the researcher thinks that even nearby farmers in the Province will benefit from the results of this study. Grazing reduces standing biomass through forage consumption and associated trampling of vegetation. Trampling also accelerates litter decomposition (Hiernaux:1989). Heavy grazing during the growing season may also reduce productions (Hiernaux:1996).

There are several reasons why, in Africa mostly, the influence of domestic livestock on vegetation is often so much more devastating than that of game. The usual farming practice, whereby the movement of animals is controlled, by the herdsman and return to their kraal after grazing. Game are usually mobile and, although often concentrated in herds, wander over a large area. They stay nowhere for any length of time and only graze small patches. Economic considerations often not only tempt the farmer to overstock his or her ranch but also force him to keep his animals in camps. This is mostly common to farmers who depend on selling their livestock for survival, they always want to have more than enough stock because that will in turn put enough cash in their pockets. For this reason, and because domestic animals are less mobile than game, part of the vegetation is more thoroughly grazed by them, and with poor management, easily over

grazed (Walter: 1961, Vessey-Fitzgerald: 1969, Walker: 1974). The impact of heavy grazing on production could be explained by a shift in floristic composition towards less palatable (and therefore less heavily grazed) species. Production would thus be maintained, albeit at the expense of forage value. However, this situation is only likely to occur in limited areas, within a few hundred metres radius of water points or herd rests areas. Where stocking rates are extremely high large amounts of manure and urine are deposited (Hiernaux: 1996).

Park Managers should be able to determine the carrying capacity of the park for sustainable management. From several studies it has become apparent that the diet of game includes far more plant species than that of domestic animals (Jewell: 1969, Hill: 1972). Range management practices centre around the regulation of the number of animals allowed to graze on a given range, along with the duration and season of their grazing. The stocking of a range must therefore be carefully regulated so that the existing grasses are not depleted or exhausted from overgrazing.

1.2 BACKGROUND

Several methods have been developed by different researchers for range condition assessment as described by Barnes et al. (1984), Stuart-Hill et al. (1986), Tainton et al. (1980), Vorster (1982), Heard et al. (1986), Willis and Trollope (1987). A cornerstone of most of the methods proposed has been a veld composition score based on a division of species into groups which are judged to have ecological affinity. These groups are commonly termed "degreasers", "increasers", and in some cases, "invaders", after Dyksterhuis (1949) (Barnes et al. :1984). These researchers also point out that as an aid to the assessment of condition, so-called benchmark sites in veld which is judged to be in excellent condition are selected in appropriate environments or similar ecological condition, and the sample site is compared with the benchmark.

Mentis (1983) criticised current methods of veld condition assessment particularly; with respect to the subjectivity of the ecological grouping, the choice of benchmarks and the arbitrary values to species or groups, as well as the lack of a quantitative model linking the carrying capacity with veld condition, with regard to ordination of data from grazing trials as a means of arranging species along a gradient of grazing capacity (stocking rate) in particular. In discussing the practical application of such information by "veld managers", he conceded that as most veld managers do not have computers, calculation of ecological distance by multivariate methods would

is impracticable. As an alternative, he suggested the use of multipliers in a "weighted averages" ordination or produce a scalar that indicates both direction and degree of departure from any specified point of reference (Barnes et al.1984).

Another method which was used by Barnes and his co-researchers was the "Weighted Palatability Composition Method" which involved the comparison of proportionate species composition, classified in terms of palatability, with estimated grazing capacity. From this comparison multipliers had been derived which were judged to be consistent with the value of species in terms of their contribution to grazing capacity. In addition, methods of multivariate analysis had also been tested as a possible means of quantifying all the communities in terms of grazing capacity.

Donaldson and Kelk (1970) conducted an investigation on the veld problems of the Molopo ranching area and found that herbage production and species composition are factors of major importance in determining carrying capacity and animal production in the Molopo area. Other factors of considerable importance are bush encroachment, droughts and low levels of soil fertility. The research data collected by these researchers showed the dominance of the less desirable, poorly productive grasses such as *Eragrostis lehmanniana* and *Aristida congesta* in the Molopo area. The more productive subclimax species such as *Stipagrostis uniplumis* and *Schmidtia bulbosa* made up a relatively small

proportion of the total vegetation and could not be expected to exert any major influence on veld production. Particularly distressing was the rarity of the valuable broad leaved climax grass species such as *Anthepora pubescens*, *Panicum kalahariense*, and *Brachiaria nigropedata* which are both palatable and productive. The complete absence of these species from many of their sites suggested that it was highly unlikely that they could become dominant components of the vegetation within a reasonable period of time. Herbs and forbs had a very high constancy of 97%.

From the research data it could also be realised that the Blackthorn (*A. mellifera*) was encroaching heavily on grass herbage production. These findings have confirmed the general opinion held by farmers in the area, that the control of encroaching blackthorn must be regarded as a primary requirement before veld production in the Molopo area could be increased.

Another factor was drought which broke during February 1966 (Data illustrating the significant effects of the prolonged drought of 1964/66 on changes in the grass species composition and the very marked decrease in the grass herbage production of Molopo ranching area have been presented elsewhere (Donaldson: 1967)) and affected most of the *Anthepora pubescens* seeds which had been reseeded, however this species had indicated that it could establish itself and maintain a stand despite the adverse conditions of drought and weed competition. The data further

reveals that *Cenchrus ciliaris*, *Sorghum aluum* and *Digitaria pruriens* suffered heavy mortality despite promising initial stand densities.

Concerning low levels of soil fertility the results of Donaldson and Kelk (1970) revealed that the soil was deficient in nitrogen and phosphorus for the adequate growth of *Cenchrus ciliaris*. The basic problem in the area has shown to be extremely low phosphate content of the soils. It is also a well known phenomenon that there is acute deficiency of phosphates in the soils and in the natural grasses of the Northern Cape ranching areas (Theiler: 1920, Henrici: 1923).

Heard et al. (1986) undertook a comparison of five methods for assessing veld condition in the Natal midlands, the Benchmark method as described by Tainton et al. (1980), the Weighted Quantitative Climax Method (WQCM) as proposed by Tainton, Fourie and Foster (1982), the Palatability method and a Key species method. Their findings showed the Weighted Quantitative Climax and Key species methods to be superior to the other three methods.

Other methods developed have included one by Stuart-Hill et al. (1986) where they developed a method of scoring bush veld according to its productive condition and found that tree density was the most important variable, for instance, Eastern Cape. The direct influence of species composition on the scoring of bush

veld condition was not important. It was also recommended that additional variable such as plant palatability, plant digestibility, plant production potential, soil type, altitude, and rainfall should be investigated to establish the influence they have on bush veld condition.

Multivariate analytical procedures have been advocated in terms of their ability to yield objectives and interpretable results. The main advantage is their usefulness in sites whose history is unknown. Ordination methods have also been used for the development of more objective condition assessment (Hacker: 1983). Foran et al. (1986) assessed vegetation change by ordering sites from repeated measurements and tracing site trajectories through ordination space. Although this technique has proved to be successful in detecting trends in vegetation. The major limitation of ordination procedures has been the ecological interpretation of the causes of change. (Bosch & Gauch: 1991, Martens et al.: 1990).

This problem has been addressed by the inclusion of sites with known management histories (Martens et al.: 1990). Quite often the histories of sites are unknown. Bosch & Gauch (1991) dealt with this problem by selecting sites to deliberately include fence line contrasts and other contrasts between areas of intensive use and light to moderate use, e.g. sites near water points and sites farther from drinking points, or sites near village or farther from villages. The ability to assess and

monitor the condition or conservation status of the vegetation of a particular area, and to interpret the assessments ecologically, is a prerequisite for rangeland planning and sound management decisions (Bosch & Gauch: 1991).

Fusco et. al. (1995) studied the vegetation standing crop biomass and species composition at varying distances from water on upland, sandy ranges in different ecological condition in the Chihuahan desert of South Central New Mexico with known grazing histories. This is in support of the idea that the inclusion of sites with known grazing histories can help in the interpretation of the ecological condition . Their findings showed that following long term conservative continuous cattle grazing on upland, sand sites of the desert were severely grazed and also that sites closer to water points were only left with some poisonous plants, all other palatable plants were heavily grazed.

It is also important at this juncture to make reference to the findings by Johnson and Mayeux (1992), that ecological theory that has been the basis of vegetation management for most of this century is now being questioned. This re-evaluation has followed the accumulation of contrary information (Scholes:1990). Westoby et al.(1989), reveal that all the concepts used in range management are based on models of ecosystem function. These alternate models of vegetation dynamics include the concepts of thresholds (Friedel:1991) and multiple stable states of differing species composition with multiple non-linear pathways between

turns (Aycock 1991). However modification of our approaches to management will require better understanding of the long term processes forcing observed vegetation changes. This requires a study, over expanded periods of time (Foster et al. :1990, Schoonmaker and Foster: 1991). Magnusen(1990) confirms that without the historical perspective of long term information, serious misjudgements in resource management can result. Recent advances in Paleo-vegetation show that an important contributor to current vegetation dynamics has been the climatic variation of the Quaternary (the last 2 million years) as described by the Schoonmaker and Foster (1991), Sprugel (1991), and others.

It has also been suggested through data that communities in Miocene and Pliocene (2 to 65 million years BP), were more complex, reflecting a warmer more humid, and relatively stable climate compared to the Quaternary (Nilsson (1982), Gould(1991), Morrison (1991), Schoonmaker and Foster (1991), Thompson (1991). Many of the species then had narrow ranges of tolerance of adaptability to environment variation and disappeared during the glacial cycles of the Quaternary. This reference is made to show that plant species present today in most parts of the world survived past climate changes either by adapting , migrating or both. The ongoing plant adaptations to climate changes may be facilitating accommodating, the thresholds, multiple steady states, and multiple secessional pathways widely observed for many plant communities.

From the approximately 100 000 to 1,6 million years of available vegetation change data, it is apparent that today's communities are composed of species that arrived at different times from different sources, and that had to cope with different biotic interactions (Ogden : 1989, Huntley: 1991, Schoonmaker and Foster: 1991). In conclusion to the point made on vegetation changes which were affected by climatic changes West (1993) says that today, no area is without some level of human impact. Box (1992) also says the future communities can never be exactly what they were. Therefore knowledge of past climate changes of at least the late Quaternary, and associated changes in environmental conditions and species composition, can be as important as knowledge of the present for understanding plant community dynamics and their implications for management (Burkhardt et al.:1993)

1.3 OBJECTIVES OF THE STUDY

- (a) To identify different site types i.e sites which could be sampled for the purpose of the development of the degradation models , that make up Botsalano Game Reserve.
- (b) To select the most extensive site types for intensive survey to be used for development of degradation models.

To develop the range condition models for the selected site types using Quantitative Multivariate Analysis Methods (QMAM).

- d To measure biomass yield of the different sample areas representing different range condition states.
- e To determine the relationship between biomass yield and range condition.

CHAPTER TWO

2.1 DESCRIPTION OF THE STUDY AREA

2.1.1 LOCATION OF BOTSALANO GAME RESERVE

The investigation was carried out at Botsalano Game Reserve, (fig.1) located on the upper catchment of the Ramatlabama drainage line, 30 km North of Mafikeng in the Lehurutshe region, Northwest province, and 350 km from Johannesburg. The approximate latitudes within which the park lies include 25S 32'E - 25S 37'E.

The reserve was first fenced in 1986 and is situated on land that was previously used for cattle ranching and a small amount of cultivation.

2.1.2 SIZE OF THE RESERVE

The size of the reserve is 5800ha. Fig. 1.1 shows a sketch of Botsalano Game Reserve divided into blocks as shown on the sketch to assist the management in monitoring the movement of animals and checking the condition of different blocks for grazing purposes. Over the years, the reserve has gained a reputation as a fertile breeding ground for many species of animals and is presently supporting one of the most successful breeding programmes for white rhino on the sub-continent. Animals frequently seen here include white rhino, buffalo, eland,

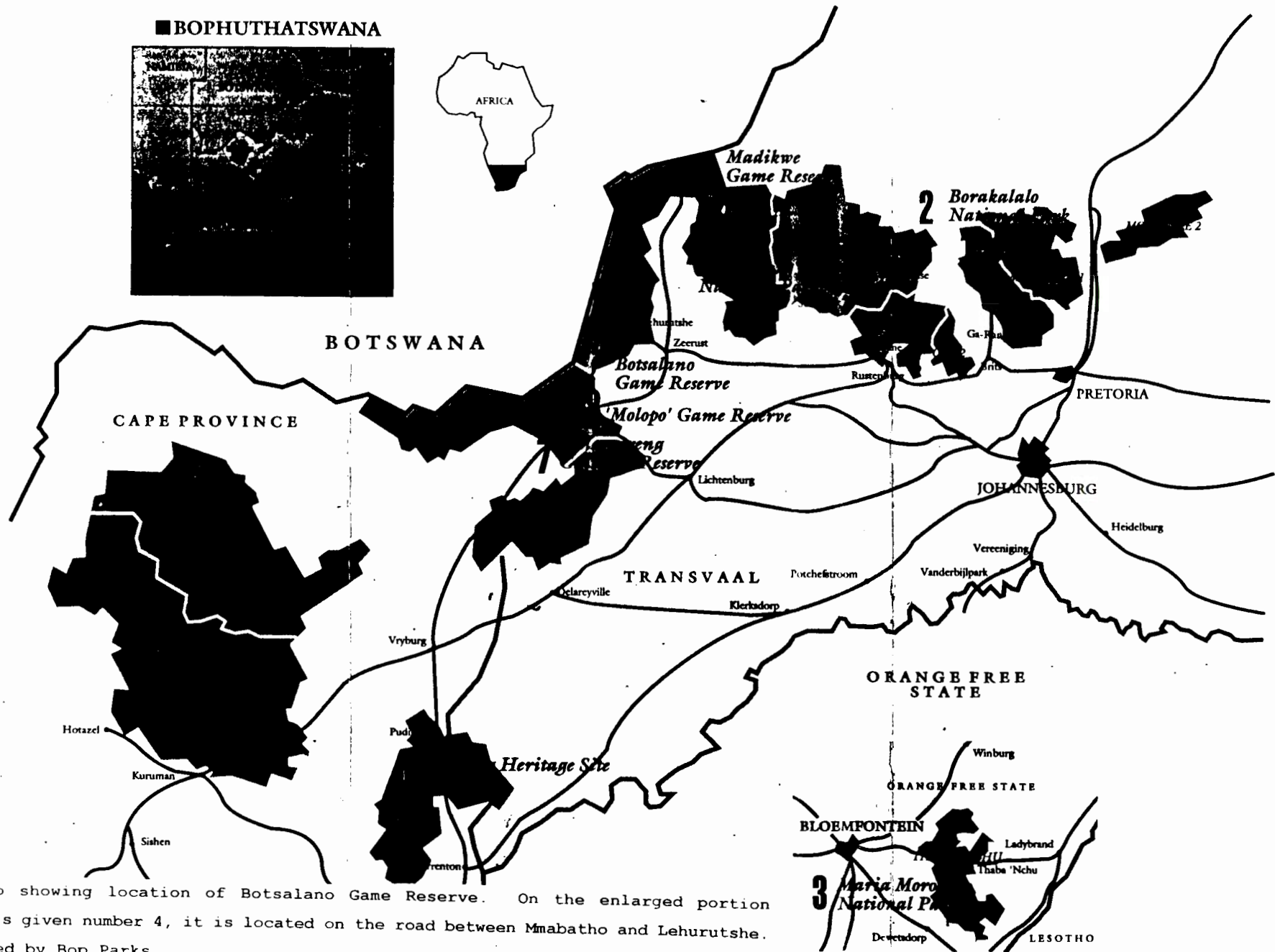


Fig. 1 Map showing location of Botsalano Game Reserve. On the enlarged portion Botsalano is given number 4, it is located on the road between Mmabatho and Lehurutshe. Map supplied by Bop Parks.

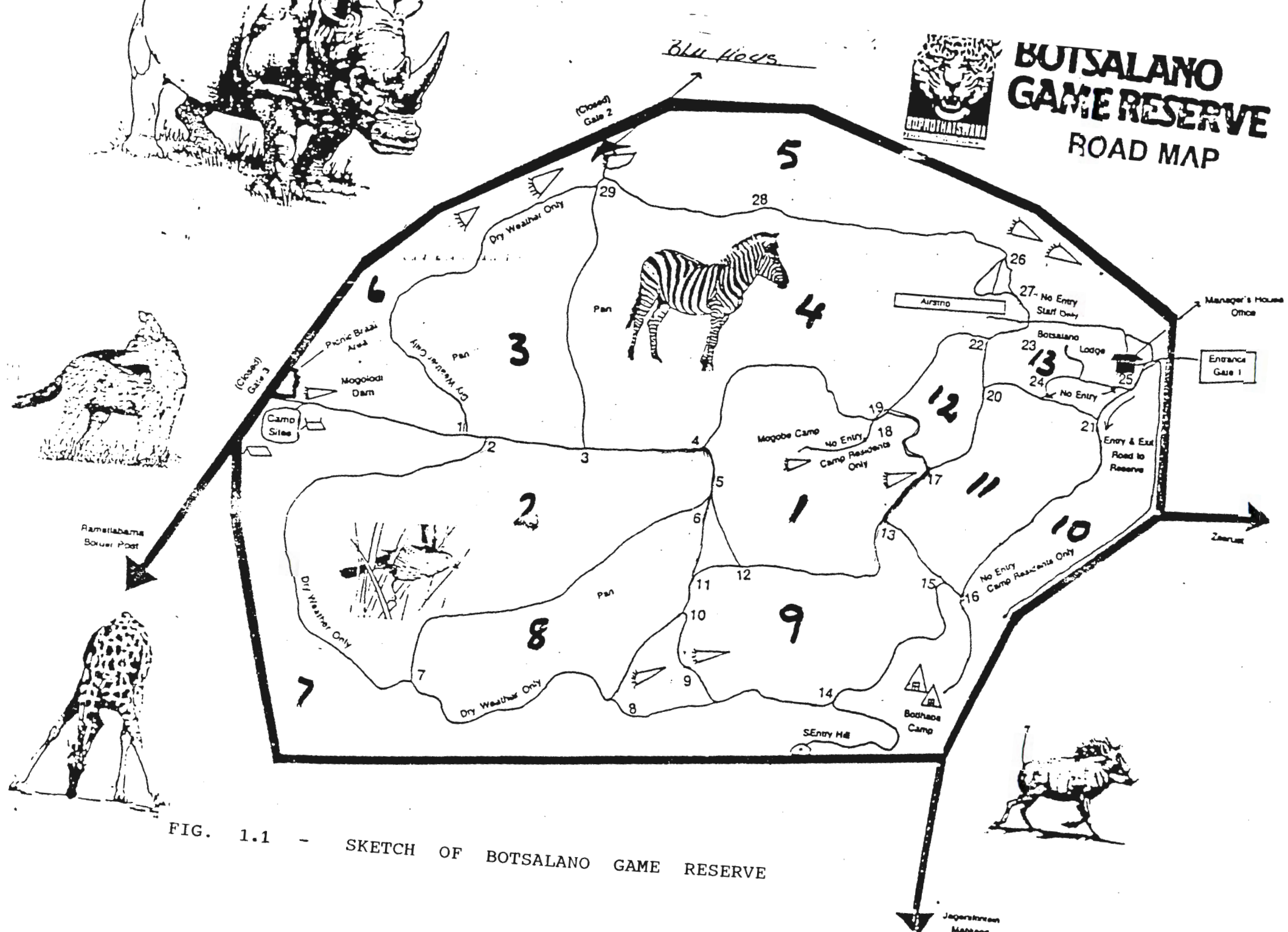


FIG. 1.1 - SKETCH OF BOTSALANO GAME RESERVE

giraffe, zebra, black wildebeest, blue wildebeest, gemsbok, springbok, blesbok, waterbuck, impala, warthog and black-backed jackal. To date, over 180 species of birds have been recorded in the reserve (Bop Parks :1993).

2.1.3 CLIMATE

Variation in topography and geology can create variation in the environment within regions of uniform climate (Ricklefs: 1990). In hilly area , the slope of the land and its exposure to the sun influence the temperature and moisture content of the soil. Winds and dust storms usually occur from September to December due to the typically flat configuration of the land in this region.

TABLE 1. Comparison of temp. and rainfall figures of 1997/98 to long term averages

Month	max. Temp. 1997/98	min. Temp. 1997/98	mean temp. 1997/98	mean max.- min Temp for 35yrs	Rainfall 1997/98	Near-norm rainfall for 63yrs
JANUARY	28.6	17.3	22.9	30.5 - 17.6	159.5	67 - 96
FEBRUARY	30.5	17.0	23.8	29.9 - 17.2	124.1	61 - 87
MARCH	25.3	15.4	20.4	28.6 - 15.6	162.1	52 - 86
APRIL	22.9	9.6	16.3	25.8 - 11.8	107.7	25 - 58
MAY	20.7	6.5	13.6	23.5 - 7.1	134.7	4 - 16
JUNE	20.0	3.6	11.8	20.6 - 3.7	0.0	1 - 5
JULY	19.7	4.3	12.0	21.2 - 3.4	2.0	0 - 2
AUGUST	24.3	6.8	15.6	23.9 - 6.1	10.4	0 - 3
SEPTEMBER	25.7	11.3	18.5	27.6 - 10.6	22.8	4 - 12
OCTOBER	28.2	12.9	20.6	28.9 - 13.8	68.2	27 - 46
NOVEMBER	29.8	14.6	22.2	29.4 - 15.7	30.0	48 - 73
DECEMBER	32.6	17.5	25.1	30.3 - 16.8	52.3	65 - 91
JANUARY	29.3	16.8	23.1		159.1	
FEBRUARY	30.5	17.4	23.9		77.5	
MARCH	29.9	15.8	22.9		99.1	

Total Rainfall - For the year 1997 = 873.3 mm

Table 1 shows the average maximum and minimum temperature (°C) and the total rainfall (mm) during the months of 1997 - March 1998 compared with the near normal rainfall categories for the North West province based on 63 years data, and the mean maximum and mean minimum temperature for the North West province based on 35 years data (Long-term operational Group Information centre LOGIC of the South African Weather Bureau : 1999). The researcher found it necessary to make reference to these figures of 1997, mainly because the vegetation that is dealt with in this study was collected in March 1998, therefore it would have been influenced by the rainfall and temperature of the summer season in 1997. These recordings were obtained from Weather Bureau in Pretoria, where the recordings are actually done on a daily basis. For the purpose of this study only the average recordings for each month were considered (South African Weather Bureau, unpubl. June : 1998 - Appendices D, E, F).

Table 1 shows that there is a seasonal change in the temperature. From September to March are summer months with temperatures above 25 °C and higher, while April to August is winter when temperature is below 24 °C.

The minimum temperatures for the warmer months were above 11 °C and those for the cooler months dropped down to 3.6 °C in June, the coldest month for the year. When considering the average or mean temperatures for the year 1997, December seems to have been the hottest month for the year, with the mean temperature of 25 °C, its actual maximum temperature was 32.6 °C. The next hottest month in this period was February with a mean temperature of 23.8 °C, then came November and January with the mean temperature of 22.2 °C and 22.9 °C respectively. March and October had similar mean temperatures, these had 20.4 °C and 20.6 °C.

September has a mean temperature of 18.5 °C, this was then followed by April with a mean temperature of 16.3 °C. August has a mean temperature of 15.6 °C. The weather was getting cooler during the months of May, June, and July, when the mean temperatures were 13.6 °C, 11.8 °C and 12.0 °C but June appeared to be the coolest month for the year 1997. The temperature of the first three months of 1998 were also recorded. It can also be observed that these first three months have really been hot, thus, January had the mean temperature of 23.1 °C, February 23.9 °C and March 22.9 °C.

The graph in fig. 2 also shows rainfall distribution for each month for the year 1997 to May 1998 (South African Weather Bureau, unpubl. June: 1998). The recordings were also from Weather Bureau in Pretoria. More rain was observed during the first five months of the year (1997), thus, January, February,

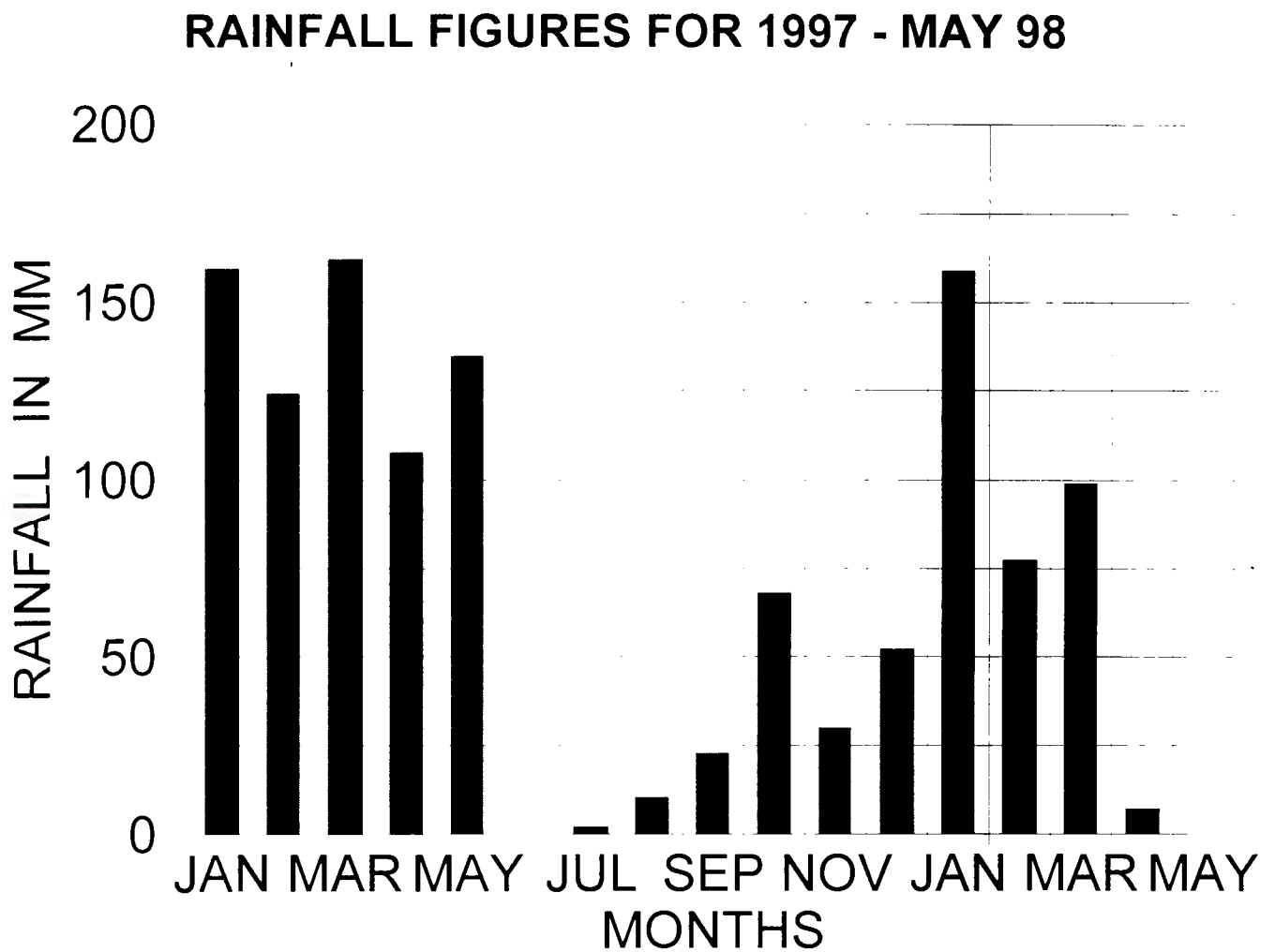


Fig. 2 Chart showing rainfall figures for the year 1997 up to May 1998 in Mafikeng area. Figures were obtained from Weather Bureau in Pretoria because the recordings in the park were incomplete.

a bad figure for such a hot year. The amount of rainfall for the first five months of the year 1997 seemed to have been very high when compared with the long term rainfall figures for the North West Province for the past 63yrs (Table 1). Comparatively June 1997 had no rain at all while for other years there was little rainfall. The rest of the year received less rainfall as compared to the first half of the year.

The first three months of 1998 had better rainfall but heaviest rain was observed only in January. The figure then dropped during the next month from 159.1 to 77.5 mm. The information from the Bureau shows that even though rainfall increased in March, to 99.1 mm but dropped in April to only 7.2 mm and none at all in May.

2.1.4 GEOLOGY AND SOILS

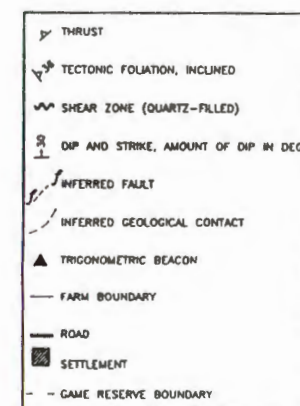
Botsalano game reserve has a high ground area that is shallow, stony and rocky in some places (fig. 3). Red and brown loamy to sandy loam being derived from the Dominion Reef, Black Reef, and Ventersdorp quartzite banded iron-stone and lava.

The valley bottoms have Amabele, Kusasa, Grovedale and Slangkop which are shallow and poorly drained soils. These are derived from the reefs mentioned above. The land has also dark brown sandy-clay to sandy loam that are made of calcrete overlying the Northern Cape granite rocks. Soils on steep slopes drain well,



COUNCIL FOR GEOSCIENCE
GEOLOGY OF THE
BOTSALANO GAME RESERVE

EXPLANATION AND LEGEND



SEDIMENTARY AND EXTRUSIVE ROCKS / INTRUSIVE ROCKS

Alluvium

GABORONE GRANITE SUITE

		2a 3a				(MP) Gaborone Main Phase	
		MP	1	2b	3b	4	Marginal Phase
Mogobane Formation	Volcaniclastic sediments						Type 1 granophyric granite
	UPPER ZONE						Type 2a quartz, feldspar porphyritic granophyre
	MASSIVE ZONE						Type 2b feldspar porphyritic granophyre
	BASAL ZONE						Type 2c spherulitic porphyritic microgranophyre
Kanyo Formation	Basaltic andesite						Type 3b spherulitic microgranophyre
	Basal porphyritic felsite						Type 4 microgranite

* LOBATSE GROUP

ARCHAIC BASEMENT

UNDIFFERENTIATED GRANITOID

* New proposed stratigraphy for Lobatse Group

- Outcrop shown by condensed ornamentation
- Mapped and compiled by D. F. Grobler (1995)

Fig. 3 MAP ON GEOLOGY OF BOTSALANO GAME RESERVE

often causing moisture stress for plants at the same time that the soils of nearby lowlands are saturated with water (Picklefs:1990).

2.1.5 TOPOGRAPHY

The land is gently undulating, comprising six low ridges that nearly run parallel to each other, east to west across the reserve. The only steep slope is the North facing slope of a single hill on the South part of the reserve, where the Northern part of the hill is cut by a game fence, including a fraction of this hill inside the park. There are also some deep depressions within the park where water accumulates.

2.1.6 VEGETATION (SOURISH MIXED BUSHVELD)

This is a semi-arid biome which is rather more clearly defined veld type than is the mixed bush veld, occupying an irregular belt on the gentle slopes to the mountains, between the sour types of the plains and valleys. It is generally a rather open savanna with *Acacia caffra* the dominant tree and karee woodlands which open out into extensive grasslands in a fairly tall dense grass veld dominated *Cymbopogon plurinodis*, *Themeda triandra*, *Elicurus muticus* and *Hyparrhenia* species (Acocks:1975).

In Botsalano, grass communities were recognised and sub-divided

11.53;

a tall grass stands, in under grazed area composed of *Themeda triandra* and unpalatable *Cymbopogon excavatus* and *Cymbopogon plurinodis*.

(b) short grass stands, in old farmlands, composed mainly of *Eragrostis* species and some few scattered *Cynodon dactylon* patches.

(c) a mixture of tall and short grasses on high ground, rocky, over grazed areas with prominent stands of *Digitaria* species, *Anthepora* species, *Heteropogon contortus* and *Brachiaria nigropedata*.

(d) a mixture of tall and short grasses on valley slopes and bottoms, composed mainly of *Aristida* species.

CHAPTER THREE

METHODOLOGY

3.1 SAMPLING PROCEDURE

Different sites were identified in the park. This identification was based on the level of utilisation of the specific area within the park. The main purpose being to sample a range of sites representing different levels of utilization. There were some areas more utilised than others, while some were mostly over utilised, under utilised, or moderately utilised. Each site was given a number.

The choice of sites was made in such a way that most other factors were kept constant such as soil colour, i.e sites were chosen mostly on reddish soils because it seemed to be most extensive soil type of the park. The only difference allowed, as far as possible was the level of vegetation utilisation. Whittaker (1978) stipulates that among the many kinds of information that may be gathered, some are more appropriate than others to the character of the community, the investigator's research purposes (Cain & Castro: 1959;3), and the requirements imposed by plans for subsequent data analyses. However, Gauch (1984) says sampling must be appropriate in intensity and breadth

to support research conclusions, but similarly, it should not occupy large amounts of time and resources beyond those required for the research objectives.

Sites were taken very close, farther and very far from the drinking places. Drinking places were chosen in this study because often there can be observable vegetation changes around drinking places. This has also been observed by Perkin & Thomas (1993) in Southern Africa, Andrew (1988) in Australia and Archer & Smeins (1991), Fusco et al. (1995) in South Western North America that the effect of grazing is particularly marked around boreholes or water points where grazing animals are concentrated in high densities for long periods. Andrew (1988) and Pickup (1994) also agree that in general, distinct zones of bare soil, ephemeral plants, woody shrubs and grasses (the 'piosphere') may be distinguished from the water point to the outer edge of the intensively used area. In this case two main drinking dams in the park were visited. Areas closer to the dam or drinking points tend to be over utilised as animals come to them regularly for drinking. When taking records in the field, twenty paces were taken going away from the water point to ensure a good representation of all levels of utilisation. Animals often come to the tree for different reasons. One of these is coming for shade on hot days, thus utilising the areas heavily. Such sites were selected to represent over utilised areas.

Camping sites with permanent structures such as houses which are located towards the centre of the park were sampled to represent less utilised areas. Animals do not often visit such areas for fear of being harmed by the people hence these sites tended to be minimally utilised. In the park there were other buildings such as the management offices, houses for people who stay in the park. Animals do not often come around such area therefore these were less utilised by the animals. These sites were taken around the Manager's house, Sergeant's house and the administration block. There was a constant noise coming from the generator next to the manager's house which could probably scare the animals.

Most animals often like the concave slopes of the park mainly because of the exposure to the sun. A variety of grasses exist here as the rain washes the soils to these concave sites, and the accumulation of water also provides favourable moisture conditions hence a better production. Other sites were taken where there used to be kraals, the vegetation there has not yet recovered therefore sites taken there were also representative of over utilised sites. Other sites however were also taken moving away from the old kraals into the park to mark the vegetation differences.

3.2 DATA COLLECTION AT EACH SITE

3.2.1 METHOD FOR VEGETATION COMPOSITION

A point method which is essentially a method for expressing botanical composition in terms of cover (Brown: 1957) was used in this study, although in this case the method was modified. A 50m long string with a pole at each end, was used. This string was marked at 1 m interval. The string was stretched, then the experimenter used a pointer made of wood to point at the species which coincide with the marked points. The diameter of the pointer was kept as fine as possible because its diameter can affect the results (Goodall: 1952). In each case if the species was hit directly the name of that species was recorded next to the point number, if the hit was not direct and there was no other plant within a radius of 15 cm, the point was recorded as bare, so there was either a hit or a bare recorded. This can be supported by Brown (1957) when she mentions that usually on dense swards any above-ground part of the plant is recorded as a hit, some workers count only hits on the base of the point (Clarke et al: 1942).

Staples (1945) counted hits made on vegetation present in the first inch above the surface of the ground, and a point which failed to touch a plant was recorded as bare space. However, this method still has some limitations, Brown (1957) also shows that the relative merits of the different methods of recording

hits have been studied and compared. When only the first plant hit is recorded, there is a tendency for the tall plants to be hit more frequently than low or prostrate ones. When only hits at ground level are counted, the creeping grasses and prostrate plants secure more than their fair share of hits. When all species encountered are recorded as the pointer is pushed to the ground, then the shorter plants are placed on a parity with the taller ones (Tinney, Aamodt and Ahlgren: 1937).

The following citations are used to justify the choice of number of points for this study. For a pasture, where information on dominants only was required, Levy and Madden (1933) considered 100 points to be sufficient, because they were focusing only on the dominants, whilst 400 or 500 points could be considered for the less abundant species. Crocker and Tiver (1948) tested the number of points required for reliable sampling of pasture fields in the south-east of South Australia, each field being 14 to 150 ha in area and widely different in botanical composition, soil type and past history. The standard deviations and coefficient of variability indicated a decrease in variability with increased number of points. The decrease in variability was particularly marked between the 100 and 200 point level, less so between the 200 and 300 or the 300 and 400 point level, it was scarcely evident above 500. Their tables show that with 100 points analyses are too inconsistent for even broad ecological studies.

"The marked decrease in the 400, however suggest that so far as the dominant species are concerned, the optimum number of points for a compromise between accuracy, speed and practical reliability is to be found in this range." (Crocker and Tiver: 1948 . A sparsely covered area requires more points than one which is well covered (Brown: 1957). In a lowland veld of Lesotho, cover of about 50% of the vegetation can be sampled with 200 points in 2 ha and 4 ha plots. In pastures in the Transvaal high veld where there is a high proportion of bare ground, West (1937) used 1000 points.

It has been calculated that to reduce the standard error of the mean to less than 10% for dominant species and 5% for the less abundant species it would be necessary to test 400 to 1500 and 2400 to 4000 points respectively. To reduce the standard error of the mean to 1% approximately 80,000 points would have to be tested (Clarke et. al. :1942).

After the completion of all the 50 points, the experimenter moved five paces within the same homogenous vegetation area and made another set of 50 points making a total of 100 points, another five paces were taken and the last set recorded. So that at each site 150 points were recorded. In the same nerve, Brown (1957) cites that the number of points does not depend on the size of the field but rather on the nature of the vegetation, its variety, the closeness or sparseness of the cover, and also on the part of the plant on which hits are to be recorded.

In this study, those plants which could not be identified by the experimenter in the field, were collected, given an identification number, preserved and taken to the herbarium for identification.

The basal hits and the nearest plant recording (to 15cm) were both recorded as hits and only in the absence of any plant within a 15cm radius was recorded as bare.

When calculating the percentage composition for each species, the number of hits of a particular species were checked from the record of that site, that number of hits was divided by 150 which was the total number of points per site and multiplied by 100. For instance, in site 2, *Aristida congesta* had 48 hits recorded out of 150 points, therefore its species composition or abundance value was calculated as follows:

$$\frac{48 \times 100}{150} = 32,0 \%$$

The results of these recordings can be found in tables on Species distribution table 3.3 and table 3.4. The percentage composition was calculated for every species using the formula;

$$\frac{\text{No. Of Species A} \times 100}{150}$$

3.2.2 SOIL SAMPLING

A soil sample was collected at each site, for the sake of uniformity on all sites. The soil sample was taken at every point number 25 of the transect in the middle.

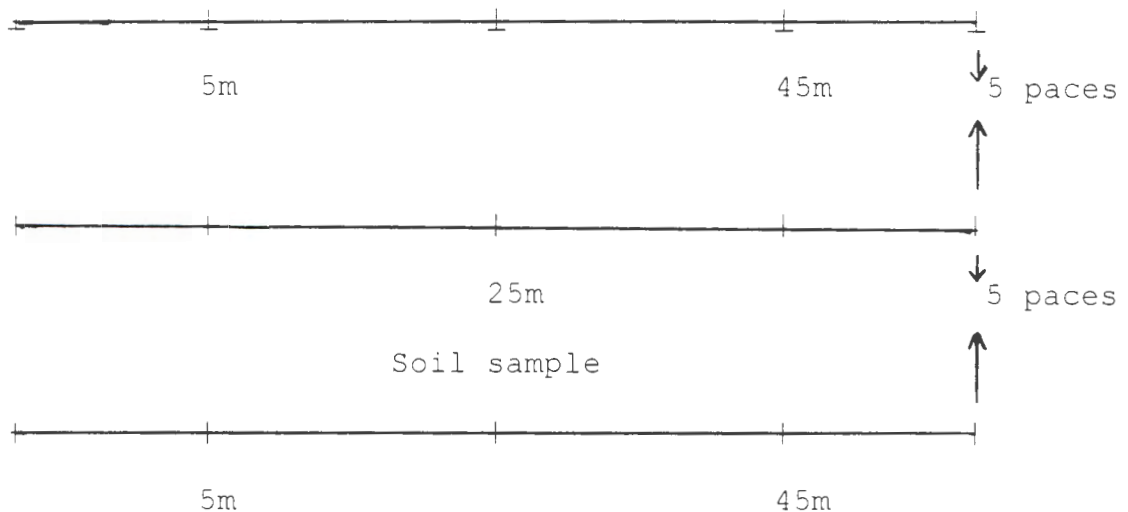


Fig. 4 The soil sample was collected at the middle transect at point 25 as shown in this figure for all the 70 sites under consideration.

The soil sample was collected and labelled according to site number. E.g. site number 10, the soil sample was given number 10.

Localised differences in the soil that were not representative of the site were avoided, for instance, where a bed rock had been obviously removed, or where droppings of a rhino were visible.

The purpose of testing any soil sample is to obtain information about a particular soil (Black et al.:1965). For any population, thus in this case being the larger aggregate of the soil material

In the whole site, there are certain characteristics which describe it. These may include the percent organic matter, amount of soluble salts, or the pH value. The purpose of sampling here or taking just a cupful of soil was to estimate these characteristics and others such as cation exchange capacity with an accuracy which would meet the researcher's needs at the lowest possible cost both money and time.

The sample was taken at the topsoil down to a depth of about 10-15 cm with the belief that if the population was relatively homogenous, a very small sample might tell us all we desire to know about the population. With soils, however, variation and heterogeneity seem the rule rather than the exception (Black et al.: 1965).

3.2.3 BIOMASS DETERMINATION

Biomass or standing crop is defined by Kent & Coker (1992) as the amount of plant material present in a quadrat at a given time. The harvests or cut weights that were collected from the field were taken to the laboratory, dried in the oven for 24 hours at the temperature of 105 °C and then weighed. The results were recorded in grams to two decimal places (refer table 2).

Different workers carry out the weight analysis in many different ways in the field. Brown (1957) describes the four general procedures for carrying out an analysis by weight as;

- a sample of the vegetation is cut, separated into species and each species is weighed.
- a sample of the vegetation is cut and the relative weight of each species is estimated by eye in the laboratory
- the relative weights of species in sampling units are estimated in the field
- the weights are estimated in the field by means of plots

Of all these procedures, the first one seems to be the most accurate of all for critical investigations regarding the behaviour of species and strains in seeds mixtures, in manuring trials and in studies on the effect of management. Brown (1957) confirms that it has been developed chiefly for measuring accurately small differences between pastures of the dense humid type. The other three procedures are for surveys, preliminary trials on dense pastures, and trials where big differences in results are expected, as on natural grasslands, rangeland type or any land which has been developed to its full capacity.

In this study, the species were not separated, only the total weight of the species was recorded. Poulton (1948) thinks there is a case for using the accurate cutting and weighing technique on range land, since sampling intensity is a function of the heterogeneity of the vegetation and not of its extent, the number

of sampling units need not be excessive and therefore the time required for sampling and analysis should not deter anyone from using weight as the criterion of measurement.

3.2.3.1 HARVESTING

Living plant biomass was harvested in 0.5 m x 0.5 m plots at points 5m, 45m of first and last 50m lines, and at point 25m of the middle line in each site.

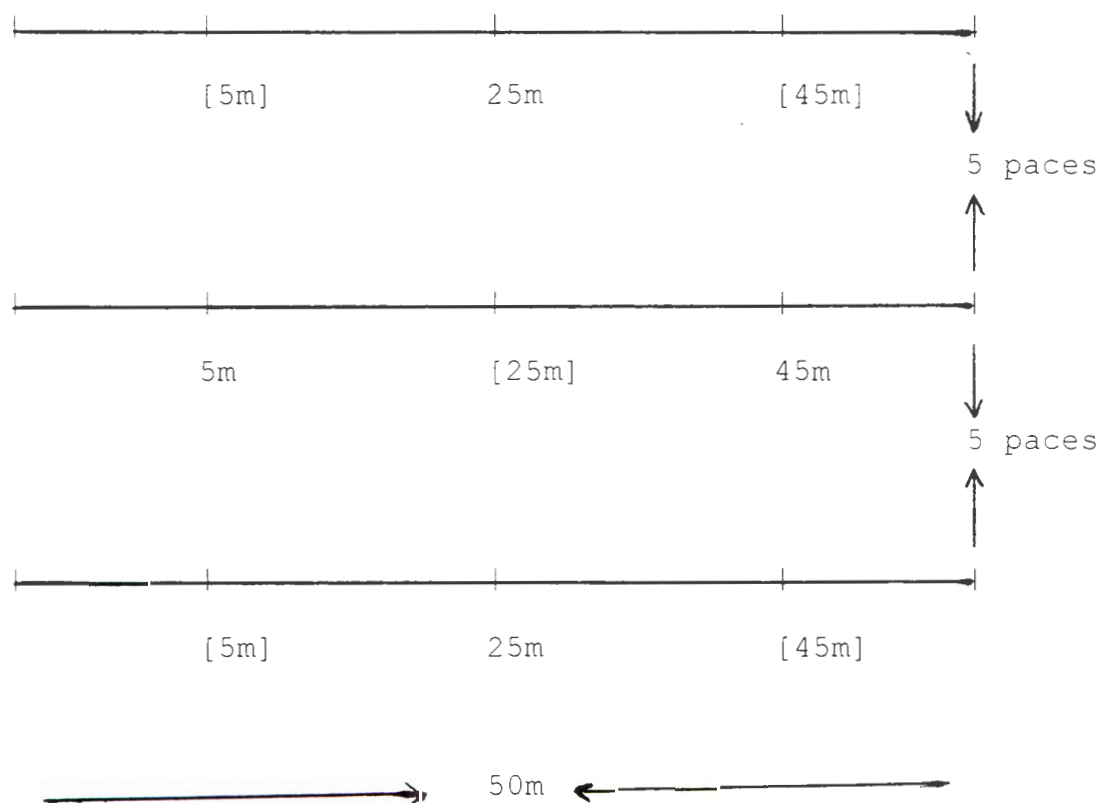


Fig. 5 Figure showing the harvest positions at each transect in each of the 70 sites.

Uniformity in height for cutting is very important. This was maintained by guiding the worker with four small black poles with a string tied around the poles. The cutting was done below the hand, this was for reasons of keeping fixed distance from the ground.

Clippings were made by the hand shear and the harvest placed inside the brown paper bag. The paper was labelled according to the site number first, then the point number, thus for each site there were five harvest samples, two point 5's, one point 25 and two point 45's, as shown in figure 5. The paper bags were labelled from harvest one to harvest five respectively.

Example of a label : 10.2, Number 10 represents site number and the figure 2 represents harvest number two. All labels for site 10 were written as follows: 10.1, 10.2, 10.3, 10.4, and 10.5.

Brown (1957) supports that small area, up to a square metre or square yard are usually cut by hand with shears. Shears can deal with herbage of any height, and an efficient or experienced worker can clip plots quicker than any machine. For the finer grasses, shears are handy because they hold the clippings.

3.3 SOIL ANALYSIS

The soil analyses procedures were conducted by the researcher with the help of the soil science technicians at the Faculty of Agricultural Science laboratories of the University of North West. The following analyses were conducted:

- soil texture (percentage of clay, sand and silt)
- soil colour
- cation exchange
- determination of K, Na, Mg and Ca.
- determination of organic carbon

3.3.1 SOIL COLOUR

Soil colours are most conveniently measured by comparison with a colour chart. The collection of charts generally used with soils is a modified version of the collection appearing in the Munsell "Book of colour" and includes only that portion needed for soils, about one-fifth of the entire range found in the complete edition. (Munsell soil colour charts : 1975).

The seven charts in the Soil Collection display 199 different standard colour chips systematically arranged according to their Munsell notations, these cards are carried in a loose leaf notebook. The arrangement is by the three simple variables that combine to describe all colours and are known in the Munsell system as Hue, Value, and Chroma.

The Hue notation of a colour indicates its relation to Red, Yellow, Green, Blue, and Purple; the Value notation indicates its lightness; and the Chroma notation indicates its strength (or departure from a neutral of the same lightness).

When using the colour charts accurate comparison was obtained by holding the soil sample placed in a test tube directly behind the apertures separating the closest matching colour chips (Munsell soil colour charts: 1975).

3.3.2 SOIL TEXTURE

3.3.2.1 VALUE OF TEXTURE IN PLANT GROWTH

The mineral particles of a soil, range in size from those easily discernible with the naked eye (stone, gravel, and sand) to those even below the range of the electron-microscope (colloidal complexes). This is just the relative proportion of mineral constituents classified according to their size. It determines to a considerable extent soil porosity and, consequently permeability to air and water, which are essential for root life and many processes that take place in soil. Foth et al. (1976) make a point that the texture of the soil largely determines the amount of surface area that is available for adsorption of water and nutrients. In addition, texture also affects the total amount and size of the individual pores which for the most part determines the rate and amount of air and water movement through.

Consequently, the rate of water intake, water supplying power, fertility, erosion and aeration are all closely related to soil texture.

A high content of coarse constituents usually increases porosity. But clay humus bond single soil grains together into larger aggregates. Buckman & Lyon (1943) also show that the texture of the soil influences the percentage of humus and nitrogen present. A sandy soil, for example, usually carries less organic matter and nitrogen than one of a heavier nature. This is probable due to the lower moisture content and to the more ready oxidation that occurs in the lighter soils. Soils lying along streams, because of their moisture relations are generally much higher in organic residues and nitrogen than their upland equivalents. The lime content of a soil, its drainage and erosion, its vegetative cover, and the vagaries of weather are other factors that may exert an influence upon the accumulation and the activity of the soil organic matter and its nitrogen.

Helling, Chesters and Corey (1964) found that in soils with uniform clay mineralogy, about 92 per cent of the variation in Cation Exchange Capacity (CEC) could be attributed to their clay and organic matter contents. Soils high in organic matter have a potentially large CEC which is pH-dependent. One reason why many natural peats are infertile is that their low pH values (3 - 4) result in low CEC. The pH-dependence of organic CEC is well illustrated by Helling, Chesters, and Corey (1964).

Tau and Dowling 1984 attempted to characterise the contribution made by soil organic matter to the permanent and pH-dependent CEC properties of several clay soils in the southern United States. They found that in montmorillonite-dominated soil, removal of organic matter caused an increase in CEC while in soils of mixed clay mineralogy, removal of organic matter resulted in a decrease in CEC.

3.3.2.2 DETERMINATION OF SOIL TEXTURE

The texture of a soil can be determined by manipulation of moist soil in the hand, the feel method, or by a laboratory method such as the Bouyoucos hydrometer method if greater accuracy is required. This is the method which was adopted in this study.

Fifty grams of soil from the collected dry sample was placed into a 250ml beaker. It was transferred into the milk shake cup, and to this 20ml of calgon solution was added. Calgon solution was made by dissolving 35.7g of Sodium hexametaphosphate [$(\text{NaPO}_3)_6$] and 7.94g Sodium carbonate (Na_2CO_3) in 1 dm de-ionised water. The main function of this solution was to break down small colloids chemically. Water was then added to the cup and stirred for 10 minutes with the milk-shaker (the shaker breaks down soil particles physically). After shaking, this was transferred into a measuring cylinder of volume 1075ml and covered to prevent any loss through evaporation.

In this method two basic processes were combined, that is dispersion and sedimentation. Dispersion deals with the separation of individual soil particles so that they remain separated during the determination, to accurately indicate particle size distribution. Since aggregates of solid particles are usually held together by some kind of binding, it is first necessary to remove these substances, or at least render them ineffective, this is the role played by Calgon solution. Once the compound particles in the soil are separated into individual particles, are said to be dispersed (Foth et al. 1976).

Sedimentation concerns the settling rate of the dispersed particles. Large particles are known to settle out of suspension more rapidly than do small particles. This is because larger particles present less specific area, hence less buoyancy than small particles.

3.3.2.2.1 SAND DETERMINATION

The stop watch was used to record the time. The solution that was prepared in section 3.4.2.2 above, had to be shaken and the time of stopping to shake was recorded. After 4 minutes the hydrometer was inserted and the reading from the hydrometer recorded. The temperature here plays an important role because when the temperature was low the hydrometer reading was high, but when the temperature had increased then the hydrometer did not go very deep hence a low reading. Foth et al. (1976) cites that the

density of water and its viscosity both change so that particles settle faster with increased temperature.

The table which gives the percentages of sand (Appendix B) with the comparison of the hydrometer reading and temperature was used. The recorded hydrometer reading was checked across under the corresponding temperature reading, and the percentage of sand recorded under the specific hydrometer reading and temperature in each sample was recorded.

3.3.2.2.2 CLAY DETERMINATION

The procedure for this was similar to the one for sand, except that for clay, the same solution that was prepared in section 3.4.2.2 above was shaken, time recorded and sample had to be left for 8 hours after which the hydrometer would be immersed. The temperature of each sample was also recorded in this case. The lower the temperature, the lower the hydrometer reading, and higher the temperature the higher the hydrometer reading as well. This showed that in cool solutions the particles take a longer time to settle and that they settle faster in warmer solutions. The table also has hydrometer readings and temperature recordings across, therefore to find the percentage of clay, the temperature recorded for a certain soil sample is checked against the corresponding temperature, and the value found there is recorded, that represents the percentage of clay. (Appendix A - table for clay in soil, Appendix B- table for sand in soil).

3.3.2.2.3 SILT DETERMINATION

This was calculated from the percentage of sand and clay obtained for each sample.

The formula used was :

$$100 - (\% \text{ sand} + \% \text{ clay}) = \% \text{ silt}$$

Example

Sample 1

$$\% \text{ sand} = 80 \qquad \% \text{ clay} = 12$$

$$100 - (80\% + 12\%) = \% \text{ silt}$$

$$100 - 92\% = 8\%$$

3.3.3 DETERMINATION OF CATION EXCHANGE CAPACITY

{Ca, Mg, K AND Na}

(i) Value or role of cations in growth or species distribution;

The clay and humus fractions of the soil are made up of extremely small colloidal particles. The particles have a large surface area per unit volume and because of their structure have a net negative electrical charge. Cation (ions with a positive (+) charge) are attracted to the negatively charged surfaces and include ions such as Ca, Mg, K and Na of the clay and humus particles. This capacity to attract and adsorb cations is called the cation exchange capacity of the soil. One of its most significant features is that it is a temporary storehouse for large quantities of available nutrients such as calcium, magnesium, and potassium that are partially protected from leaching yet are available for plant consumption.

This is basically the reason why these were determined in the soil samples. Under natural conditions when exchangeable calcium, magnesium and Potassium are removed from the clay and humus by leaching or plant absorption, they are replaced by hydrogen. This exchangeable hydrogen is responsible for soil acidity (Foth et al. : 1976).

(ii) The role of ammonium acetate in this procedure:

Ammonium acetate has been used here because of its valuable qualities. Firstly, it is highly buffered. As a result, when a neutral one Normal (1N) solution of Ammonia acetate is used to saturate a soil with Ammonium, the last part of the solution leached through the soil emerges with the same pH as the solution added.

Secondly, Ammonium also has special advantages in connection with measurement of the cations displaced from soils. However, Ammonium acetate has some disadvantages. With soils of high organic matter content, and with soils containing appreciable kaolin, halloysite or other 1:1 type clay minerals, it will often give somewhat lower values for exchange capacity than the Barium acetate or Barium chloride-triethanolamide methods (Mehlich: 1945). This is due to the less complete replacement of adsorbed hydrogen and Aluminium ions by Ammonium acetate. Also with soils which contain vermiculite clay, interlayer cations such as Ca, Mg, Na or H can be replaced by Ammonium, but the Ammonium so

fixed is not then replaceable by the usual methods employed. The procedure here constituted two main steps, that is extraction and determination.

3.3.3.1 EXTRACTION

For the extraction part, 10g of soil was measured and, placed in a 100cm centrifuge tube, stoppered tube, stoppered and the mass of tube and soil was determined.

3.3.3.1.1 FORMATION OF SOLUTION A FOR DETERMINATION OF Ca, Mg, Na and K

50cm³ of 1 mol dm⁻³ Ammonium acetate solution was added and shaken horizontally by an electric shaker for 60 minutes. The sample was removed from the shaker and left overnight. It was then centrifuged at 3500 rpm to obtain a clear supernatant solution, this was done for 10 minutes.

The supernatant solution was then decanted as completely as possible into a 100 cm³ volumetric flask, without losing any soil. Again 50 cm³ of 1 mol dm⁻³ Ammonium acetate solution was added to the soil and shaken well by hand to ensure that the soil had dispersed properly. This was then placed on shaker for 30 minutes, centrifuged and clear solution decanted into the same 100 cm³ volumetric flask. The volume was then made up with Ammonium acetate solution. This was filtered and kept for the determination of Ca, Mg, Na and K and was labelled solution A.

3.3.3.1.2 DETERMINATION OF CALCIUM (Ca) AND MAGNESIUM (Mg)

To determine Calcium and Magnesium, 5 cm³ of Ammonium acetate extract solution A) was pipetted into a 200 cm³ volumetric flask. 10 cm³ La- solution and 10 cm³ of 6 mol dm⁻³ HCL were added to dissolve any precipitate. The volume was then made up with de-ionised water. Ca and Mg were determined on an atomic absorption spectrophotometer.

In the absorption method light of the proper wavelength is passed through the flame in which the element being determined is present. Light is absorbed by the neutral atoms and molecules. Ca⁺⁺ and Mg²⁺ are not easily excited therefore they need a high temperature flame which can be obtained from an atomic absorption spectrophotometer. On the other hand this high-temperature flame favours the line radiation of Ca⁺⁺ and Mg²⁺ since with an increase in temperature there is an increase in neutral atoms through dissociation of molecules containing elements. As the temperature increases, interferences are reduced for Ca²⁺ and Mg²⁺ because there are more neutral atoms available for excitation and fewer atoms combined with O, OH, P, Al etc. (Black: 1965).

3.3.3.1.3 DETERMINATION OF SODIUM (Na) AND POTASSIUM (K)

When excited atoms, ions and molecules return to lower energy levels, light at characteristic wavelengths is emitted. Excited atoms and ions give "line" radiation at very definite wavelengths. The wavelength of the spectral line used for determining potassium is 766,5 nm on the atomic absorption spectrophotometer. The most useable emission spectra for sodium analysis are the 589,0 and 589.6 nm lines. All alkali metals are easily excited by a flame therefore to reduce interferences from other elements and to lessen ionisation, a low (cold) flame is recommended. This is mainly because K^+ and Na^+ are more easily excited than Ca^{2+} and Mg^{2+} .

3.3.4 DETERMINATION OF ORGANIC CARBON

Schollenberger (1927) proposed that organic material in soil may be oxidised by treatment with a hot mixture of $K_2Cr_2O_7$ and sulphuric acid.

After completion of the reaction, the excess dichromate is titrated with iron (II) ammonium sulphate hexahydrate. The reduced dichromate is assumed to be equivalent to the organic C present in the sample, assuming that soil organic matter has an average valence of zero.

3.3.4.1 PROCEDURE

Soil was ground to pass a 0,35 mm sieve, using a porcelain mortar and pestle. 1g of dry soil was transferred to a 500 cm³ Erlenmeyer flask. 10 cm³ of K₂Cr₂O₇ solution was pipetted to the soil sample, the flask was then swirled to disperse the soil in the solution. 20 cm³ concentrated sulphuric acid was added to the solution, the flask was again swirled rapidly and more vigorously for about 1 minute. The flask was allowed to cool for 30 minutes.

150cm³ de-ionised water and 10cm³ concentrated ortho-phosphoric acid were added. 1 cm³ Barium di-phenylamine sulphonate (indicator) was added, titration was then carried on. As the end point was approached, the solution colour changed to a dark violet brown. Iron (II) ammonium sulphate was added drop by drop until the colour changed green. Necessary readings were recorded, and calculations for the organic carbon were carried out. The answers reflected the amount of carbon in 1g of soil since only 1 g of soil was used.

3.4 DATA ANALYSIS

Multivariate analysis was chosen for this study. The basic purpose of using multivariate analysis in this research is that, this type of analysis of community data tend to minimise redundancy, reduce noise, elucidate relationships, and identify

outliers Gauch: 1982). It also provides relatively automatic objective means for shifting the level of abstraction from raw data conveniently collected in terms of species abundances in samples to community-level properties such as community types and low-dimensional representations of community gradients (Shimwell :1971, Whittaker :1978). The environment and community are defined by a multiple of variables which often interact or have an influence on each other.

Multivariate analyses also serve to relate communities to other kinds of data, including environmental and historical data. Results from multivariate analyses also serve to improve our understanding of communities, making possible better models of communities. Improved community models then provide the basis for designing more appropriate and effective multivariate methods.

For the purpose of this, the arrangement of unit (internal analysis) of the samples-by-species data matrix progresses well because this matrix contains sufficient information. (Lambert and Williams : 1962). However, in contrast, the environmental interpretation (external analysis) involves searching for correspondence between community variation and environmental variation .

3.5 DATA ORGANISATION

In this study ISPD (Intergrated System For Plant Dynamics) was used. ISPD is a software package which enables the user to define relatively homogenous grazing areas, construct vegetation models, and store relevant data for each of these areas in a data base. The package also provides the user with a framework by which the modules for condition and grazing capacity assessment and for defining appropriate management options can be prepared for direct implementation in any area of natural vegetation. This was basically used for model constructions which use ordinations of sample sites.

The numbers of sites were recorded, species were also given numbers, which were recorded and followed by their abundance scores which were obtained from the percentage composition calculations. Only eight species were entered in a row, being a requirement of the software format The format is called Cornell Ecological Programs format (CEP) (Hill: 1981). The species number and the abundance score within each couplet were laid out in the column specified by the format statements. If there were more than eight species present in a site, then the site number was repeated at the start of the next row and the remaining species entered in the same way. A two way table data matrix was constructed.

Example:

```

1  1 10.67  2  6.00  3  8.66  4 23.33  5  2.66  6  4.00  7
      5.33  8  2.00

```

```

1  8  0.67 10  2.66 11  2.66 12  0.67 13  2.00 26 16.00 27 1.33
    16 1.33
1 29 1.33 30  0.67 31 1.33 32  0.67 33  0.67 34  4.00
    4 32.00  6  3.33  3 25.33 7  5.33  9  1.33  8 11.33 16 0.67
    1  4.67
1 11 1.33 17  1.33 26  2.00 10  3.33  1  6.67  5  0.67 13 0.67

```

Once all the data had been entered, the next row had zeros instead of a site number. This means that there are no further data. After the data terminator (zeros), followed the species names, starting on a new row, these were written in the same order as the species numbering of the raw data. For each species name, eight columns were used, split into two groups, four first letters to represent the genus name and one space between, the other three for the species name, hence *Chloris virgata* would be CHLO VIR. Up to ten names were entered on one row and further names continue on the next row. The result looks like a jumble of letters.

Example:

```

ANTHARG ARISBAR HETECON ARISCON BULBBUR POGOSQU BRACNEG MELIREP
ERAGECH ERAG TRI
DIGIERI ARISSCA TRICGRA EUSTPAS ARISDIF ANTHPUB CYMBVAL DIHEAMP
EPAGSUP ELIC MUT

```

Following the species names, and starting on a new row, the same principle was applied to the sites. Eight columns were used to identify each site. Here the word 'survey' was used to record site numbers. One space was left between the word survey and the number. Ten names and numbers were fitted on one line and the next continued on the next line.

EXAMPLE:

```
SURVEY 1SURVEY 2SURVEY 3SURVEY 4SURVEY 5SURVEY 6SURVEY 7SURVEY
8SURVEY 9SURVEY10
SURVEY11SURVEY12SURVEY13SURVEY14SURVEY15SURVEY16SURVEY17SURVEY1
8SURVEY19SURVEY20
```

3.5.1 ORDINATION TECHNIQUES

Ordination endeavors to represent sample and species relationships as faithfully as possible in a low-dimensional space (Anderson: 1971, Orloci:1978, Everitt:1978, Noy-Meir:1979). The end product is usually two or more-dimensional graph, in which similar samples or species or both are near each other and dissimilar entities are far apart with similar sites ending up in close proximity to each other. The techniques used in this study were DCA (Detrended correspondence analysis) and DMOC (Degradation Model Construction).

3.7 DATA REFINING

Habitat variations occur within a particular rainfall zone, this can therefore lead to large variations or noise in the data (Austin et al.: 1981, Gauch: 1982) which make the identification of a reliable degradation gradient impossible. The initial results showed heterogeneity in the ordination results, because this was the first step in the analysis procedure, which was done by means of detrended correspondence analysis (DCA) (Hill & Gauch : 1980, which is suitable for data sets with relatively long gradients (Gauch :1982)). The ordination results of this data were under the influence of various habitat factors which were investigated to identify possible relative homogenous vegetation: habitat groups within the data set. The sites for this study were deliberately selected to represent differences caused by grazing, degradation gradient should occur on the first axis. For this reason, the second and higher are combined into a single value, that is the residual or distance off the first ordination axis. The resultant ordination plot therefore differs from the customary plot of the first axis against the second. This was not the case with the initial ordination. It can be noted on the ordination results for all the seventy sites that the ordination does not represent any single factor. Most of the sites are just jumbled together towards the centre of the graph not spreading accordingly to any axis. Under these circumstances re-ordination was necessary, the spread of the samples on the graph was also not ideal i.e spreading evenly throughout the ordination graph.

The data were then split into two sets according to texture of soils as this was found out to be one variable which might have contributed to ordination results. The two groups were subjected to both DCA and DMOC ordinations and the results were acceptable. Sites which were considered outliers were removed from the data matrix, because these were with residuals larger than an arbitrary 50% of the Euclidean length of axis-1. The position of sites on the ordination axis indicates the position of the samples along the degradation gradient, but the position along the residual axis indicates a gradient in model fit or appropriateness (from good to poor). Thus, if samples are too far from the first axis, the ordination model does not provide a good fit to the data.

After dividing the data into sets, ordinations were carried out on each set. The first set, which is referred to as model A, had three samples with residuals larger than an arbitrary 50% of the Euclidean length of axis-1, were discarded from the data matrix, and the ordinations repeated. This model has 26 sites with the first axis going up to 89.5 and the second axis going up to 38.7 these axes are for the DMOC results (fig. 9.1). For the second set referred to as model B, six sites were also discarded for the same reason and the first axis went up to 70.1 while the residual was 31.1 also for the DMOC ordination (fig. 11.1). The ordinations obtained after that, satisfied one of the conditions that the second axis should be half or less of the first axis.

CHAPTER FOUR

RESULTS

Table 2 BIOMASS RESULTS OF ALL 70 SURVEYS

Results of biomass taken from the five harvest samples of each plot, dried in the oven for 24 hours at 105 °C and weighed. Mean Dry weight is recorded here, standard deviation and yield per square metre as calculated by multiplying the 0.5m X 0.5m plot weight by 4 to give the yield in grams per square metre.

SITE NO.	MEAN DRY WEIGHT	STANDARD DEVIATION	YIELD PER Sq.m
1	62.74	11.37	250.96
2	63.48	16.34	253.92
3	90.62	52.58	362.48
4	75.46	42.96	301.84
5	65.28	10.39	261.12
6	63.90	13.55	255.60
7	69.58	22.07	278.32
8	58.62	14.28	234.48
9	70.90	21.19	283.60
10	53.26	11.94	213.04
11	54.78	7.32	219.12
12	61.80	4.94	247.20
13	50.64	15.72	202.56
14	48.14	17.25	192.56
15	15.24	3.47	60.96
16	56.54	8.66	226.16
17	64.60	15.23	258.40
18	56.44	28.64	225.76
19	19.76	0.84	79.04
20	28.18	11.84	112.72
21	69.00	31.83	276.00
22	52.38	13.91	209.52
23	48.76	12.41	195.04
24	63.52	30.45	254.08
25	66.36	20.37	265.44
26	53.38	11.79	213.52
27	64.54	13.36	258.16
28	21.44	25.39	85.76
29	22.50	13.01	90.20
30	59.68	16.23	238.72
31	17.64	15.85	70.56

SITE NO.	MEAN DRY WEIGHT	STANDARD DEVIATION	YIELD PER Sq.m
32	25.10	22.70	100.40
33	42.50	27.39	170.00
34	35.56	11.86	142.24
35	47.64	12.75	190.56
36	47.46	16.11	189.84
37	58.52	19.56	234.08
38	50.20	15.58	200.80
39	48.26	15.88	193.04
40	69.20	18.97	276.80
41	65.42	19.79	261.68
42	40.54	11.26	162.16
43	61.52	13.81	246.08
44	48.44	7.75	193.76
45	57.32	22.75	229.28
46	50.86	7.37	203.44
47	42.22	6.85	168.88
48	43.60	10.19	174.40
49	52.06	10.83	208.24
50	50.94	7.28	203.76
51	67.28	14.64	269.12
52	49.56	6.03	198.24
53	60.34	11.14	241.36
54	42.86	16.12	171.44
55	59.64	37.69	238.56
56	54.34	15.06	217.36
57	58.28	21.71	233.12
58	51.88	12.69	207.52
59	42.68	9.92	170.72
60	57.32	7.68	229.28
61	58.08	9.32	232.32
62	70.12	11.27	280.48
63	69.28	23.89	277.12
64	84.82	21.07	339.28
65	61.56	23.92	246.24
66	54.08	4.79	216.32
67	59.98	21.32	239.92
68	77.58	23.64	310.32
69	64.38	8.49	257.52
70	63.52	22.94	254.08

The results recorded in the above table show the information on biomass, the first column shows the site numbers, this is followed by the mean weight recordings in column two, these have been calculated from the five harvest which were made from each site. The mean is often defined to be the average of values of the distribution, and it is the most commonly used

measure because of its simplicity and other theoretical advantages. The mean values for different sites were recorded to two decimal places.

Variance was measured in units of squared observations, to obtain the measure of spread in the same units as the mean, the positive square root of the variance was used and this is called Standard deviation. These are the values recorded in column 2 of table 2.

The two values, mean and standard deviation, are often different. They are neither directly nor indirectly proportional, thus one cannot conclude that for sites with higher mean values their standard deviation will also be high or will be low. That is the reason, why these are two independent measures. The third column of the table shows readings for yield per square metre, which were calculated for each site. The mean which was calculated for a 0.5 m x 0.5 m plot was multiplied by 4 to convert the yield to yield per square metre.

CONSTRUCTING THE HISTOGRAM

When plotting the histogram, the biomass results were first grouped into yield per square metre classes of equal width i.e 30g as shown in the table 3 below. All 70 results in table 2 lie between 60.96g and 362.48g on the working scale and was divided into 11 classes by taking a 30g class-width. Table 3 was used to sort out the raw data into classes with a wide column in which a 'slash' was made as each result was entered and every fifth slash was made in the reverse direction to form a cluster of 5 for convenience in totalling. Each result was entered only once. After entering all the numbers, the number of slashes were counted, recorded and added up to a total of 70. The cumulative frequency column was also entered. The last column of the table are percentages.

**Table 3 DISTRIBUTING THE 70 BIOMASS RESULTS INTO WEIGHT
CLASSES**

CLASSES		FREQUENCY	CUM. FREQ.	PERCENT.
60 - 90	//	2	2	2.85
90 - 120	/	1	3	1.43
120-150	/	1	4	1.43
150 - 180	//// /	6	10	8.57
180 - 210	//// //// ////	14	24	20.00
210 - 240	//// //// //// /	16	40	22.86
240 - 270	//// //// //// ///	18	58	25.71

270 - 300	//// /	6	64	8.57
300 - 330	////	4	68	5.71
330 - 360	/	1	69	1.43
360 - 390	/	<u>1</u>	70	<u>1.43</u>
		70		99.99

INTERPRETING THE HISTOGRAM

This histogram is regarded as a useful summary of a set of biomass results taken from Botsalano game reserve. Firstly, the highest bar, the 240 - 270 class in fig.6 is referred to as the modal class, or one can say the class which contains the mode. Just like the arithmetic mean, the mode belongs to the category of parameters referred to as 'measures of central tendency.' (Wardlaw: 1985) The tallest bar may contain the mode but is not itself the mode. The histogram itself is a frequency diagram because it shows the frequency of occurrence of results with particular classes. For instance, the tallest bar, which represents the class of 240 - 270 contains 18 observations and therefore has a relative frequency of $18/70$ or 25.71%. The area under the whole histogram represents 100% of the population of results.

The central 5 bars divide the histogram into central zone, which contains a majority of the observations, leaving 'tails' on each side. The central area represents 60 of the 70 observations, which corresponds to 85.71% of the total number. There are the

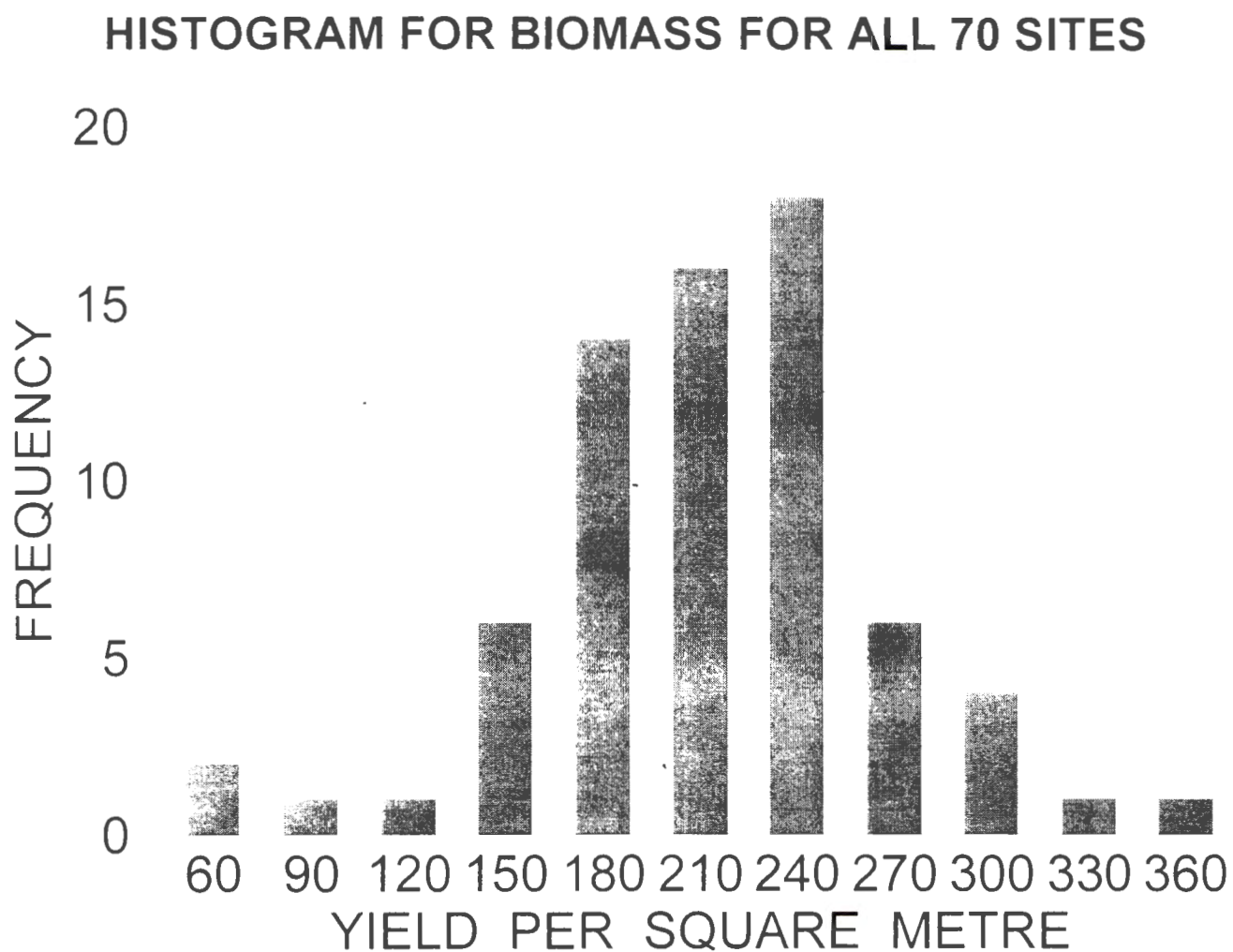


Fig. 6 Histogram showing the biomass results for all the 70 sites under considreation

lower and upper tails of the distribution. The lower tail containing 5.71 % of the observations and the upper tail 8.57%. This is actually explained here to show that the relative area which is vertically under a part, or parts of a distribution is a direct measure of the relative frequency of occurrence of observations in this case being the yield per square metre of the sites taken.

Tables 4 and 5 the distribution of species in different sites, each abundance value is recorded as calculated using the formula shown in section 3.2.1 of chapter three. Each species presence is indicated by the value recorded for each site, where zero is recorded means that particular species did not occur in that site.

Spp.	1	67	70	25	22	63	61	26	27	24	6	13	16	40	11	41	5	49	59	51	34	21	23	33	35	15
Cym va	0	0	0	0	0	0	3	0	0	1	2	2	0	0	0	0	1	9	5	3	2	0	0	0	3	0
Eus pas	0	0	0	0	8	0	0	0	1	0	17	1	26	0	5	2	3	0	0	0	3	0	0	0	0	0
Rhy re	0	0	0	0	0	0	0	2	1	13	0	0	0	0	0	0	0	0	0	0	0	7	13	0	0	0
Era tric	3	0	1	7	0	0	1	4	3	9	5	35	23	19	7	12	13	17	19	17	54	17	20	0	72	78
Ari bar	6	3	0	0	0	0	0	0	0	0	37	33	0	27	41	34	29	4	16	28	0	0	0	0	0	7
Cyn da	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	10	0
Dig eri	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	3	0
Era ech	1	0	0	0	0	0	0	0	5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	9	0	0
Wal de	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	1	0	0
Sch pin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dig vel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shrubs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	1	1	1	1
Stones	1	0	0	1	0	0	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bare	4		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	20	10

TABLE 5 SPECIES DISTRIBUTION ALONG THE ORDINATION GRADIENT FOR MODEL B

SITE NUMBERS

LOW DEGRADATION

HIGH DEGRADATION

Spp.	66	65	59	55	53	54	52	45	44	43	48	60	47	46	42	11	39	38	7	18	30	32	29	28	31
Sch pa	0	0	30	13	7	3	11	0	0	0	8	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Eli mut	0	0	1	1	1	1	4	5	3	3	1	3	5	7	1	0	0	0	8	0	5	0	0	0	0
Ari co	31	35	5	11	9	24	7	33	22	26	5	10	12	13	35	20	14	18	15	27	4	7	0	6	0
Cym v	0	0	8	7	4	2	7	3	4	5	8	6	3	5	4	0	1	0	1	0	17	0	2	5	0
Ant ar	2	3	13	15	19	12	10	7	15	18	14	11	15	10	17	1	3	7	1	1	0	0	0	0	0
And eu	16	7	22	32	33	26	28	22	21	20	6	32	30	30	20	0	6	6	0	1	0	0	0	0	0
Era su	4	7	0	3	0	2	1	1	4	3	7	5	5	7	0	1	0	1	7	0	3	0	0	0	0
Ari bar	1	0	1	0	7	1	8	7	5	3	0	4	1	3	5	41	22	0	1	4	0	0	0	0	0
Era tric	0	0	6	8	8	10	12	9	8	10	24	7	11	15	0	7	19	26	16	9	18	18	12	0	11
Eus pa	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	5	0	1	8	15	4	0	1	0	0
Mel re	0	1	0	2	0	0	0	1	5	5	1	0	5	3	0	3	3	5	7	3	0	0	0	0	0
Dig eri	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	2	0	0	1	1	17	0	0	0	0
Tri gra	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0
Ari dif	1	7	0	0	1	1	0	0	0	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0

[illegible]

Table 6 SOIL COLOUR RESULTS FOR ALL 70 SITES

Soil colour results of the sample plots in the total data set, taken by comparing the soil sample against the Munsell Soil colour charts. This is arranged by the three variables that combine to describe all colours, thus Hue, Value and Chroma describing the colour, lightness and strength of the soil respectively. Reddish brown tend to be the dominant colour for all the plots. Soil samples were collected from Botsalano Game Reserve in March 1998, soil colours were confirmed on daily basis after collection.

SITE NO.	SOIL	COLOUR
1	10R 3/1	Dark reddish gray
2	10R 3/1	Dark reddish gray
3	10R 3/1	Dark reddish gray
4	10R 3/1	Dark reddish gray
5	5YR 4/4	Reddish brown
6	5YR 4/4	Reddish brown
7	5YR 4/4	Reddish brown
8	5YR 4/4	Reddish brown
9	5YR 4/4	Reddish brown
10	5YR 4/4	Reddish brown
11	5YR 4/4	Reddish brown
12	5YR 4/4	Reddish brown
13	5YR 4/4	Reddish brown
14	10YR	Dark brown
15	5YR 4/4	Reddish brown
16	5YR 4/4	Reddish brown
17	5YR 4/4	Reddish brown
18	5YR 4/4	Reddish brown
19	5YR 4/4	Reddish brown
20	5YR 4/4	Reddish brown
21	5YR 4/4	Reddish brown
22	5YR 4/4	Reddish brown
23	5YR 4/4	Reddish brown
24	5YR 4/4	Reddish brown

SITE NO.	SOIL COLOUR
25	5YR 4/4 Reddish brown
26	5YR 4/4 Reddish brown
27	5YR 4/4 Reddish brown
28	5YR 4/4 Reddish brown
29	5YR 4/4 Reddish brown
30	5YR 4/4 Reddish brown
31	5YR 4/4 Reddish brown
32	5YR 4/2 Dark reddish gray
33	5YR 4/2 Dark reddish gray
34	5YR 4/2 Dark reddish gray
35	5YR 4/2 Dark reddish gray
36	5YR 4/4 Reddish brown
37	5YR 4/4 Reddish brown
38	5YR 4/4 Reddish brown
39	5YR 4/4 Reddish brown
40	5YR 4/4 Reddish brown
41	5YR 4/4 Reddish brown
42	5YR 4/4 Reddish brown
43	5YR 4/4 Reddish brown
44	5YR 4/4 Reddish brown
45	5YR 4/4 Reddish brown
46	5YR 4/4 Reddish brown
47	5YR 4/4 Reddish brown
48	5YR 4/4 Reddish brown
49	5YR 4/4 Reddish brown
50	5YR 4/4 Reddish brown
51	5YR 4/4 Reddish brown
52	5YR 4/4 Reddish brown
53	5YR 4/4 Reddish brown
54	5YR 4/4 Reddish brown
55	10YR 3/4 Dusky Red
56	10YR 3/4 Dusky Red
57	5YR 4/4 Reddish brown
58	5YR 4/4 Reddish brown
59	5YR 4/4 Reddish brown

SITE NO.

SOIL COLOUR

60	5YR 4/4 Reddish brown
61	5YR 4/4 Reddish brown
62	5YR 4/4 Reddish brown
63	10YR 3/4 Dusky Red
64	10YR 3/4 Dusky Red
65	10YR 3/4 Dusky Red
66	10YR 3/4 Dusky Red
67	10YR 3/4 Dusky Red
68	10YR 3/4 Dusky Red
69	10YR 3/4 Dusky Red
70	10YR 3/4 Dusky Red

Table 7 SOIL COLOUR RESULTS FOR SITES IN MODEL A

Soil colour results for the sample plots after dividing the data into two sets, this set was the set of soils with a higher percentage of clay. However the reddish brown colour still dominate this set. Samples were also collected from the park in March 1998.

SITE NO.	SOIL COLOUR
1	10R 3/1 Dark reddish gray
5	5YR 4/4 Reddish brown
6	5YR 4/4 Reddish brown
11	5YR 4/4 Reddish brown
13	5YR 4/4 Reddish brown
15	5YR 4/4 Reddish brown
16	5YR 4/4 Reddish brown
21	5YR 4/4 Reddish brown
22	5YR 4/4 Reddish brown
23	5YR 4/4 Reddish brown
24	5YR 4/4 Reddish brown
25	5YR 4/4 Reddish brown
26	5YR 4/4 Reddish brown
27	5YR 4/4 Reddish brown
33	5YR 4/2 Dark reddish gray
34	5YR 4/2 Dark reddish gray
35	5YR 4/2 Dark reddish gray
40	5YR 4/4 Reddish brown
41	5YR 4/4 Reddish brown
49	5YR 4/4 Reddish brown
50	5YR 4/4 Reddish brown
51	5YR 4/4 Reddish brown
61	5YR 4/4 Reddish brown
63	10YR 3/4 Dusky Red
67	10YR 3/4 Dusky Red
70	10YR 3/4 Dusky Red

Table 8 SOIL COLOUR RESULTS FOR SITES IN MODEL B

Soil colour results for the plots whose clay percentages were less, the clay percentage here ranges from 7 - 13 %. There is not much difference as far as soil colour is concerned, this set is still also dominated by reddish brown soils. That is why colour was not considered a factor along which the data set could be split. The samples were also collected from the Park in March 1998.

SITE NO.	SOIL	COLOUR
7	5YR 4/4	Reddish brown
11	5YR 4/4	Reddish brown
18	5YR 4/4	Reddish brown
28	5YR 4/4	Reddish brown
29	5YR 4/4	Reddish brown
30	5YR 4/4	Reddish brown
31	5YR 4/4	Reddish brown
32	5YR 4/4	Reddish brown
38	5YR 4/4	Reddish brown
39	5YR 4/4	Reddish brown
42	5YR 4/4	Reddish brown
43	5YR 4/4	Reddish brown
44	5YR 4/4	Reddish brown
45	5YR 4/4	Reddish brown
46	5YR 4/4	Reddish brown
47	5YR 4/4	Reddish brown
48	5YR 4/4	Reddish brown
52	5YR 4/4	Reddish brown
53	5YR 4/4	Reddish brown
54	5YR 4/4	Reddish brown
55	10YR 3/4	Dusky red
59	5YR 4/4	Reddish brown
60	10YR 3/4	Dusky red
65	10YR 3/4	Dusky red
66	10YR 3/4	Dusky red

Table 9 SOIL TEXTURE RESULTS FOR ALL 70 SITES

Soil texture results for all the sample plots , the Bouyoucos method was used to get the readings and compared with the temperature readings. For recording the sand readings, the hydrometer was immersed after 4 minutes, and for clay readings it was immersed after 8 hours. Calculations were conducted to get the percentages of silt. The soil samples were collected from Botsalano Game Reserve in March 1998.

SITE NO.	%SAND	%CLAY	%SILT
1	86	11	3
2	89	7	5
3	86	11	3
4	80	12	8
5	86	11	3
6	88	11	1
7	88	8	4
8	88	11	3
9	88	11	1
10	86	12	2
11	89	9	2
12	86	12	2
13	86	12	2
14	89	7	4
15	85	10	5
16	88	11	1
17	88	8	4
18	88	7	5
19	80	10	10
20	79	11	10
21	86	10	4
22	88	10	2
23	86	11	3
24	88	10	2
25	88	10	2
26	86	11	3
27	86	12	2

SITE NO.	%SAND	%CLAY	%SILT
28	87	8	3
29	88	7	6
30	87	10	2
31	88	7	6
32	86	8	4
33	85	10	5
34	88	10	2
35	85	11	4
36	86	11	2
37	88	11	3
38	87	7	3
39	88	10	5
40	86	10	2
41	88	11	1
42	87	10	3
43	88	11	2
44	88	10	2
45	86	10	2
46	88	10	2
47	86	10	2
48	86	11	3
49	88	10	2
50	88	10	2
51	86	11	3
52	88	10	2
53	88	9	3
54	86	10	4
55	86	10	4
56	85	11	4
57	86	12	2
58	86	12	2
59	86	11	3
60	87	10	3
61	78	12	10
62	72	18	12

SITE NO.	%SAND	%CLAY	%SILT
63	76	13	11
64	77	13	10
65	86	11	3
66	86	11	3
67	84	10	6
68	78	14	8
69	76	14	10
70	76	13	11

Table 10 SOIL TEXTURE RESULTS FOR SITES IN MODEL A

Soil texture results for samples in the finer textured soils, these are the plots whose percentage clay is 10% and above, these were taken from the set of results in table 9.

SITE NO.	% SAND	%CLAY	%SILT
1	86	11	3
5	86	11	3
6	88	11	1
11	86	12	2
13	86	12	2
15	85	10	5
16	88	11	1
21	86	10	4
22	88	10	2
23	86	11	3
24	88	10	2
25	88	10	2
26	86	11	3
27	86	12	2
33	85	10	5
34	88	10	2
35	85	11	4
40	86	10	2
41	88	11	1
49	88	10	2
50	88	10	4
51	86	11	3
61	78	12	10
63	76	13	11
67	84	10	6
70	76	13	11

Table 11 SOIL TEXTURE RESULTS FOR SITES IN MODEL B

Soil texture results also taken from table 3.4, these were the set of sites whose percentage clay was considered low, the percentage of clay here ranges from 7% to 11%.

SITE NO.	%SAND	%CLAY	%SILT
7	88	8	4
11	89	9	2
18	88	7	5
28	87	8	6
29	88	7	6
30	87	10	2
31	88	7	6
32	86	8	4
38	87	7	3
39	88	10	5
42	87	10	3
43	88	11	2
44	88	10	2
45	86	10	2
46	88	10	2
47	86	10	2
48	86	11	3
52	88	10	2
53	88	9	3
54	86	10	4
55	86	10	4
59	86	11	3
60	87	10	3
65	86	11	3
66	86	11	3

4.1 DETERMINATION OF CATIONS

CALCIUM

$$Y = 0,035x - 0,025$$

$$X = \frac{(Y + 0,025) \times 250 \times 50}{0,035 \times 5 \times 10}$$

Reading from AA = 0,028

Dilution factor = $\frac{250}{5}$

Volume of liquid = 50ml

Mass of soil = 10g

SAMPLE 1

$$\frac{(0,028 + 0,025) \times 250 \times 5}{0,035 \times 5 \times 10} = 1.51$$

= 379mg/Kg i.e 379mg of Calcium per Kilogram of soil.

MAGNESIUM

$$Y_{Mg} = 0,625x + 0,015$$

$$X_{Mg} = \frac{(Y - 0,015) \times 250 \times 50}{0,625 \times 5 \times 10}$$

$$= \frac{(0,298 - 0,015) \times 50 \times 5}{0,625}$$

$$= 0,44 \times 250$$

$$= 110\text{mg/Kg}$$

POTASSIUM

$$Y = 20x$$

$$\begin{aligned}
 X_{Na} &= \frac{Y}{20} \times 250 \times \frac{50}{10} \\
 &= \frac{45}{20} \times 250 \\
 &= 562,5 \text{ mg/Kg}
 \end{aligned}$$

SODIUM

$$Y_{Na} = 100x$$

$$\begin{aligned}
 X_{Na} &= \frac{Y}{100} \times 250 \times \frac{50}{10} \\
 &= \frac{4}{100} \times 250 \\
 &= 10 \text{ mg/Kg}
 \end{aligned}$$

4.2 CATION EXCHANGE CAPACITY

$$CEC = (T \times 20) - (X - X) \times 0,2 \quad T$$

$$X - X = 31,44 - 27,71$$

$$= 3,73$$

$$T = 3,3$$

$$T = 15,4$$

$$CEC = (3,3 \times 20) - 3,73 \times 0,2 \times 15,4$$

$$= 66 - 3,73$$

$$= 62,27 \times 0,2 \times 15,4$$

$$= 191,8$$

$$= 192 \text{ cmol/Kg} = 1,92 \text{ mol/Kg}$$

4.3 DETERMINATION OF ORGANIC CARBON CONTENT

$$\begin{aligned} \text{Concentration of Fe(NH}_4)_2(\text{SO}_4)_2 \text{ mol dm}^{-3} &= \frac{10 \text{ cm}^3 \text{ K}_2\text{Cr}_2\text{O}_7 \times 0.167 \times 6}{20 \text{ cm Fe(NH}_4)_2(\text{SO}_4)_2} \\ &= 0.501 \text{ mol dm}^{-3} \end{aligned}$$

Organic C =

$$\frac{(10 \text{ cm}^3 \text{ Fe(NH}_4)_2(\text{SO}_4)_2 \text{ blank} - 10 \text{ cm}^3 \text{ Fe(NH}_4)_2(\text{SO}_4)_2 \text{ sample}) \times M \times 0.3 \times f}{1.0 \text{ g}}$$

Where M = Concentration of the $\text{Fe(NH}_4)_2(\text{SO}_4)_2$ in mol dm^{-3}

f = recovery factor

1.0g = soil mass

SAMPLE 70

$$\frac{(20 \text{ cm}^3 - 14.6 \text{ cm}^3) \times 0.5 \times 0.3 \times 1.3}{1.0 \text{ g}}$$

= 1.053 % of C

Table 12 VALUES FOR CEC, Ca, Mg, K, AND Na FOR ALL 70 SITES

Results of Cation Exchange Capacity, determination of Calcium and Magnesium by using a high temperature flame which was obtained from an atomic absorption spectrophotometer. Also determination of Sodium and Potassium ions using atomic absorption spectrophotometer but with a low flame. This table contains all the results for all the plots, the soil samples used for these determinations were the same soil samples which were collected from the park in March 1998.

SITE NO.	CEC	Ca	Mg	K	Na
1	1.60	215	130	112	35
2	1.62	212,5	202,5	62,5	25
3	1.96	218	104	124	25
4	1.92	379	110	562,5	10
5	2.89	212,5	140	150	2,5
6	1.61	210	80	75	15
7	1.64	212,5	202,5	62,5	25
8	1.49	212,5	167,5	268,5	30
9	1.72	150	245,7	214,9	58
10	1.28	114	198	202	85
11	1.49	212,5	142,5	125	32,5
12	1.89	262,6	145,3	109,8	86,9
13	1.75	185,4	125,5	178	98
14	1.84	329	90	262,5	12,5
15	1.04	212,5	40	25	57,5
16	1.96	212,5	202,5	275	35
17	1.78	100	231,9	48	95
18	1.96	212,5	140	200	2,5
19	1.00	35	196	25	-
20	1.01	48	180	96	12
21	1.43	212,5	140	125	25
22	1.48	212,5	140,5	125	30,5
23	1.76	212,5	160	87,5	50
24	1.47	212,5	142,5	123	32,0
25	1.48	212,5	140	125	32,5
26	1.56	345	143,5	120	30

SITE NO.	CEC	Ca	Mg	K	Na
27	1.72	285	142,5	150	27,5
28	1.49	212,5	142,5	125	32,5
29	1.05	285	147,5	275	25
30	1.43	212,5	140	125	25,5
31	1.50	285	190	150	45
32	1.06	355	107,5	320	90
33	1.07	355	60	162,5	87,5
34	1,68	250	140	137,5	-
35	1.08	285	120	135,5	55,5
36	1.32	212,5	175	162,5	45
37	1.63	329	60	112,5	35,5
38	1.55	355	115	100	67,5
39	1.68	250	165	150	45
40	1.53	245	152	100,5	48
41	1.48	212,5	50	140	38
42	1.90	212,5	242,5	225	27,5
43	1.98	255	105	275	50
44	1.87	-	40	350	100
45	1.92	142,5	87,5	287,5	25
46	1.96	245	154	225	45
47	2.03	212,5	168	254	55
48	1.06	355	107,5	320	90
49	1.49	277,5	102,5	205	50
50	1.90	212,5	242,5	225	27,5
51	1.87	212,5	106	250	100
52	2.05	246	100	185	60
53	1.98	329	67,5	350	107
54	2.04	212,5	180	187,5	30
55	1.99	212,5	47,5	200	25
56	1.98	235	50,7	120	59
57	1.25	140,5	88	320	90
58	1.97	245	120	210	75
59	1.87	250	150	118	48
60	1.89	212,5	135	180	75
61	1.99	240	145	250	25

SITE NO.	CEC	Ca	Mg	K	Na
62	2.54	212,5	135	112,5	5
63	2.98	285	190	150	12
64	2.14	212,5	180	187,5	30
65	1.99	205	175	100	50
66	2,43	342	55	145,5	55
67	1.68	205	125	115,5	45
68	2.10	230,5	185	130	50
69	1.99	212,5	98,5	210	75
70	2.04	212,5	162	250	15

Table 13 VALUES FOR CEC, Ca, Mg, K AND Na FOR MODEL A

Soil results showing the amounts of the above mentioned ions in the samples which were grouped under Model A, these results below were also taken from the full set of the results in table 12, soil samples were all taken from the Botsalano Game Reserve in March 1998.

SITE NO.	CEC	Ca	Mg	K	Na
1	1.60	215	130	112	35
5	2.89	212,5	140	150	2,5
6	1.61	210	80	75	15
11	1.49	212,5	142,5	125	32,5
13	1.75	185,4	125,5	178	98
15	1.04	212,5	40	25	57,5
16	1.96	212,5	202,5	275	35
21	1.43	212,5	140	125	25
22	1.48	212,5	140,5	125	30,5
23	1.76	212,5	160	87,5	50
24	1.47	212,5	142,5	123	32,0
25	1.48	212,5	140	125	32,5
26	1.56	345	143,5	120	30
27	1.72	285	142,5	150	27,5
33	1.07	355	60	162,5	87,5
34	1.68	250	140	137,5	-
35	1.08	285	120	135,5	55,5
40	1.53	245	152	100,5	48
41	1.48	212,5	50	140	38
49	1.49	277,5	102,5	205	50
50	1.90	212,5	242,5	225	27,5
51	1.87	212,5	106	250	100
61	1.99	240	145	250	25
63	2.98	285	190	150	12
67	1.68	205	125	115,5	45
70	2.04	212,5	162	250	15

Table 14 VALUES FOR CEC, Ca, Mg, K AND Na FOR MODEL B

Soil results for the values of the above mentioned ions, the soil samples were also taken from the same game reserve in March 1998.

SITE NO.	CEC	Ca	Mg	K	Na
7	1,64	212,5	202,5	62,5	25
11	1,49	212,5	142,5	125	32,5
13	1,96	212,5	140	200	2,5
28	1,49	212,5	142,5	125	32,5
29	1,05	285	147,5	275	25
30	1,43	212,5	140	125	25,5
31	1,50	285	190	150	45
32	1,06	355	107,5	320	90
38	1,55	355	115	100	67,5
39	1,68	250	165	150	45
42	1,90	212,5	242,5	225	27,5
43	1,98	255	105	275	50
44	1,87	-	40	350	100
45	1,92	142,5	87,5	287,5	25
46	1,96	245	154	225	45
47	2,03	212,5	168	254	55
48	1,06	355	107,5	320	90
52	2,05	246	100	185	60
53	1,98	329	67,5	350	107
54	2,04	212,5	180	187,5	30
55	1,99	212,5	47,5	200	25
59	1,87	250	150	118	48
60	1,89	212,5	135	180	75
65	1,89	205	175	100	50
66	2,43	342	55	145,5	55

Table 15 VALUES FOR ORGANIC CARBON FOR ALL 70 SITES

Results of organic carbon percentage for the whole set, percentages were calculated after the titrations with iron (II) ammonium sulphate hexahydrate which reduces the dichromate used to treat the soil with sulphuric acid. The same soil samples were used to determine the amount of Carbon in all the samples.

SITE NO.	ORGANIC CARBON %
1	0,33
2	0,73
3	0,62
4	0,68
5	0,39
6	0,34
7	0,75
8	0,67
9	0,85
10	0,76
11	0,48
12	0,55
13	0,59
14	0,45
15	0,19
16	0,61
17	0,54
18	0,68
19	0,14
20	0.16
21	0,49
22	0,50
23	0,65
24	0,52
25	0,54
26	0,68
27	0,72

SITE NO.	ORGANIC CARBON %
28	0,18
29	0,19
30	0,58
31	0,14
32	0,16
33	0,15
34	0,42
35	0,18
36	0,53
37	0,55
38	0,62
39	0,69
40	0,49
41	0,48
42	0,71
43	0,85
44	0,84
45	0,83
46	0,88
47	0,92
48	0,32
49	0,42
50	0,40
51	0,44
52	0,95
53	1,06
54	0,98
55	0,99
56	0,98
57	0,21
58	0,99
59	1,02
60	0,97
61	0,80
62	0,87

SITE NO.	ORGANIC CARBON %
63	0,85
64	0,88
65	0,97
66	0,98
67	0,95
68	0,95
69	1,07
70	1,05

Table 16 VALUES FOR ORGANIC CARBON FOR SITES IN MODEL A

Soil results for the amount of organic carbon in the sites which were found to have more percentage of clay, and which were classified as Model A, these results have been taken from table 15 which contains results for the whole data set.

SITE NO.	ORGANIC CARBON %
1	0,33
5	0,39
6	0,34
11	0,48
13	0,59
15	0,19
16	0,61
21	0,49
22	0,50
23	0,65
24	0,52
25	0,54
26	0,68
27	0,72
33	0,15
34	0,42
35	0,18
40	0,49
41	0,48
49	0,42
50	0,40
51	0,44
61	0,80
63	0,85
67	0,95
70	1,05

Table 17 VALUES FOR ORGANIC CARBON FOR SITES IN MODEL B

Soil results for the percentages of organic carbon in the soil samples which constituted Model B. The results were also taken from the results in table 15. All these soil samples were collected from Botsalano Game Reserve in March 1998.

SITE NO.	ORGANIC CARBON %
7	0,75
11	0,48
18	0,68
28	0,18
29	0,17
30	0,58
31	0,14
32	0,16
38	0,62
39	0,69
42	0,71
43	0,85
44	0,84
45	0,83
46	0,88
47	0,92
48	0,32
52	0,95
53	1,06
54	0,98
55	0,99
59	1,02
60	0,97
65	0,97
66	0,89

* 2 : DECORANA Dca

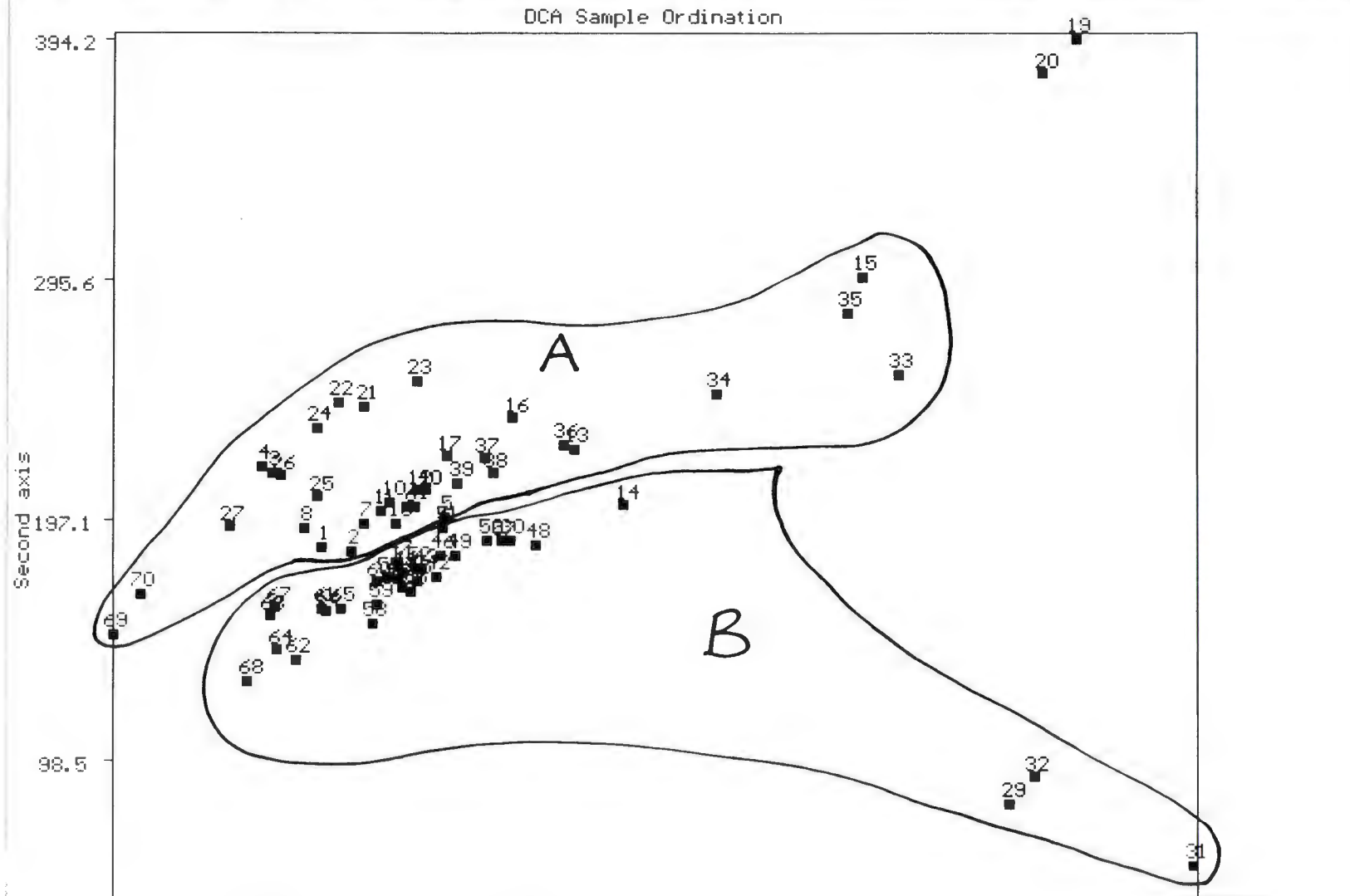
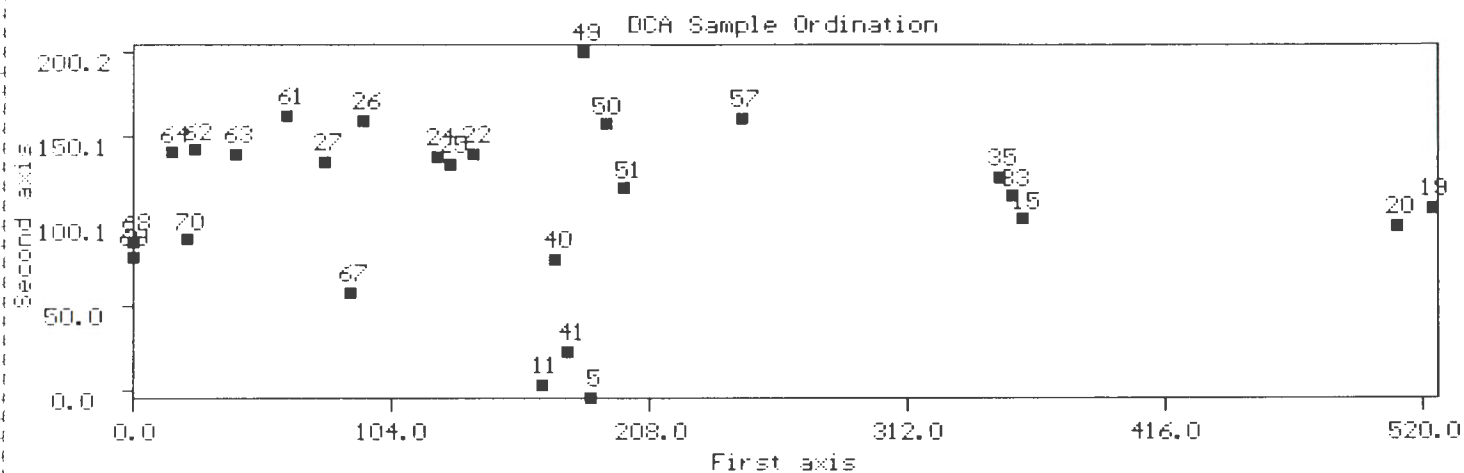


Fig. 7 Distribution of the sample plots in the total data set for all the 70 sites. Vegetation composition results were used for these ordinations. The data was grouped into group A and B as shown and the two groups ordinated separately using DMOC ordination. The X axis cut automatically when this ordination is printed.

* 14 : DECORANA Dca



4

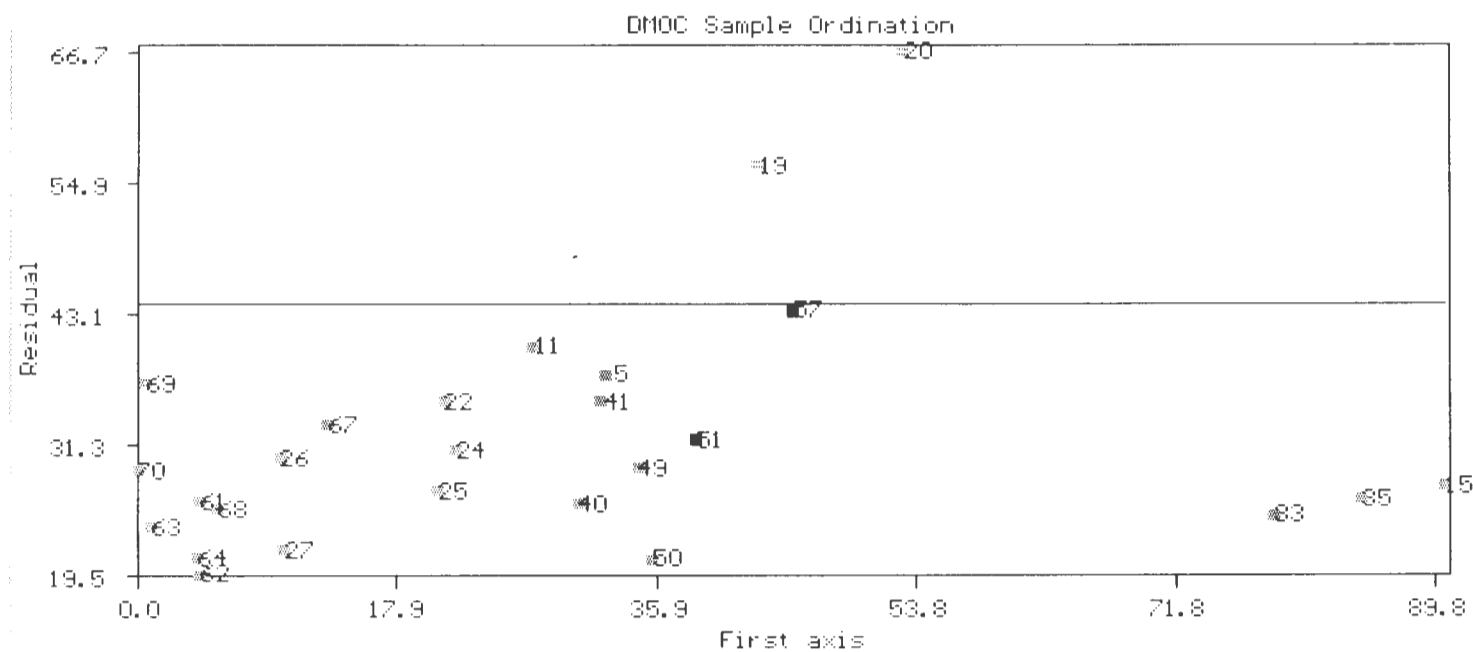
26

0.0

yes

Fig.8 DCA ordination for model A. Position of sample plots on sites with more clay soils, plant species were used to compile data for this ordination, the above results were obtained after the removal of outliers.

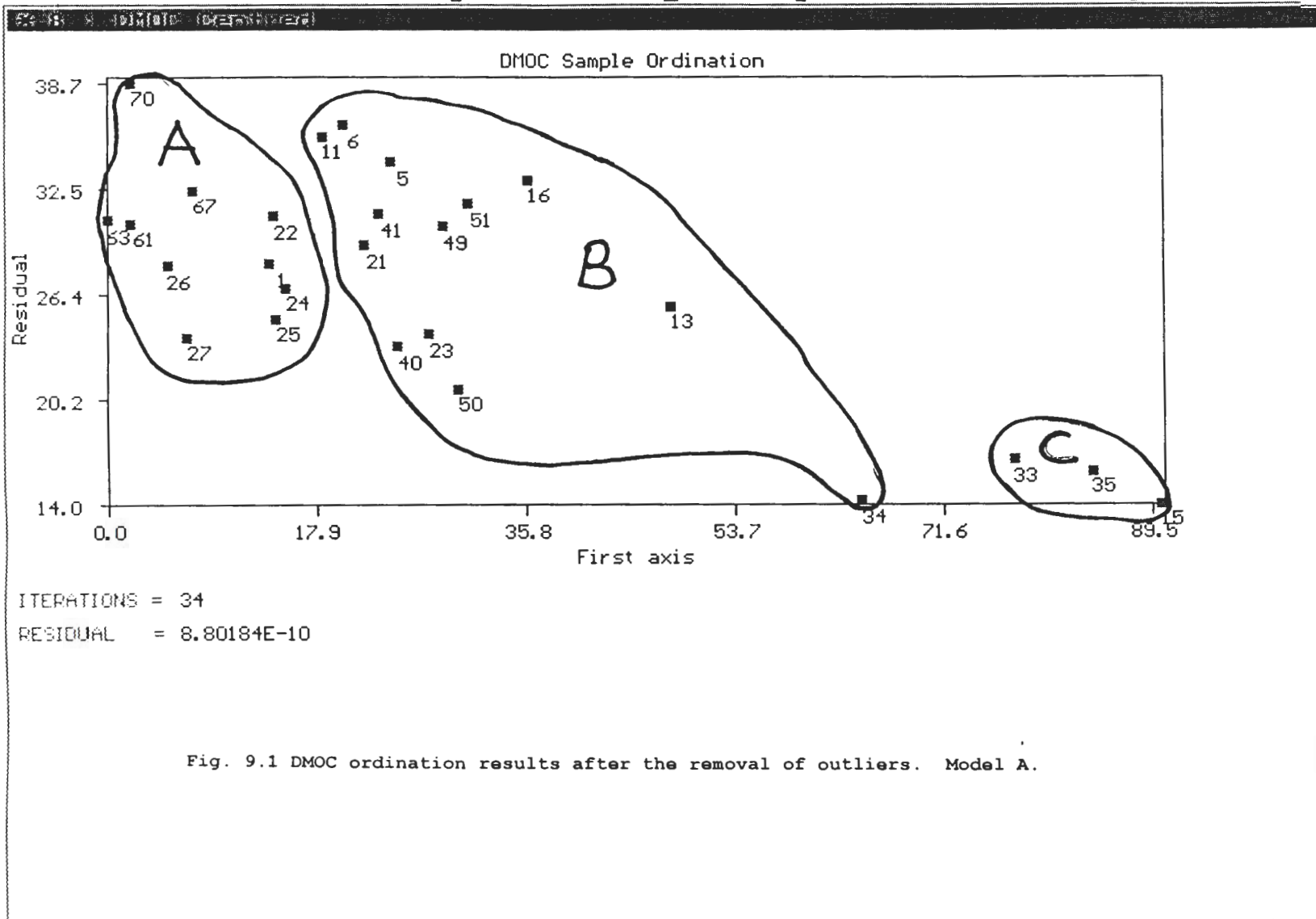
* 18 : DMOC Centred



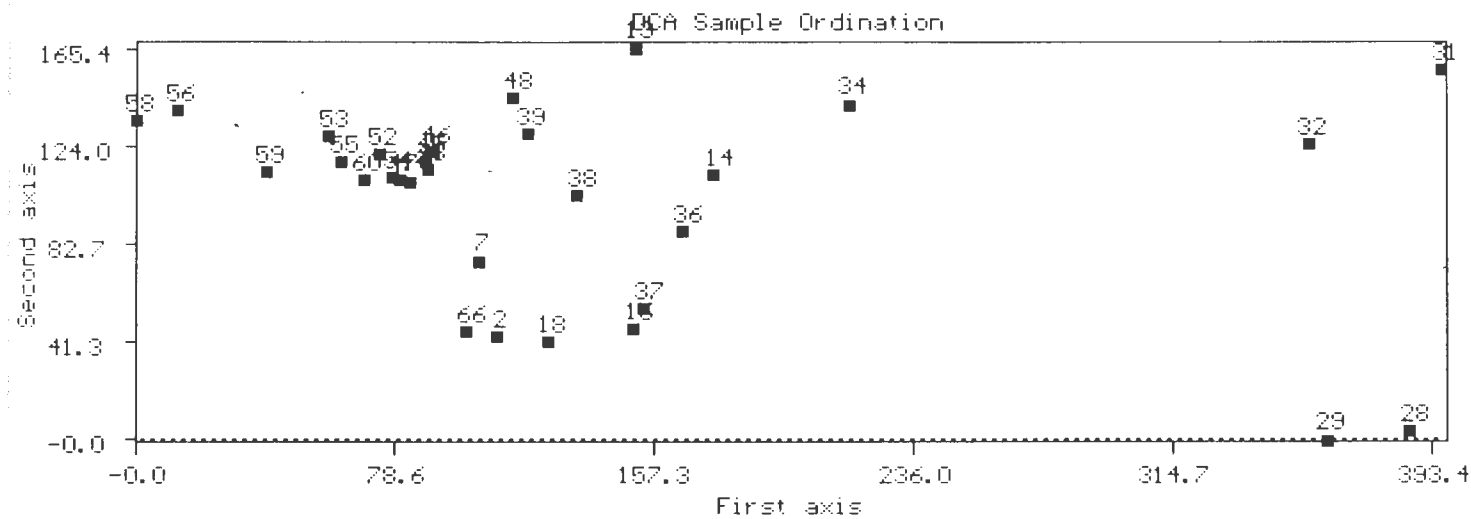
19.5 32

5.97977E-10

Fig. 9 PCA ordination for model A.



* 16 : DECORANA Dca



Number of species in the first 10% of sites: **4**

Number of species in the first 20% of sites: **26**

Number of species in the first 30% of sites: **0.0**

Is the first 10% of sites a good representation of the whole? **yes**

Fig. 10 DCA ordination for model B, the sample plots on the sites with less percentage of clay. All the data on plant species were also collected from Botsalano Game Reserve in March 1998.

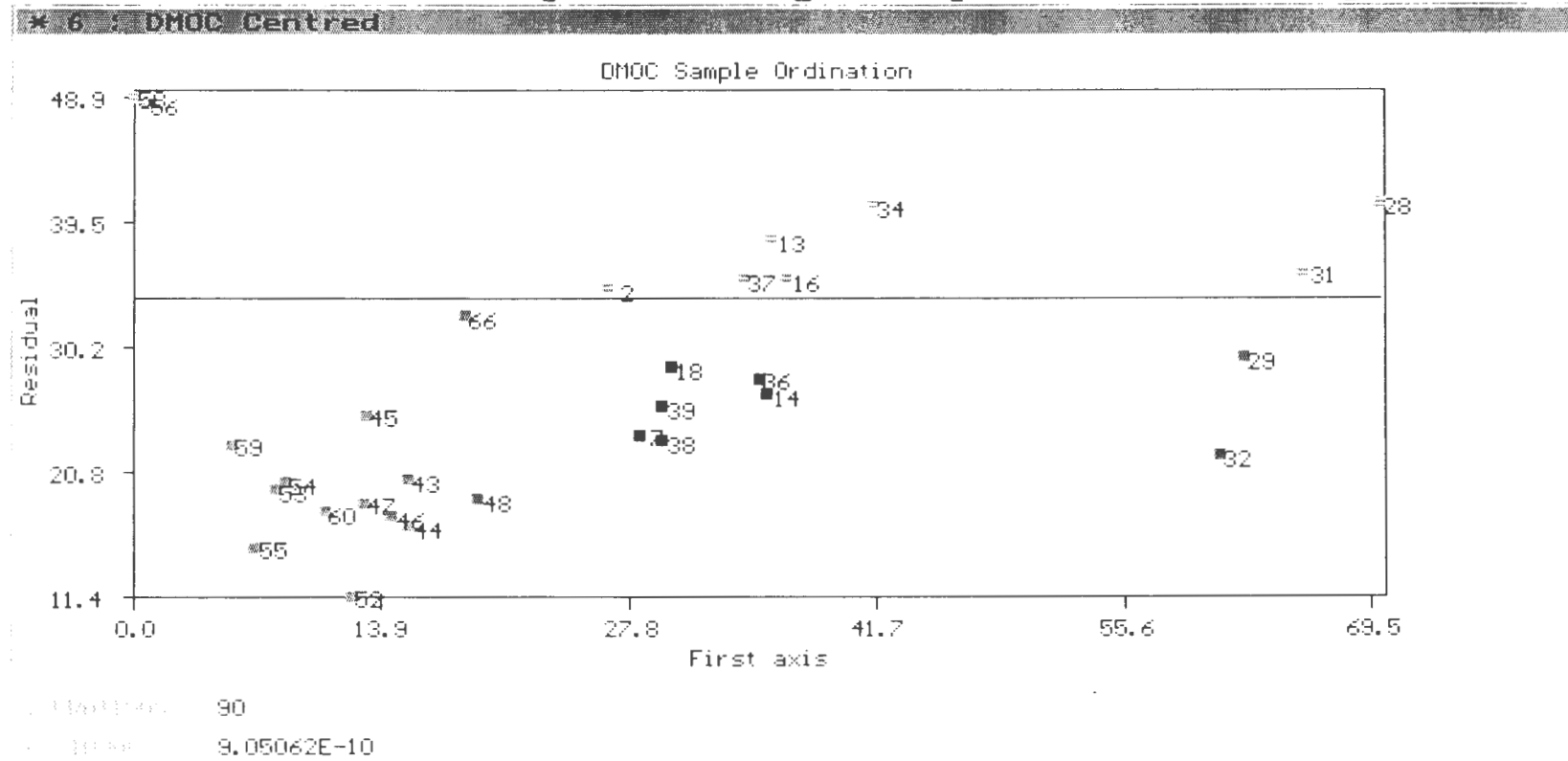


Fig. 11 PCA ordination for model B

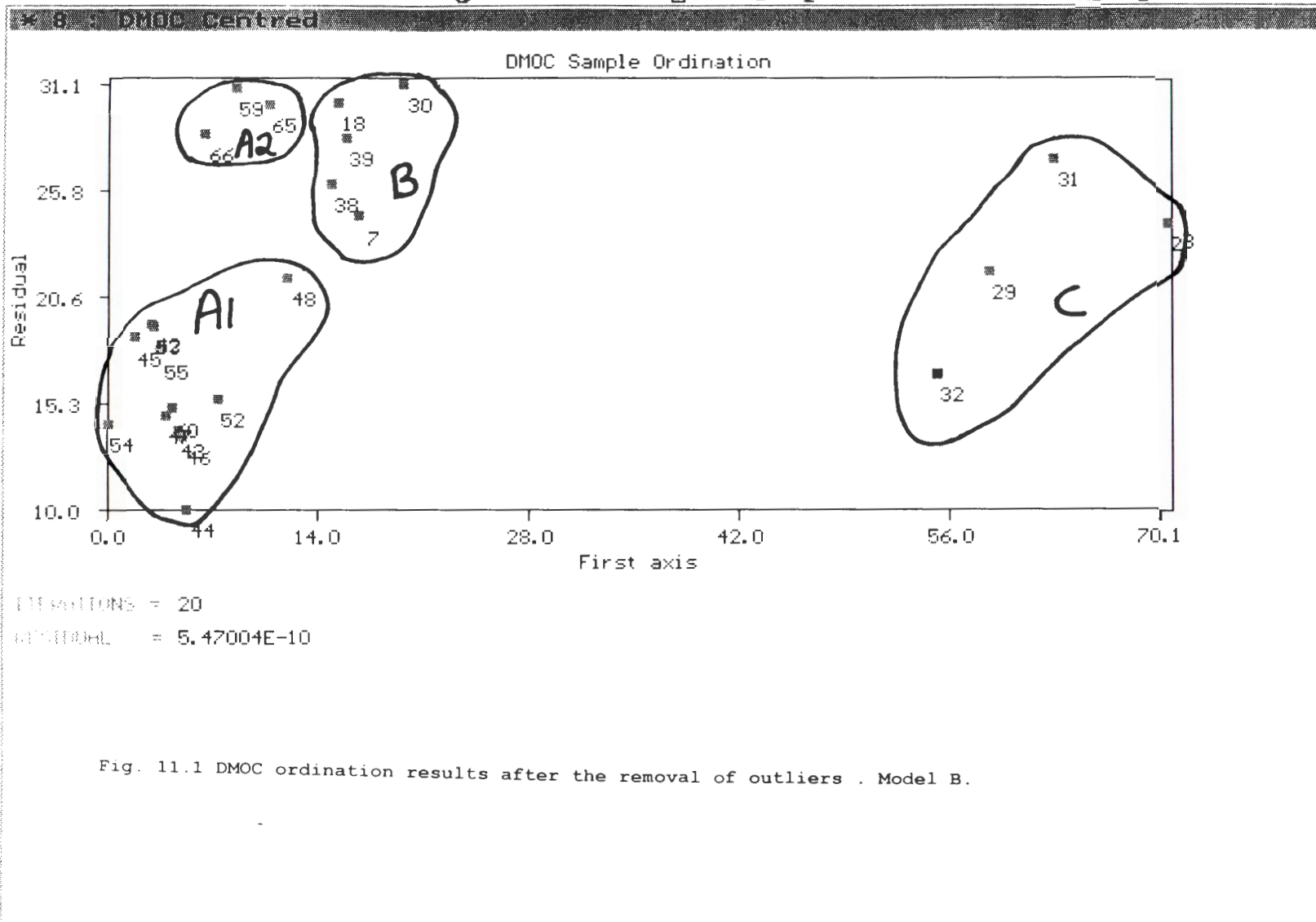


Fig. 11.1 DMOC ordination results after the removal of outliers . Model B.

CHAPTER FIVE

INTERPRETATION OF RESULTS

5. 1 INTRODUCTION TO INTERPRETATION OF RESULTS

In this study ordinations were carried out for the purposes of developing degradation models for the Botsalano game park. The first major data set which consisted of all 70 sites that were sampled in the field were ordinated using detrended correspondence analysis (DCA) (Hill & Gauch : 1980) which is suitable for data sets with relatively long gradients (Gauch : 1991). The data consisted of lists of species present and their abundance, but due to the "noise" in the results, the researcher found it necessary to split the data set. This was basically because the sites seemed to form clusters as indicated in fig.7 separated into A and B). The two axes of this ordination only appear well on the computer but when printing the first axis automatically cut off. It was not known for sure which factor might have contributed to this clustering hence the decision to split the data set into two sets. The two sets were then ordinated again separately using both DCA and DMOC for getting the models in fig.9.1 and fig.11.1. The ordinations are only accepted if the residual or second axis is 50% of the first axis which was the case in both ordinations (Bosch & Gauch: 1991). A high residual may indicate the existence of a fairly strong influencing factor other than the one reflected in the first axis.

Since the sites were deliberately selected to represent differences caused by grazing, all other factors that might affect the results such as soil moisture, soil colour and texture were kept constant during the field work. Habitat variations occur within a particular rainfall zone and this can therefore lead to large variations or noise in the data set (Austin et. al.:1981; Gauch :1982) which make identification of a reliable degradation gradient impossible. It was therefore very important to conduct soil analyses on some of these soil characteristics for verification that the only difference between sites would be in the level of utilization and not the soil character and also for verification of similarities and differences between the sites. The results then showed that the soil colour did not differ much, most soils were reddish soils. The organic matter content and cation exchange capacities were also tested. Among all these, the texture appeared to be the one that might have contributed to the instability of the results. One set contained relatively higher percentages of clay referred to as Model A, where the average clay percentage of these sites was 11.5% (range 10 - 18). The other set contained relatively lower percentages of clay, called Model B, where the average clay percentage of the sites in this model was 7.8% (range 7 - 13) . Each of these vegetation data sets were then ordinated, results can be seen in chapter four (fig. 9.1 and fig. 11.1).

When comparing the cation exchange capacity of the sites in Model A and B, one finds that the range does not differ much. In model A the cation exchange capacity (CEC) range is from 1.00 mol/kg to 1.98 mol/kg, and for model B, it is 1.05 mol/kg to 2.43 mol/kg. This difference is very small, therefore CEC could not be used to check the differences between the models. The mean values for the CEC of the two models were 1.70 mol/kg and 1.75 mol/kg respectively which show a difference of 0.05 which is quite small.

The mean organic carbon content of the two models was also calculated. It was found to be 0.54% of carbon for model A and 0.68% for model B. Only a difference of 0.14% which is regarded a small figure. The range of percentage of organic carbon range from 0.15% to 1.05% for model A and 0.14% to 1.06% for model B. The percentage carbon also does not reflect a great difference between the models.

The texture of the two models were compared with regard to percentage clay and percentage sand, it was found that percentage sand ranges from 76% to 88% for model A and from 86% to 89% for model B. The mean values for percentage of sand were found to be 83% for model A and 86% for model B showing a 3% difference in the mean percentage. The results for percentage clay ranges from 10% to 13% for model A and from 7% to 11% for model B. There is an overlap of figures in the percentages, this is because the sites were only selected according to the ordination results

hence the clay percentages could not be changed. The same overlap can also be expected in all other results. The mean values for percentage of clay were 12% for model A and 10% for model B.

Table 18 PERCENTAGES OF SAND IN MODEL A

This table shows the groups of classes for percentage of sand in model A. The classes are indicated as letters and the frequency for each class is also shown.

CLASSES (%)	FREQUENCY
76 - 78 A	3
79 - 81 B	0
82 - 84 C	1
85 - 87 D	13
88 - 90 E	9

Fig. 12 shows a pie chart for the % sand in model A. The inference that one can deduce from this figure is that model A had more sites falling in class D, these make 50% of the records, 32,62% of the sites fall in class E, 11,54% in class A and 3,85% in class C and no site in class B.

PERCENTAGES OF SAND IN MODEL A



Fig. 12 Pie chart showing percentages of sand in Model A

Table 19 PERCENTAGE OF SAND IN MODEL B

This table shows groups of classes for percentage of sand in model B.

CLASSES		FREQUENCY
86	A	9
87	B	5
88	C	9
89	D	1

Fig. 13 which is a pie chart for percentages of sand in model B show that this model had equal percentages of 37,50% for classes A and C while class B had 20,83% and the lowest was class D with only 4.17%.

PERCENTAGES IF SAND IN MODEL B

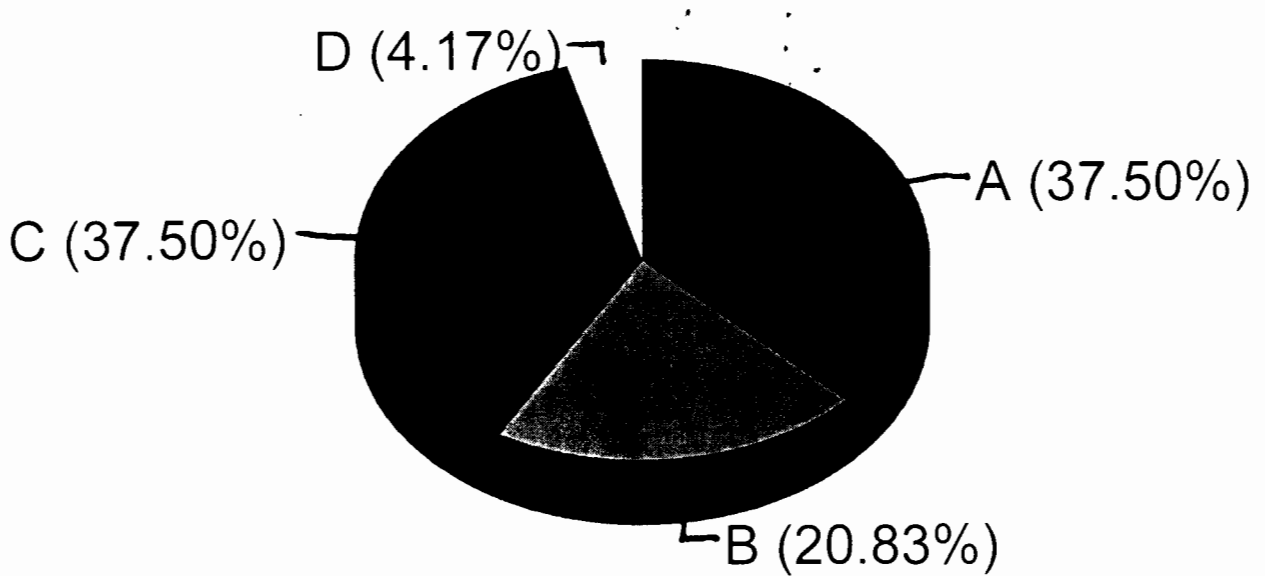


Fig. 13 Pie chart showing percentages of sand in Model B

Table 20 PERCENTAGES OF CLAY IN MODEL A

This table shows classes and frequencies for the percentage of clay in Model A. Classes are indicated as letters.

CLASSES	(%)	FREQUENCY
10	A	11
11	B	9
12	C	4
13	D	2

Fig. 14 shows a pie chart for the percentage of clay in Model A. This shows that more sites in model A had 10% clay these made 42,31% of the whole set. 34,62% of the sites were in class B, 15,38% in class C and finally only 7,69% in class D.

PERCENTAGES OF CLAY IN MODEL A

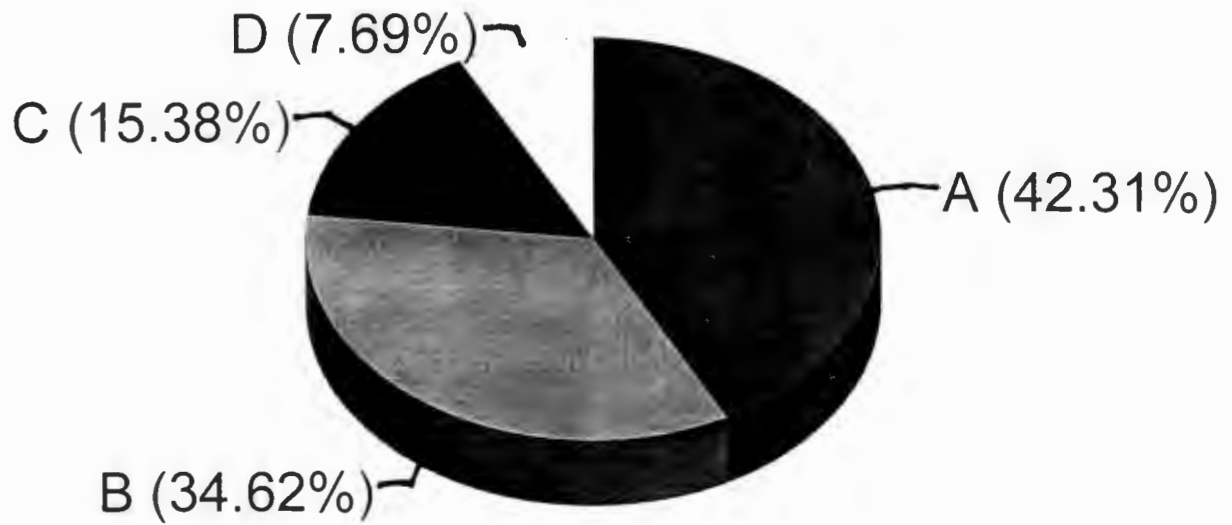


Fig. 14 Pie chart showing percentages of clay in Model A

Table 21 PERCENTAGES OF CLAY IN MODEL B

This table shows the classes and frequencies for percentage of clay in model B.

CLASSES (%)		FREQUENCY
7	A	4
8	B	3
9	C	2
10	D	11
11	E	4

Fig. 15 which is the pie chart for the percentages of clay in model B show that 45,83% of the sites fell in class D, that was followed by equal percentages for both classes A and E of 16,67%, 12,50% in class B and only 8,33% in class C.

These results were thus used to verify the ordination results that to some extent there is some difference in the two models. After obtaining the ordination results it was then important to verify the acceptability of the axes. After removal of sites which did not fit well in the data (outliers) the residuals for both the models went down below 50% of the first axis which was one property of the ordination results.

PERCENTAGES OF CLAY IN MODEL B

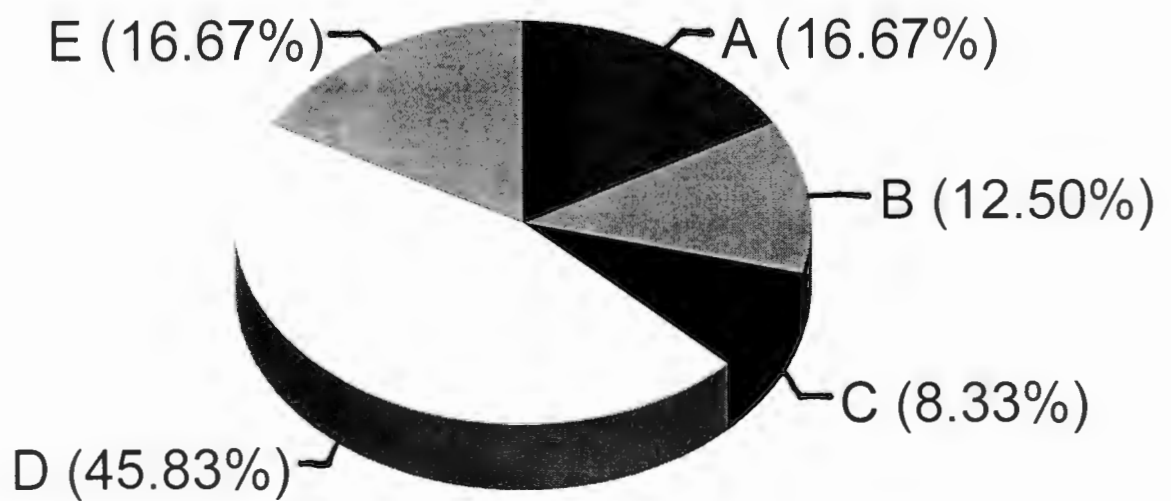


Fig. 15 Pie chart showing percentage of clay in Model B

5.1.1 MODEL A

This is a set of sites with more clay probably representing the heavier soils in the area, the average percentage clay content is 11.5%. On this model 26 surveys were plotted on a graph for degradation after initial ordination and splitting of data. The first axis of the graph represents degradation level. The results show that sites very close to the represent less utilised sites, these are shown as group A in fig.9.1. The moderately utilised sites are in group B in the same figure and going to the far right are the highly over utilised sites, the group C sites as indicated on the model (fig. 9.1)

If one compares the positions of site 63 and site 15, they are both at the extreme ends of the model. One can therefore deduce from this, that the two sites are highly different. This can therefore be confirmed by comparing all other factors like position relative to known land marks, soil characteristics and species composition. Site 63 was taken on a less utilised area of the park, in a relatively good condition. This was one of the sites with high biomass yield of 277.12g of dry weight per square metre, the colour of the soil was dusky red. Soil colour is the most obvious and easily determined character of the soil. Although it has little direct influence on the functioning of the soil, one may infer a great deal about soil from its colour, if it is considered with other observable features. The significance of soil colour is almost entirely an indirect

measure of other more important characteristics or qualities that are not so easily and accurately observed.

The clay content percentage of site 63 was found to be above the average percentage of the set and this was 13%. Texture in this case also plays an important role because soil particle size determines the amount of available surface area for adsorption of water and nutrients. In addition it influences the amount and size of individual pores which for the most part determine the rate and amount of air and water movement through soils.

The cation exchange capacity which is a temporary storehouse for large quantities of available nutrients such as calcium, magnesium and potassium that are partially protected from leaching yet are available for plant consumption was determined. The CEC amount for site 63 was 2.98mol per kilogram of the soil, calcium was 285mg per kilogram, magnesium was 190mg/kg, potassium was 150mg/kg and sodium was 12mg/kg. The organic carbon content of site 63 was also determined and found to be 0.85% of carbon. It could be noted from table 16 that this percentage is very high as compared to the percentages in the rest of the model. The species composition of site 63 consisted of 43,33% abundance of *Heteropogon contortus*, 10% of *Themeda triandra*, 12% of *Diheteropogon amplexus* and 11,33% of *Aristida congesta*. In this study these species tend to decrease in abundance if the level of utilization increases, they are therefore found in abundance in site 63.

Looking at site 15 which is found at the extreme right of the model. This site was taken in an area very close to the watering point. The vegetation of the site looked poor by judgement of the eye, the plants that were found there, were also very small in size. They appeared to be species that were recovering from heavy overgrazing and over trampling by animals. This is highly probable when one considers the position of the site, so close to the dam. This was the site that represented a typical over-utilised area. The biomass yield of site 15 tended to be the smallest in the model, the amount was 60,96g of dry weight per square metre. The colour of the soil in this site was reddish brown, as mentioned earlier, colour is one of the most useful and important characteristics for soil identification, especially when looked at in conjunction with the soil structure.

The percentage clay content of site 15 was determined and found to be 10% which is lower than the average percentage of the set. The cation exchange capacity of site 15 was 1.04mol per kilogram of soil, calcium was 212,5mg/kg of the soil, magnesium was 40mg/kg, Potassium was 25mg/kg and sodium was 57,5mg/kg. The organic carbon content of site 15 was found to be 0.19% of carbon. The species composition of site 15 consisted of 78,67% of *Eragrostis trichophora* and 6,67% of *Aristida congesta barbicollis* and the rest of the sites were recorded as bare.

On the basis of the comparison of these two sites in the model, one cannot hesitate to see the differences displayed in the two sites. One can therefore look at this model as being representative of the degradation trends in the park.

Site 13 which is positioned towards the centre in the model appears to represent moderately utilised sites. This was an open grassland of the park, where animals could only be seen passing the area but not staying for long periods of grazing. The biomass yield of site 13 was 202,56g dry weight per square metre which is less than that of site 63 but more than that of site 15. The colour of the soil was also reddish brown. Majority of sites in this study had reddish soils, which was mainly because during the field work the colour was kept almost constant even though it was just by the look of the eye. The colour of the soils would not vary. The only thing that had to differ for the sites was the level of degradation.

The red colour of soils is generally related to unhydrated iron oxide, although manganese dioxide and partially hydrated iron oxides may also contribute red colours. Since unhydrated iron oxide is relatively unstable under moist conditions, red colour usually indicates good drainage and aeration. Strongly red soils are expected on convex surfaces underlain by pervious rocks. Many red soils owe their colour to inheritance from the parent material and not to soil-forming processes, since the redness in some rocks may persist for centuries even under moist conditions.

Sites 61, 63, 67, and 70 (fig. 9.1) are found very close to the second axis. These are the sites which were close to the buildings, therefore less utilised (group A). They had high biomass yield ranging from 232g/m² to 277 g/m².

Species abundance curves and regression analysis curves were fitted for those species which were outstanding for most sites, for less degraded sites, moderately degraded and severely degraded sites for both models. However it was also found that same species appear on different conditions for the two models.

The indicator species curves have been designed to show the degradation gradient on the x-axis taken from the ordination graphs and the second axis (y) shows the species abundances, the regression analysis curve is also fitted in the same graph.

Fig. 16 shows the curve for *Heteropogon contortus*, the high abundance of this species in less degraded sites which are the sites closer to the second axis and it decreases as the level of utilisation increases, thus for sites moving away from the second axis. The statistics for this species is 0.681 and its correlation coefficient is 0.325.

The organic carbon percentages were 0.80%, 0.85%, 0.95%, 0.95%, and 1.05% which were considered high values as compared to the percentages of other sites in the model which are below 0.80%.

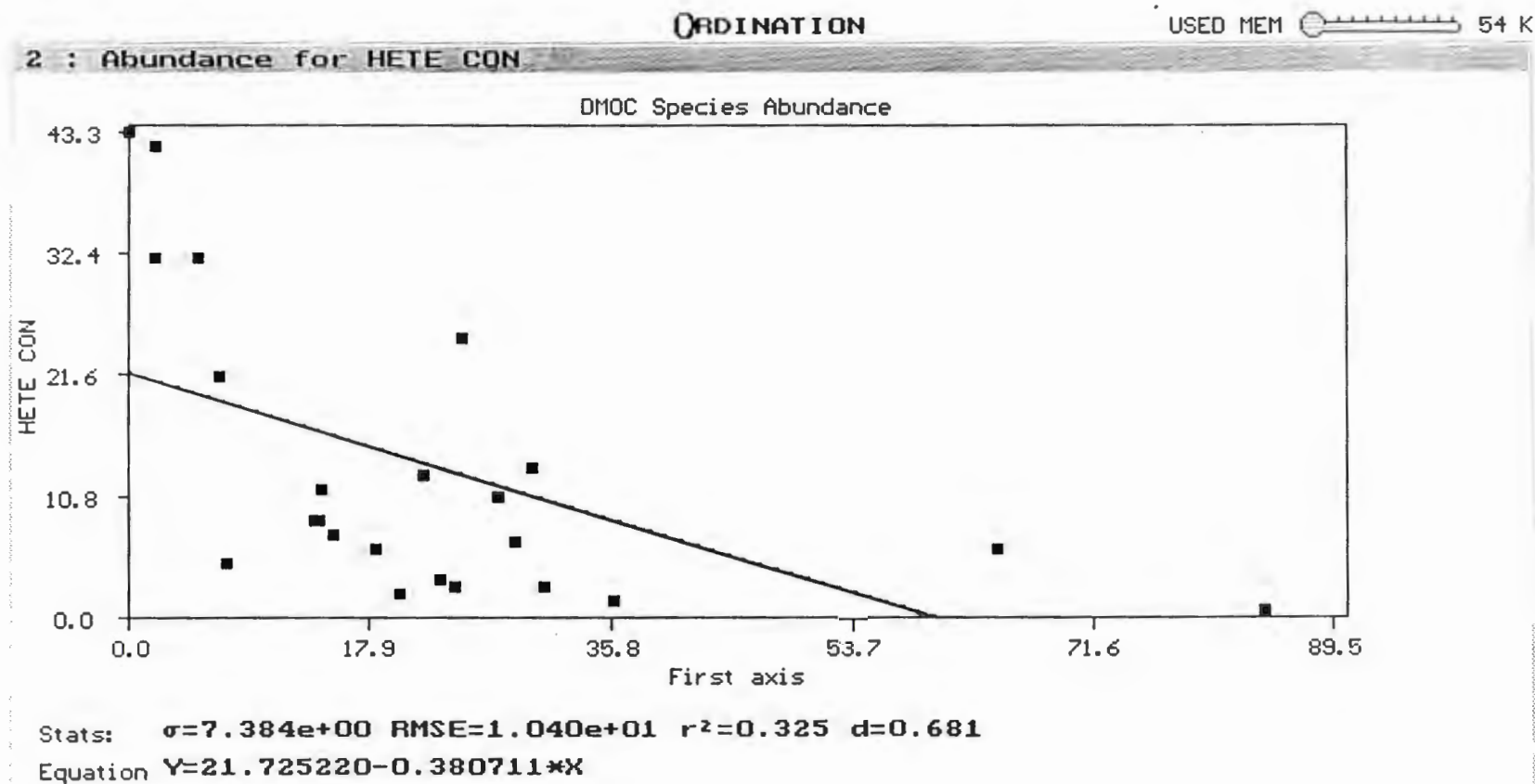
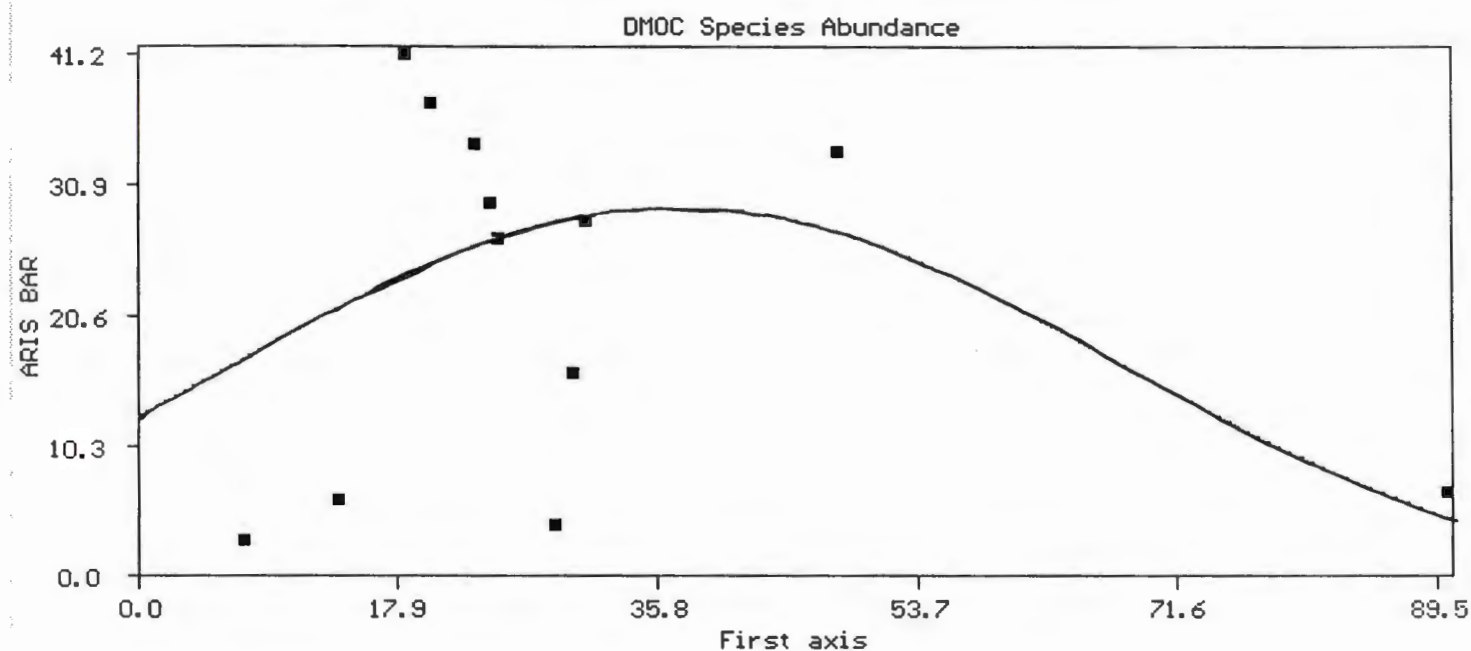


Fig. 16 Species abundance and regression analysis curve for *Heteropogon contortus* for Model A

Another set of sites which represent less utilised sites is that of sites 22, 24, 25, 26 and 27 (group A fig. 9.1) which were around a place where there used to be old kraals. Animals do not seem to like this place as it is full of stones and few grass species. The dominant species also include *Heteropogon contortus*, *Melinis repens*, and *Aristida diffusa*. Organic carbon percentage for these sites range from 0.5 to 0.72 %. The biomass yield for these sites is also more than 200g of dry weight per square metre. Site 5, 11, 40 and 41 are found almost towards the centre of the model. These are representatives of moderately utilised sites, and were a bit farther from the watering point (group B fig. 9.1). The dominant species here include *Aristida barbicollis* and *Aristida congesta*. The organic carbon percentage range between 0.39 to 0.49, which represents a middle range in this array of sites. Sites 49, 50, 51 and 16 were also in an open grassland in the park. There was no evidence of any environmental or artificial features which could cause animals to frequent that area. It was just an open area with a minimum number of small trees and shrubs. These were also taken to represent a moderately utilized area of the park. These sample sites are in block 3 and 4 of the park which are far from all animal attractions.

The curve in fig.17 shows a curve which starts with minimum abundance at the less utilised sites and increases to maximum at the moderately degraded sites which are found towards the middle of the graph. The abundance then decreases as the condition changes to severe degradation. The species abundance curve of

2 : Abundance for ARIS BAR



Stats: $\sigma=6.367e+00$ RMSE=1.191e+01 $r^2=0.232$ d=0.589

Equation $Y=29.439588*\exp(-(X-41.137873)^2/(2*28.213186^2))$

Fig. 17 Species abundance and regression analysis curve for *Aristida barbicollis* for Model A

Aristida congesta barbicollis suggests that it is an indicator of medium degradation in the study area. The statistics for this species is 0.539 and the correlation coefficient is 0.232.

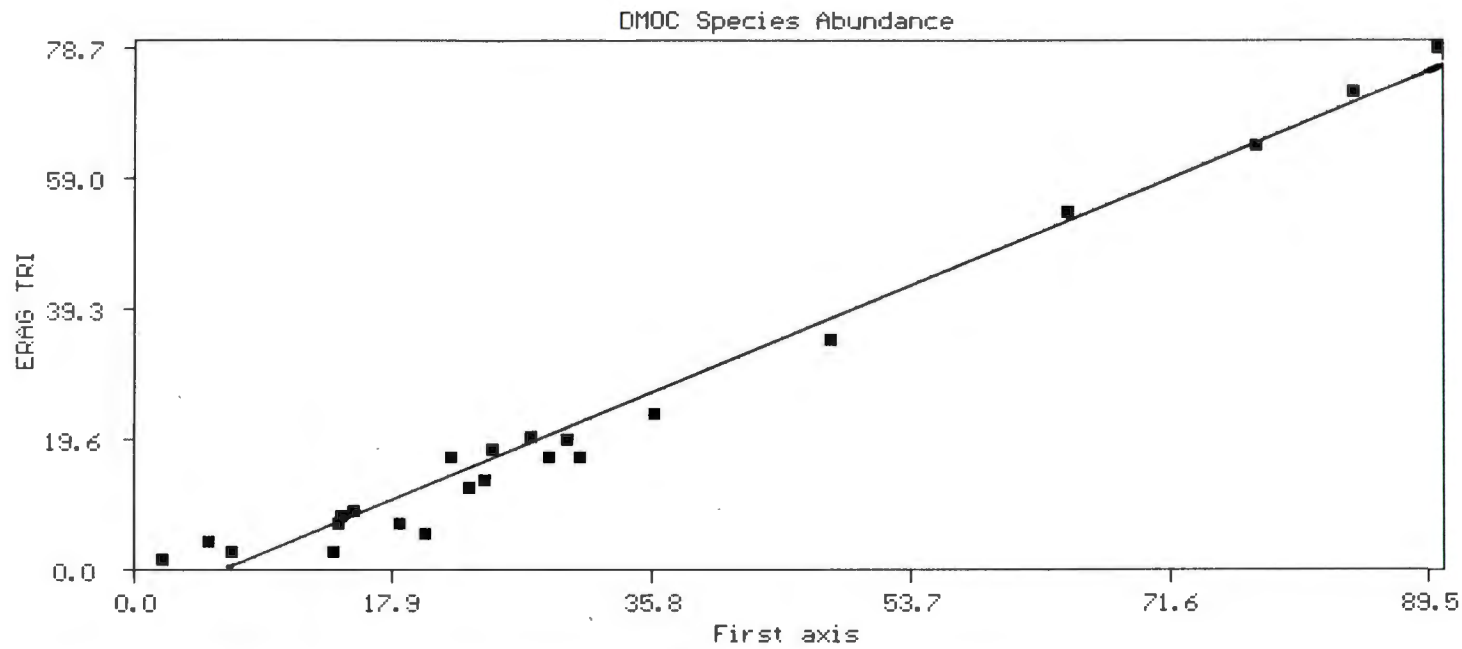
Fig. 18 shows an abundance and regression analysis curve for *Eragrostis trichophora* which appears to have a linear curve, this species clearly indicates its low presence in less degraded sites which then increases steadily as the level of degradation increases and reaches maximum at the severely degraded sites. The statistics for this species is 0.994 and the correlation coefficient is 0.997.

Fig. 19 shows the curve for *Themeda triandra* which increases with the low degradation level and decreases down to zero as the degradation increases. Its statistics is 0.497 and the correlation coefficient is 0.441.

Fig. 20 shows a curve for *Melinis repens* which is also found in abundance at the less utilised sites and decreases as the level of utility increases. Statistics is 0.381 and the correlation coefficient is 0.029.

Fig. 21 a curve for *Andropogon eucomus* which has a similar appearance to that of *Aristida congesta barbicollis* which starts with minimum abundance at less degraded sites and increases at the moderate utilization and decreases again as the level of utilization increases. Statistics is 0.831 and the correlation coefficient is 0.559.

2 : Abundance for ERAG TRI

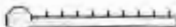


Stats: $\sigma=2.256e+01$ RMSE=3.407e+00 $r^2=0.977$ d=0.994

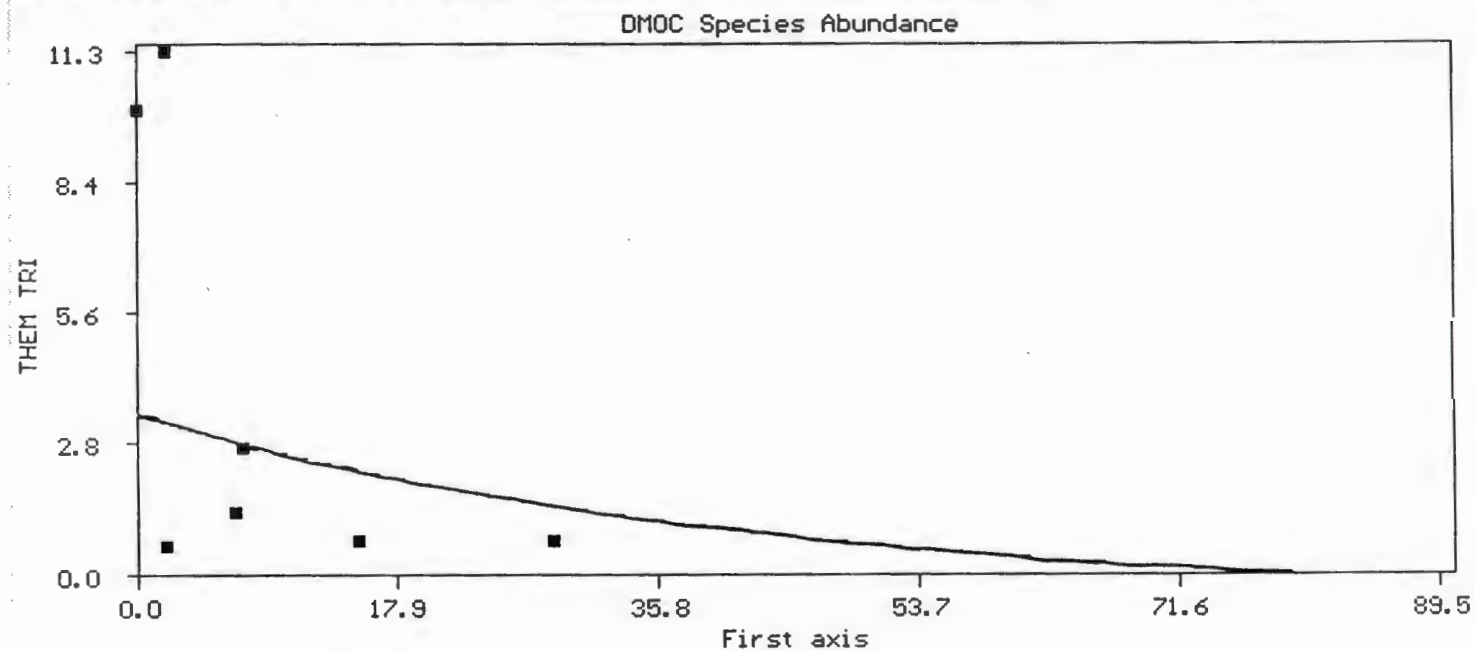
Equation $Y=-6.074133+0.904700*X$

Fig. 18 Species abundance and regression analysis curve for *Eragrostis trichophora* for Model A

ORDINATION

USED MEM  72 K

2 : Abundance for THEM TRI

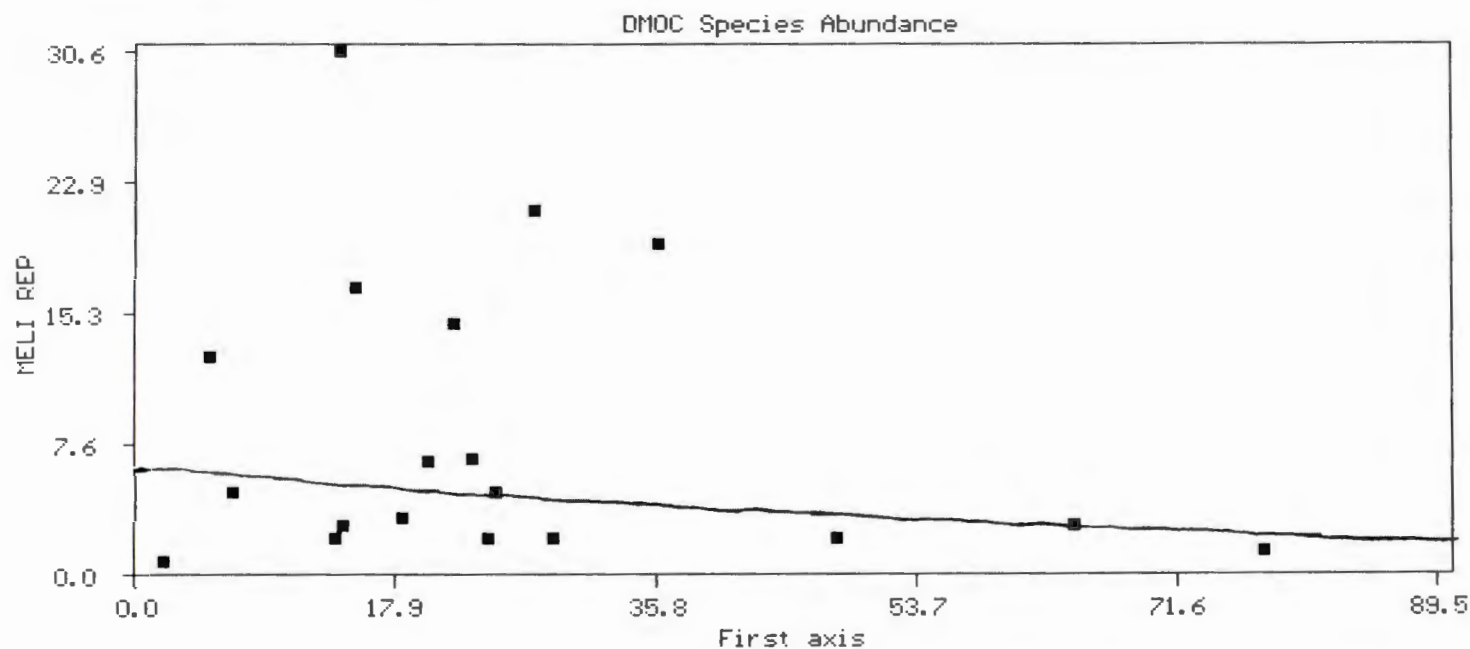
Stats: $\sigma=1.190e+00$ RMSE=4.006e+00 $r^2=0.441$ d=0.497Equation $Y=3.781318*\exp(-0.073298*X)$ Fig. 19 Species abundance and regression analysis curve for *Themeda triandra* for Model

A

ORDINATION

USED MEM  72 K

2 : Abundance for MELI REP

Stats: $\sigma=1.106e+00$ RMSE=8.765e+00 $r^2=0.029$ d=0.381Equation $Y=6.895608*\exp(-0.013326*X)$ Fig. 20 Species abundance and regression analysis curve for *Melinis repens* for Model

A

ORDINATION

USED MEM  72 K

2 : Abundance for ANDR EUC

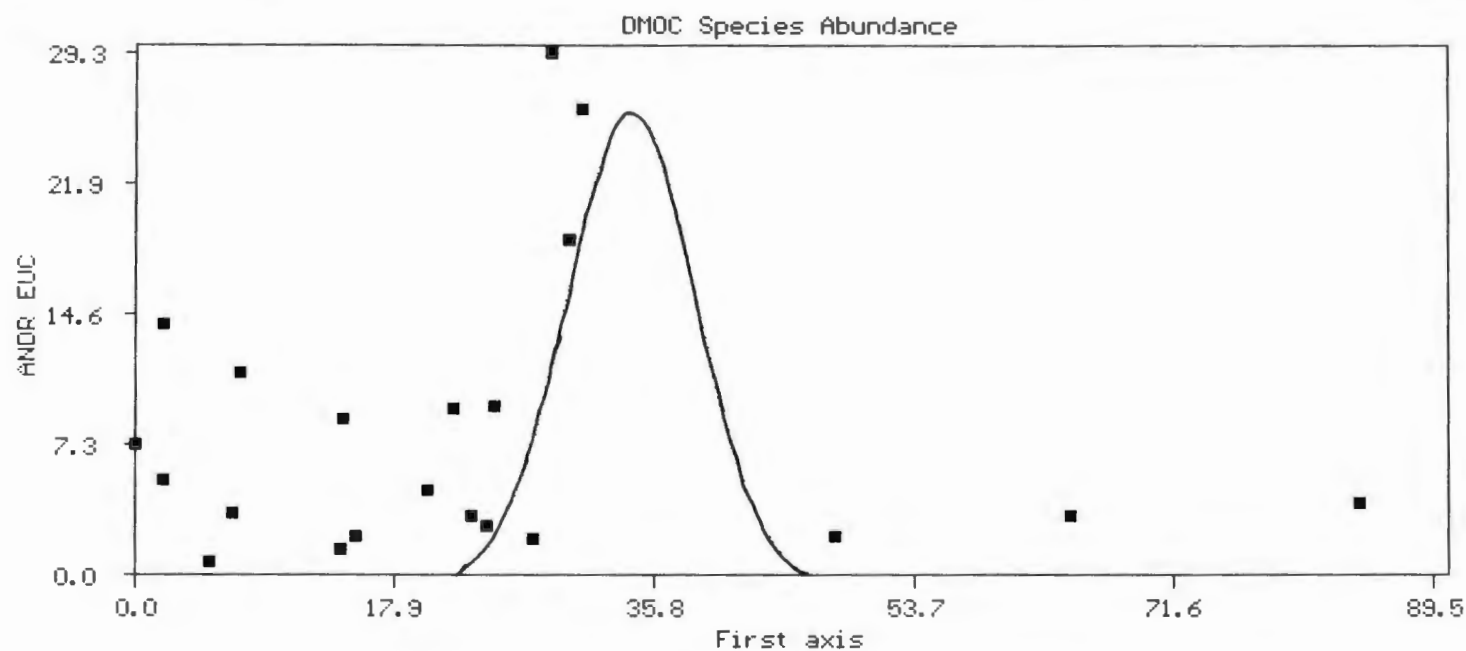
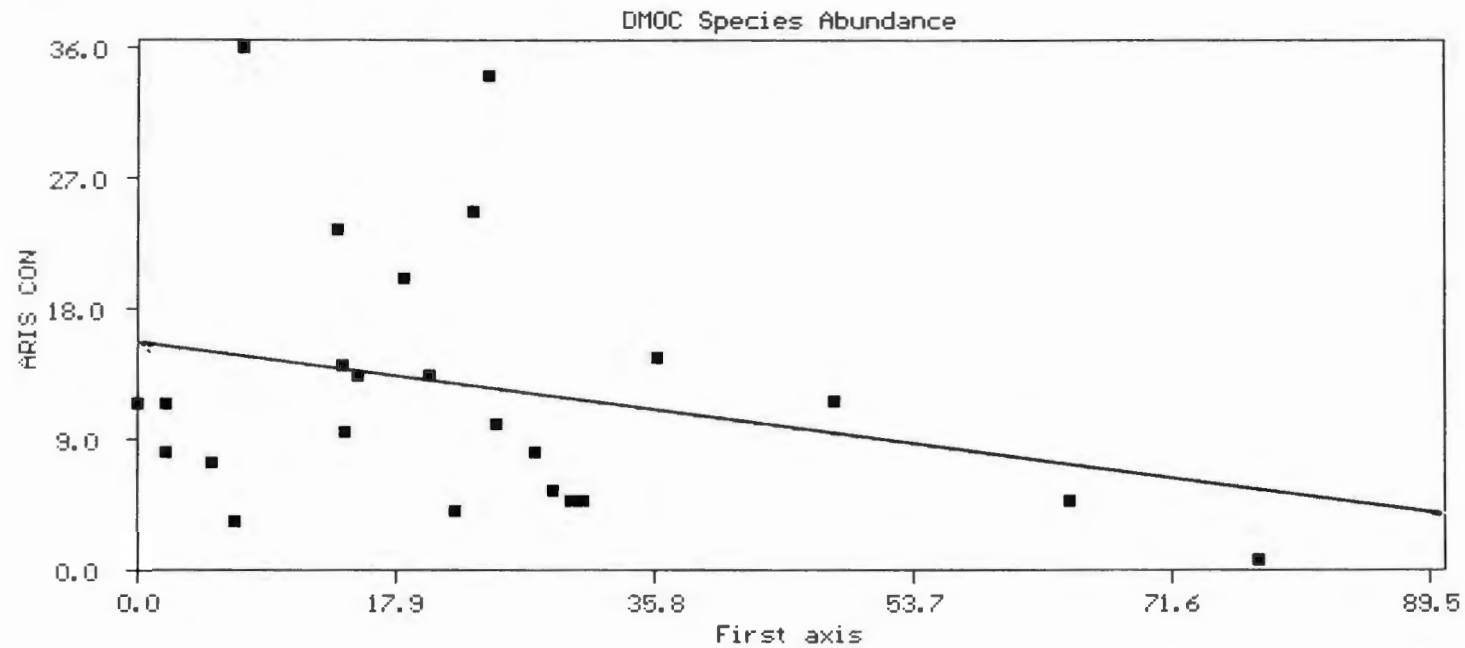
Stats: $\sigma=8.234e+00$ RMSE=6.566e+00 $r^2=0.559$ d=0.831Equation $Y=25.566379*\exp(-(X-31.717560)^2/(2*4.103544^2))$

Fig. 21 Species abundance and regression analysis curve for *Andropogon eucomus* for Model A

2 : Abundance for ARIS CON



Stats: $\sigma=2.798e+00$ RMSE=8.621e+00 $r^2=0.092$ d=0.359

Equation $Y=15.821441-0.148814*X$

Fig. 22 Species abundance and regression analysis curve for *Aristida congesta* for Model

A

Fig. 21 a curve for *Aristida congesta* which shows a spread at low and moderately utilized and decreases also as degradation level increases. Statistics is 0.359 and the correlation coefficient is 0.990.

This model shows three sites which are towards the extreme right of the graph, representative of heavily utilized sites. Site 15 was very close to a drinking point where animals frequent for drinking and resting purposes, it can be representative of heavy utilization in the past. Sites 33 and 35 were also close to one of the biggest drinking points in the park i.e Mogobe dam. These two show the signs of heavy utilization by animals when they come for drinking. The Cation Exchange Capacity of these two are 1.07 and 1.08, which are also considered very low. The organic carbon percentages are also very low for sites 33 and 35, viz; 0.15% and 0.18% respectively.

One can therefore look at this model as being representative of the degradation levels of the park. If sites 63 and 15 are compared on the model, where distance is very large meaning that the two sites are extremely different in all aspects, i.e. level of utility, and organic carbon percentage. The distance of points representing surveys on the graph also clarifies the similarities between the different sites. For instance, 22, 24 and 25 are very close on the graph, just as 15, 33 and 35 are very close. This short distance between the sites shows the similarity between the sites.

5.1.2 MODEL B

This was the second model developed for Botsalano Game Reserve. Fig. 11.1 shows an indication of two homogeneous groups due to different soil attributes. In this model, the extreme sites that will be compared are site 54 (which is found on the residual) and site 31 (which is one of the sites found at the extreme end of the first axis). Site 54 was positioned in an open grassland area and can be the representative of sites with relatively good condition. The biomass yield was 171,44g of dry weight per square metre. Site 54 had reddish brown soils, which is one indication that the soils are relatively old or at least that the soil material has been subjected to relatively intense weathering for a considerable time.

Under natural conditions when exchangeable calcium, magnesium and potassium are removed from the clay and humus by leaching or plant absorption, they are replaced by hydrogen, which is then responsible for soil acidity. The results in table 13 and 14, show that the soils in the park contain relatively more calcium than magnesium, and more potassium than sodium. Site 54 had 212,5mg of calcium per kilogram, 180mg/kg magnesium, 187,5mg/kg potassium and 30mg/kg sodium, the CEC amount for site 54 is 2.04mol per kilogram which is considered very high when compared with the rest of the figures in the same model.

The colour of the soil alone could not be used to give the indication of organic content of the soil. The investigation was carried out and site 54 was found to have 0.98% of carbon. The species composition of site 54 was 12% *Anthepora argentea*, and 34.67% *Andropogon eucomus*. These species were found in this study to be common in higher abundances in those sites which were regarded as non-degraded, hence they can be referred to as indicators of good condition in this game park.

Site 31 which is found at the right of the first axis of model 'b' was taken very close to the drinking dam. It can be a representative of those heavily utilised sites, because animals tend to frequent the area both for drinking and resting hence the areas around the dam are heavily over utilised. The biomass yield of site 31 was about 70g of dry weight per square metre. There was hardly anything to harvest in this area. The soil colour for this site was reddish brown.

The cation exchange capacity of site 31 was 1.5mol/kg of soil. This figure is very small compared to the other figures in the model. The organic carbon percentage was 0.14% which is the smallest amount for the whole data set. Few species that were seen in site 31 included, mainly *Eragrostis* species, thus *Eragrostis plana* 36%, *Eragrostis trichophora* 11.3%, *Eragrostis rigidior* 13.3% and *Eragrostis heteromera* 36%.

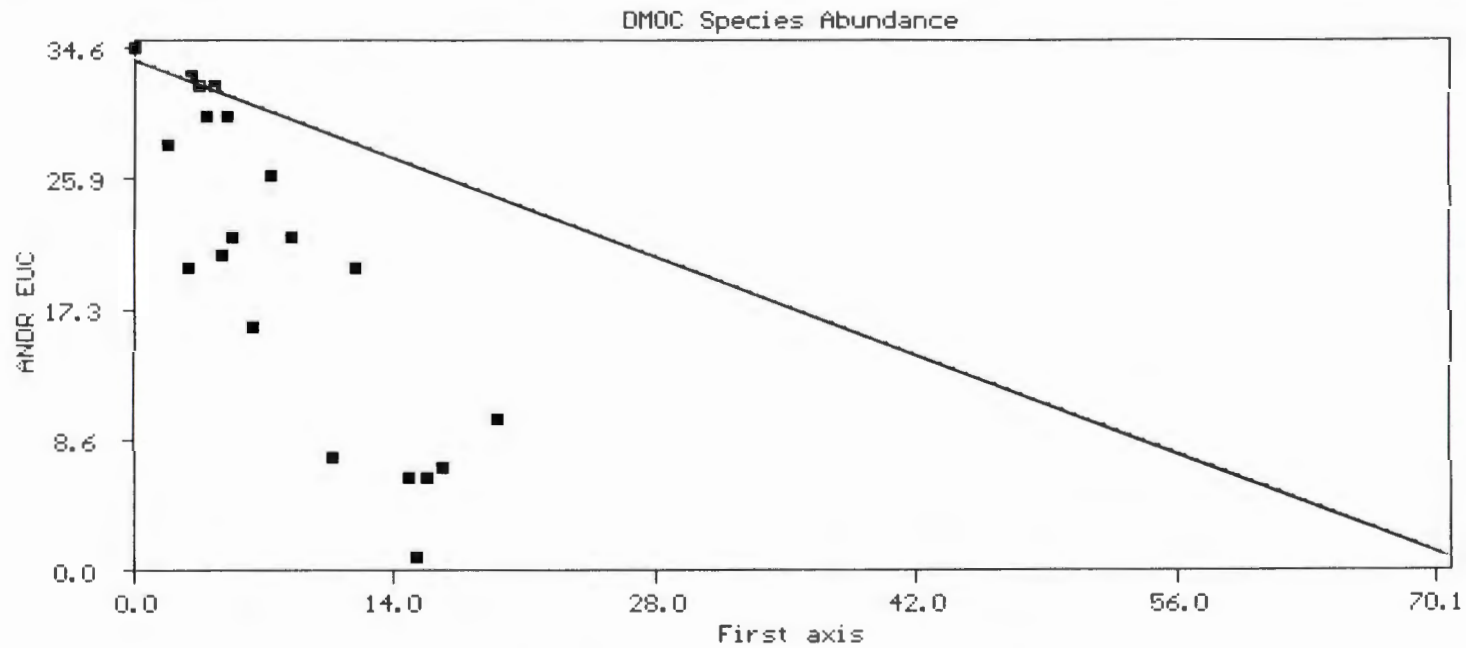
The sites which are very close to the residual and which represent less utilization, include sites which were also in the open grassland. They are 59, 65 and 66 (group A2 fig.11.1), and were dominated by *Schimidtia pappophoroides* and *Andropogon eucomus*. Sites 42, 44 and 45 are very close on the graph (group A1 fig. 11.1), and were taken in the open grassland of block 3. They had a similar species composition, viz: were dominated by *Aristida congesta*, *Anthepora argentea* and *Andropogon eucomus*. The organic carbon percentage of these sites closer to the second axis were 0.85%, 0.84% and 0.83% while the organic carbon percentage for sites 59, 65 and 66 were 1.02%, 0.97% and 0.89%, respectively.

Fig. 23 shows a curve for *Andropogon eucomus* which shows maximum abundance at less degraded sites, decreasing as the degradation becomes moderate. Statistics is 0.923 and the correlation coefficient is 0.748.

Fig. 24 a curve for *Anthepora argentea* which shows a similar behaviour to *Andropogon eucomus* where it attains maximum abundance in less degraded sites and decrease as the level of degradation becomes moderate. Statistics is 0.704 and the correlation coefficient is 0.300.

Fig. 25 a curve for *Eragrostis trichophora* shows high abundance in less degraded sites and increases further with moderate degradation and decreases with an increase in degradation level. Statistics is 0.482 and the correlation coefficient is 0.185.

2 : Abundance for ANDR EUC

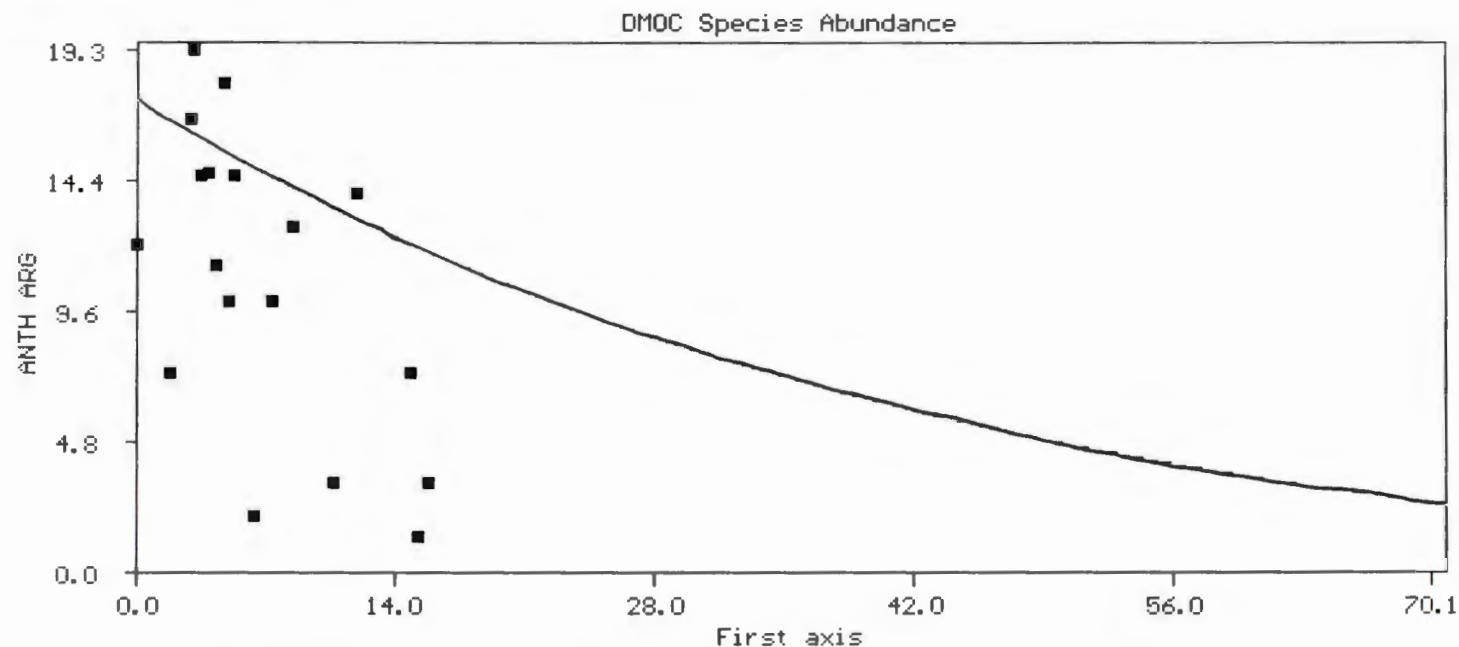


Stats: $\sigma=9.288e+00$ RMSE=5.253e+00 $r^2=0.748$ d=0.923

Equation $Y=33.309949-1.628987*X$

Fig. 23 Species abundance and regression analysis curve for *Andropogon eucomus* for Model B

2 : Abundance for ANTH ARG

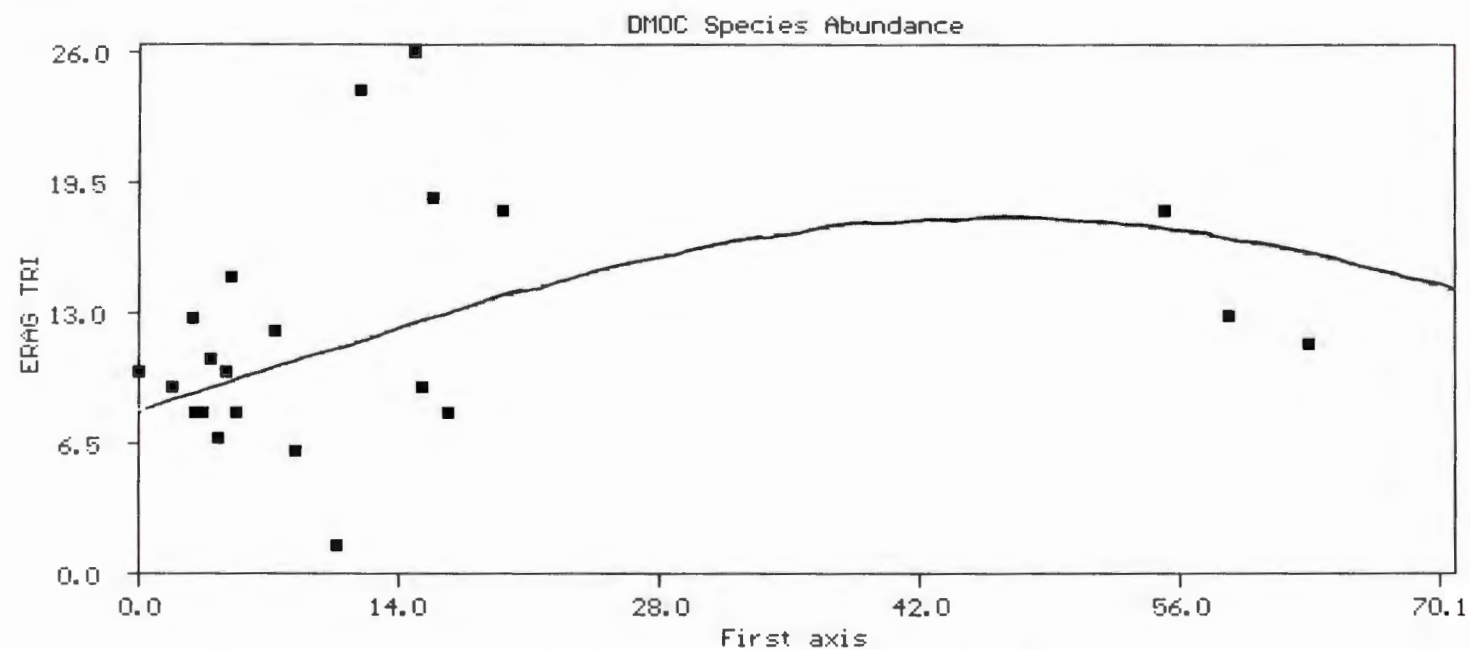


Stats: $\sigma=3.897e+00$ RMSE= $4.748e+00$ $r^2=0.300$ $d=0.704$

Equation $Y=17.296120*\exp(-0.100108*X)$

Fig. 24 Species abundance and regression analysis curve for *Antheopora argentea* for Model B

2 : Abundance for ERAG TRI



Stats: $\sigma=2.217e+00$ RMSE=5.221e+00 $r^2=0.185$ d=0.482

Equation $Y=17.840905*\exp(-(X-40.462626)^2/(2*34.109639^2))$

Fig. 25 Species abundance and regression analysis curve for *Eragrostis trichophora* for Model B

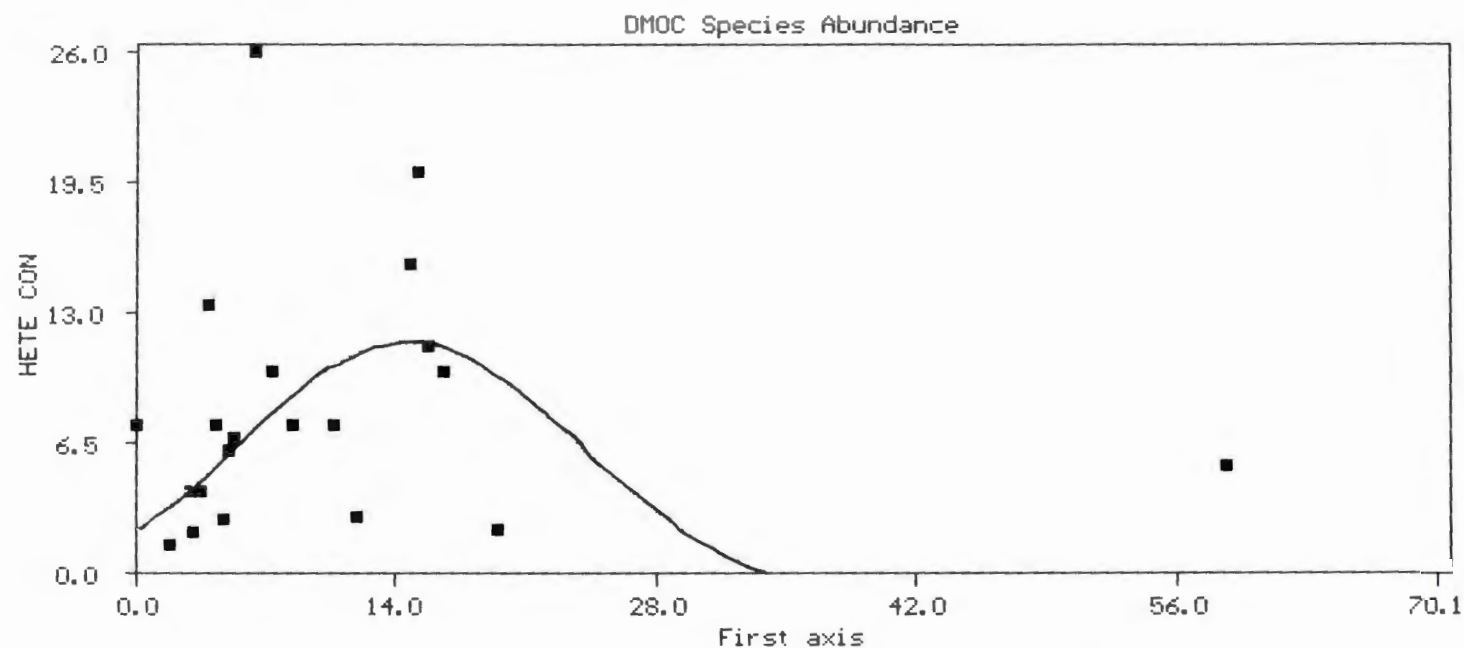
Fig. 16 a curve for *Heteropogon contortus*, this species shows maximum abundance for less degraded sites and then decreases to zero as the degradation level increases. Statistics is 0.516 and the correlation coefficient is 0.147.

Fig. 27 a curve for *Aristida barbicollis* starts with minimum abundance at less degraded sites and increases to maximum at moderate degradation and none at all for severely degraded sites. Statistics is 0.774 and the correlation coefficient is 0.433.

Fig. 28 a curve for *Aristida congesta* showing maximum abundance spreading for less degraded to moderately degraded sites and decreases as degradation increases. Statistics is 0.572 and the correlation coefficient is 0.216.

Sites 18, 7, 30, 39 and 38 (group B fig. 11.1) were taken going away from Mogobe dam in to the park. Their positions on the graph represent the moderately used sites. These areas were neither heavily nor lightly used, hence the sites are positioned to represent moderately utilized. The dominant species in these sites include *Eragrostis trichophora*, *Heteropogon contortus*, and *Aristida congesta*, *Eustachys paspaloides*. The organic carbon percentage of these range from 0.42 to 0.61.

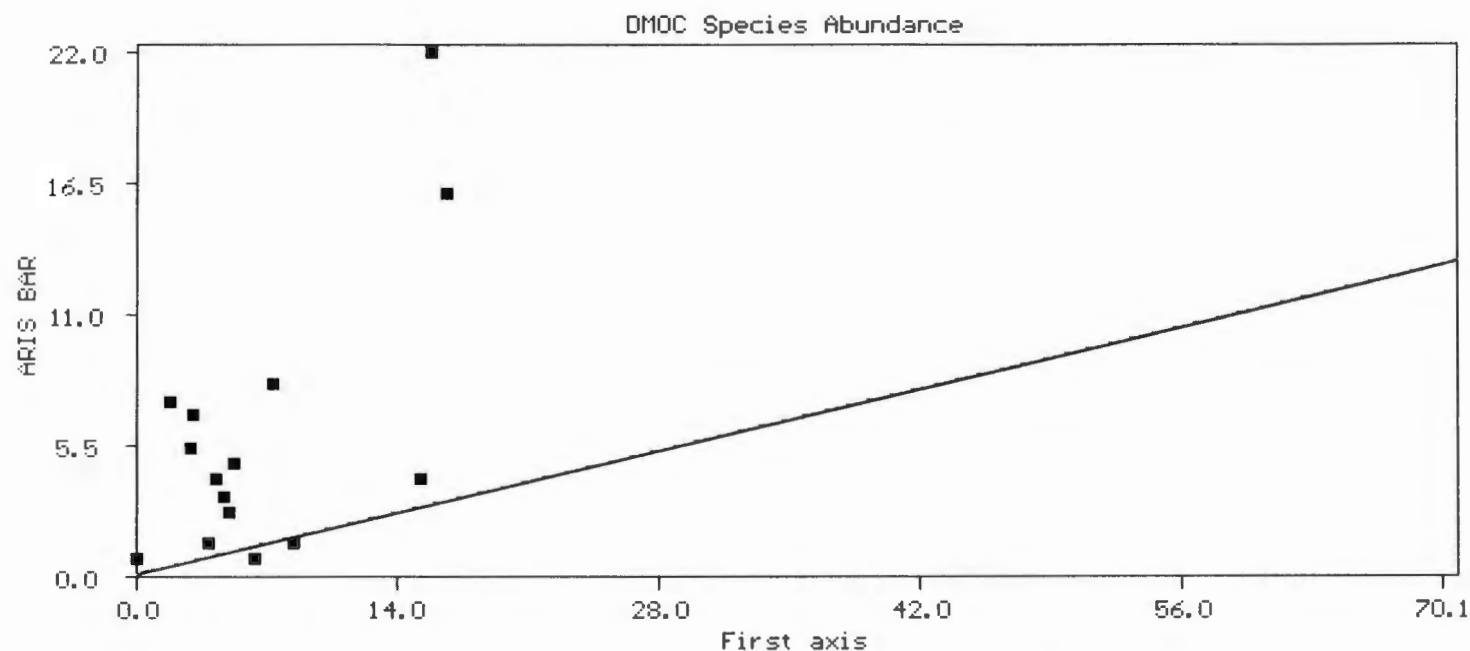
2 : Abundance for HETE CON



Stats: $\sigma=3.061e+00$ RMSE=5.697e+00 $r^2=0.147$ d=0.516
 Equation $Y=12.051654*\exp(-(X-12.081493)^2$
 $/(2*7.476954^2))$

Fig. 26 Species abundance and regression analysis curve for *Heteropogon contortus* for Model B

2 : Abundance for ARIS BAR



Stats: $\sigma=3.897e+00$ RMSE=4.310e+00 $r^2=0.433$ d=0.774

Equation $Y=0.764780+0.755154*X$

Fig. 27 Species abundance and regression analysis curve for *Aristida barbicollis* for Model B

ORDINATION

USED MEM  70 K

2 : Abundance for ARIS CON

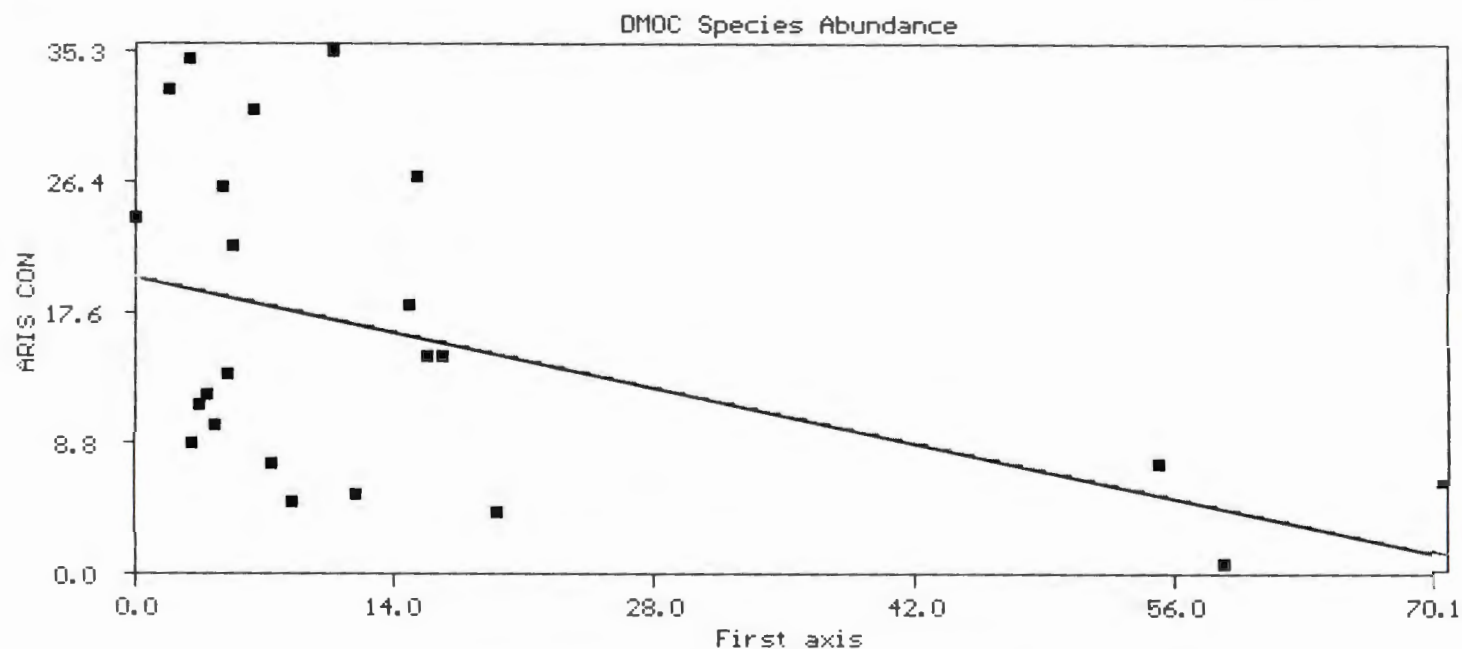


Fig. 28 Species abundance and regression analysis curve for *Aristida congesta* for Model B

The last set of sites are far on the right side of axis 1 . The four sites which represent the highly utilised areas of the park, are sites 28 and 29 which were very close to a drinking point in block 2 and sites 31 and 32 which were very close to Mogobe dam. These four sites are therefore representative of heavily utilized sites. The dominant species in site 28 and 29 were *Eragrostis heteromera*, *Eragrostis rigidior*, *Eragrostis trichophora* and *Eragrostis biflora*. The organic carbon percentage of these two sites are 0.18 and 0.17 which are considered very low when compared with other figures in the model.

Sites 31 and 32 were also dominated by *Eragrostis* species like *Eragrostis plana*, *Eragrostis heteromera*, *Eragrostis rigidior*, *Eragrostis trichophora* and *Eragrostis echinochloidea*. The organic carbon percentage of these two sites are 0.14 and 0.16 which are considered the lowest percentages of all.

After the ordinations were run and manipulated until acceptable results were obtained, any variations that occur on the residual axes could be due to various factors such as differences in rainfall, minor soil variations and management history of the sample plots. However, these variations were minimised by the elimination of outlier sites. The ordination models now seem to provide a good fit to the remaining sites, which implies that the defined degradation gradients can be regarded as appropriate bases for the condition of the park.

5.1.3 INTERPRETATION OF BIOMASS RESULTS

In this study those sites which were taken in highly utilised areas were expected to have very low yields, similarly, sites which were taken in areas which were less utilised were expected to have very high yields. Heavy use leads to less regeneration both vegetatively and reproductively. Plants are grazed in a way that does not provide room for flowering and seeding. It can also weaken the food supply needed for cell division which supports vegetative growth. When studying production of rangelands, it is of great importance to consider the species composition and biomass yield of the area, mainly because the biological properties of a community change as species enter and leave the community.

Ricklefs(1990) agrees that as a community matures, the ratio of biomass to productivity increases, The maintenance requirements of the community also increase until production can no longer meet the demand, at which point the net accumulation of biomass in the community stops (Odum:1969, Whittaker:1975, Peet:1981). However, the end of biomass accumulation does not necessarily signal the attainment of climax, species may continue to invade the community and replace others whether the biomass of the community increases or not.

For the purpose of clarifying the correlation between the biomass values of sites and their degradation gradient, Spearman's rank correlation coefficient was used to test for significance using the t-statistic and the table available in most statistical books. The value of t has to exceed 2.49 in a one-tailed test at 0.01 level. The t value for model A was 5.44 and that for model B was 4.39, both the values were above 2.49 which shows a negative correlation between biomass and degradation (fig. 29 and fig. 30).

The relationship is considered negative in this study because it has been found through Spearman's ranking that those sites whose biomass yields are low, their level of degradation is high. This is the same for sites whose biomass yields are high, then they have low degradation values. Then such sites have low degradation values due to their closeness to the residual on the ordination graph.

Sites, 1 to 4 were on a less utilised area, the grass species were still in a good condition. The only thing that might have brought the difference in their yield is that site 1 and 2 were very close to the road, hence a lower yield because of disturbance resulting from road construction. As a result site 2 had a biomass yield of 253 g/m² which is regarded a high value and a degradation value of 90. The removal of top soil and addition of small stones when making the road might have affected

RELATIONSHIP BETWEEN BIOMASS AND DEGR. FOR MODEL A

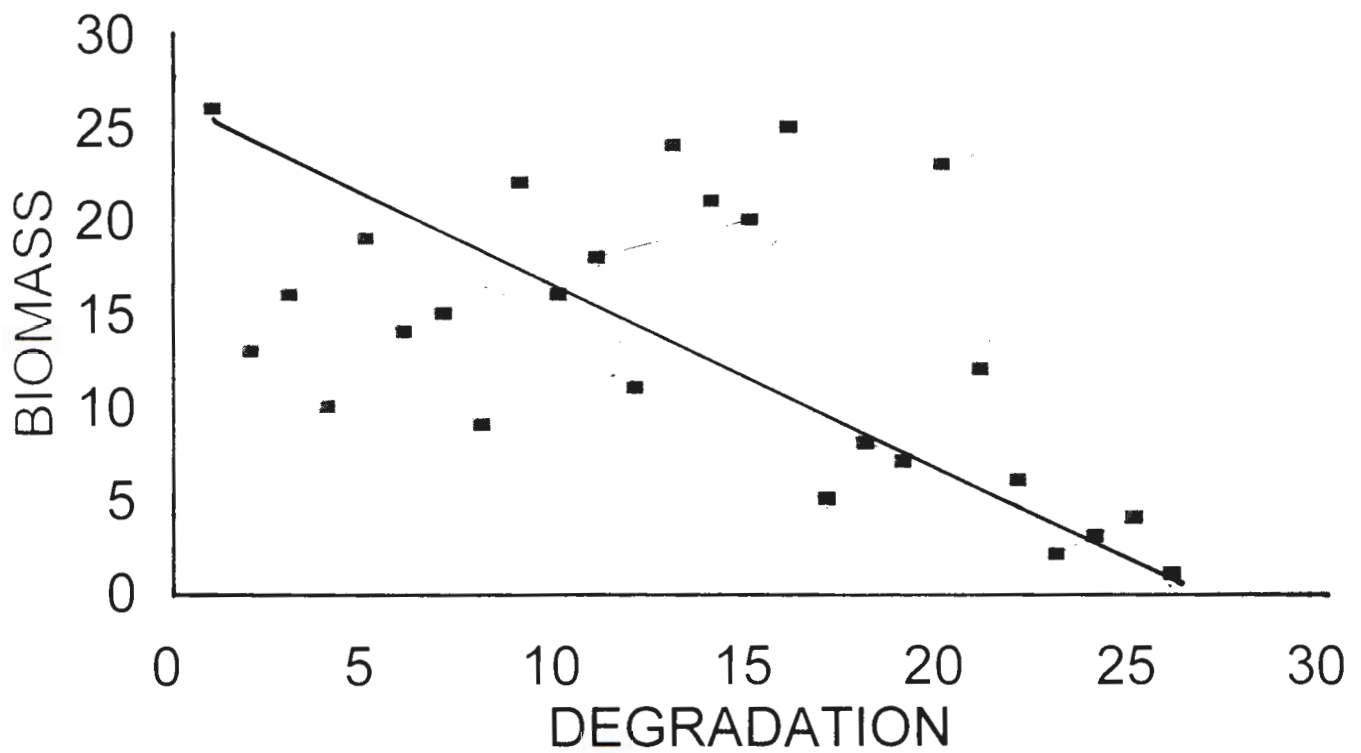


Fig. 29 Relationship between Biomass and Degradation for Model A. Table of results used for this graph is in appendix H.

RELATIONSHIP BETWEEN BIOMASS AND DEGR. FOR MODEL B

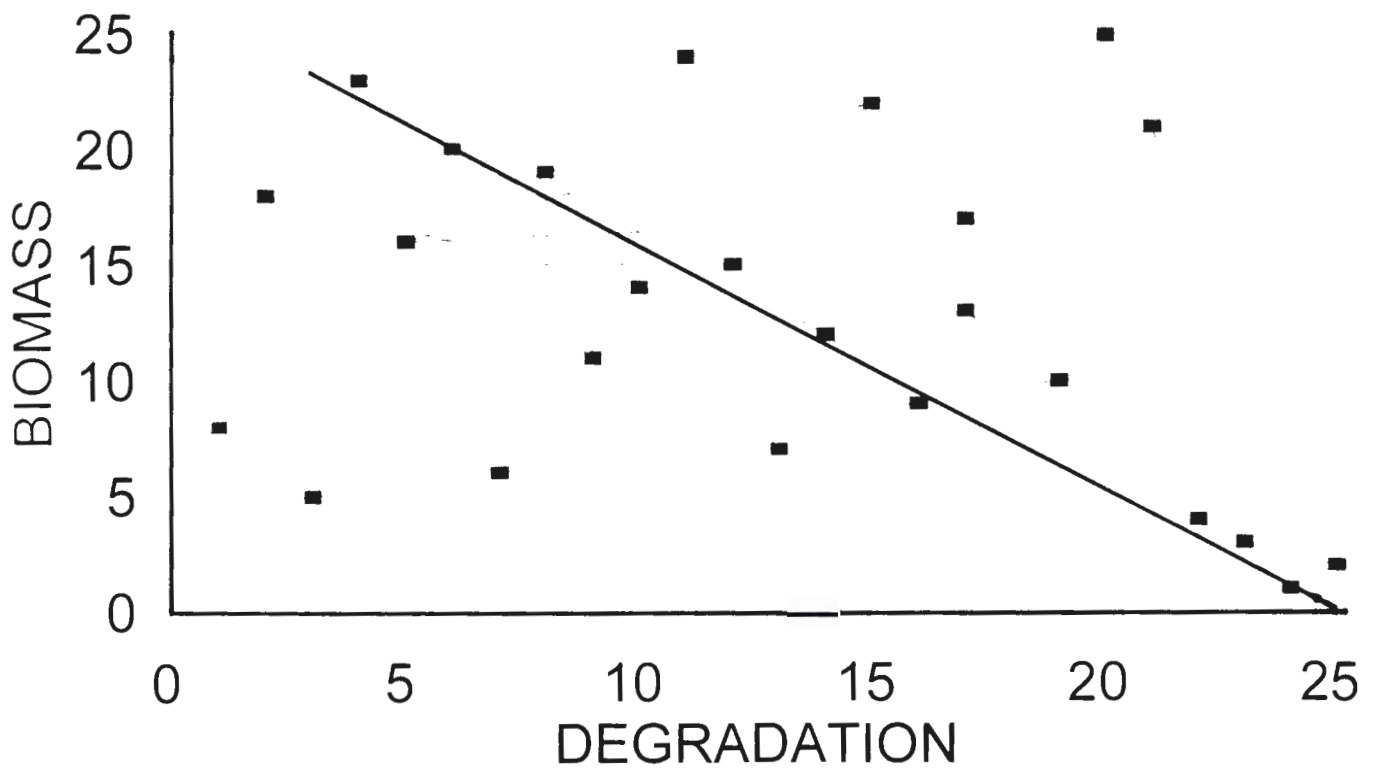


Fig.30 Relationship between Biomass and Degradation for Model B. Table of results used appear in appendix I.

same species as well. Sites 5 to 8 were also in block 8 farther away from drinking points, hence their yields are more than 200 g of dry weight per square metre which can be considered moderate. The degradation value of site 5 has been found to be 19, which is considered not very low or very high. This confirms the condition of the site to be moderately utilised. The same goes for sites 9 to 12. These were also taken on the reddish soils in block 9 and also have yields above 200 g/m² of the dried vegetation sample. In this set of samples, site 11 had a biomass yield of 219 g/m². However this set of sites were taken where there was fire in the previous years. Huntley 1972, Tainton, Groves and Nash: 1977 confirm that fire followed by subsequent clipping has shown to reduce total dry matter yield relative to post-fire protection. It is because of this, that fire is used very sparingly by proponents of controlled selective grazing, usually only in higher rainfall sour-veld areas (Grossman et al.:1981). Moving closer to the dam were sites 13 to 15 where the yield for site 13 was 202 g/m² of the dried sample while for site 14 the yield went down to 192 g/m² of the dry weight. This site was closer to the dam in block 9. Similarly site 15 was very close to the drinking point, but the yield was only 60 g/m² this is one of the sites which were heavily utilised hence a very low yield. The degradation value for this site was estimated at 89,5 which means that the site was positioned further away from the residual on the ordination graph showing that the site is severely degraded. Animals frequent the place for drinking and resting purposes.

Sites 16 to 18 were also in block 1. The yields in these sites are 116g, 133g, 115g of dry weight per square metre, while degradation values are between 36 and 14,2 which are regarded as moderately utilised sites depending on the ordination scale for each model. Another set of sites was taken in an area within the park which was initially used for kraals. Sites 19 and 20 represent the most heavily utilised area in this set of sites. The species in these area were still under recovery because there might have been heavy grazing and resting by animals in the past. The biomass values for these two sites were 79 g/m² and 112 g/m² respectively. Other sites in the set were into the park hence some difference in the yield as compared to site 19 and 20. There were some differences with the sites taken in the area but moving some paces away from the kraals.

Sites 28 to 30 were farther away from the dam in block 2. This was one of the drinking points, which seemed not to be preferred by many animals. The reason could be that 50% of the dam was invaded by the water plants which are not preferred by many animals. Sites 28 and 29 had biomass yields of 85 g/m² and 90 g/m² respectively, which are considered very low. The degradation values were 70 and 56,4 respectively, which are regarded as high in the model indicating that these sites were also moderately to severely degraded.

Mogobe dam is one of the most common and biggest drinking places in the park. Sites were selected very close, farther away and

very far from this point. These are in a set of sites from 31 to 41. Site 33 and 34 were very close to the dam hence the low yields of 170 g/m² and 142 g/m². Their degradation values were 74 and 61 which are regarded high depending on the models in which the concerned sites appear hence showing highly degraded sites.

Site 42 to 56 were in an open grassland in block 3. The yields in this set of sites are not very high. This was one of the areas of the park which could be considered moderately utilised. The yields in this set range between 162 g/m² and 269 g/m² which are not very high. Next to block 3 is block 4 which was almost similar to block 3 in species composition and the level of utility. These two blocks were not heavily utilised, but moderately utilised. The last set of sites was taken around the buildings. These include sites from 61 to 70. It is in this set of sites that we find less utilised sites with very high yield. Most of the sites in this group have yields above 250 g/m² and even two of the sites above 300 g/m². These are the ones taken very close to the buildings, where animals do not often come for grazing.

The degradation values of sites in this set range from 00 to 8 in Model A and from 0 to 13 for model B. These low values indicate the good condition of the sites because these were positioned very close to the residual in the ordination graphs, hence low degradation values.

Walker (1982) stated that the presence of a large unpalatable biomass increases the resilience of a system through an inertia or buffering effect. The grasslands with such a component represent the vegetation which would probably be able to withstand seasonal drought conditions and much higher stocking rates without a drastic loss of cover, erosion, bush encroachment, and could therefore be regarded as relatively stable and resilient.

CHAPTER SIX

DISCUSSIONS AND CONCLUSIONS

6.1 GENERAL DISCUSSIONS

Land degradation seems to be a problem facing many rangelands, game reserves also experience this problem because of the numbers of animals kept there. However, the principal causes of degradation were found to be water and wind erosion accompanied by damage or loss of vegetation and soil salinisation by Woods (1983) and Chartres (1987).

In this study, attention was paid more to under utilised, over utilised and moderately utilised areas of the park. Biomass results of the sites taken from the different areas of the park also help highlight the level of utilisation of different areas. For instance under normal circumstances, one would expect over utilised sites to have a low biomass yield and under utilised sites to have a higher biomass yield. This was also verified by using Spearman's rank correlation coefficient to check the correlation between biomass and degradation. The results then showed a strong negative correlation.

A knowledge of the reaction of species to climate and its interaction with defoliation, together with an understanding of the soil factors that are limiting the recovery process, would therefore be of special importance in devising management strategies for the improvement of degraded rangelands (Bosch & Gauch: 1991

Kotze et al.(1984) support the fact that the amounts of herbage available will differ between sites with markedly different species composition. It is also assumed by the same researchers that for a veld of a given composition, grazing capacity is directly related to yield i.e. those areas which are highly grazed will probable produce low yield which may result from the unpalatable grasses which are not preferred by animals. The measurement of yield at each site would allow for valid comparison.

Extreme climatic or grazing conditions can also cause large changes in the vegetation (Noy Meir & Walker :1984). It was observed in this study in the park, that there are areas whose vegetation could be regarded as representing a good condition. This was also confirmed by referring to species present in such areas. It has been discussed in this study which sites seem to have been less degraded, moderately and severely degraded and the species which are found in the different levels of degradation, for instance, in Model A, Gaussian models provided the best fit for species abundance data on the degradation gradient for

species like *Heteropogon contortus*, *Aristida barbicollis*, *Andropogon eucomus* and *Eragrostis trichophora* whose D-statistic is higher than 0.600. For model B such species included *Heteropogon contortus* again with D- statistic of 0.516 and *Aristida barbicollis*, *Andropogon eucomus* and *Anthepera argentea* which are well above 0.600. *Aristida congesta* has the value of 0,572 which is also closer to 0.600. The other chosen species for model A however had lower D-statistic and these tended to be non-responsive they are *Themeda triandra* with 0.497 and *Melinis repens* and *Aristida congesta* which have values less than 0.400. From the regression analysis curves of these species (Chapter five) it could be noted that some species tend to increase with less degradation and decrease as the level of degradation increases form moderately degraded to severely degraded.

Most of the sites are taken in blocks which are clearly known and understood by the present management, it is therefore very important that the two models developed for Botsalano Game Reserve be used for the restoration of those moderately to severely degraded areas of the park. Degradation reduces the capacity of rangeland resources to produce goods and services of value to society (Johnston et al. 1990). It is very important that the management of the park pays attention to those areas which have been found heavily degraded i.e these are the areas very close to watering points and areas close to the old kraals, site numbers are indicated and block numbers where these sites were samples are discussed in section 5.1.3. Even those which are

moderately degraded are also indicated in this section. The DMOCC ordination models also have sites grouped into group A1, A2, B and C for model B to indicate increasing level of degradation from A1 to C, and groups A, B, C in Model A also indicate the same increase. Further deterioration due to severe overgrazing leads to the encroachment by karoo shrubs (Bosch:1989).

6.2 METHOD APPRAISAL

When beginning an ecological investigation of an area, it is useful to subdivide the general vegetation cover into more homogenous subunits (Mueller-Dombois:1974). In this study a detailed soil map of the area was used to select the most extensive soil type. This was where most of the sampling was done. Mueller-Dombois (1974) also supports the fact that maps often provide the opportunity for a fair distribution of sampling in the sense of geographic distribution and vegetation variation.

The point method that was used in this study for collection of data in the field, has also been used by many investigators. Most of them have the general opinion that this method has every prospect of becoming the accepted one for large-scale surveys as well as for exact field analysis (Brown:1957). All those who have used this method confirm that for analysis by area there is a saving of time and labour when compared with other methods. Though best suited for short vegetation (up to 4 - 6 metric) the method can be adapted for taller vegetation and can be used on

level or uneven ground. The pin point makes possible the exact distinction between species, even if the sward is dense (Brown :1957).

According to Goodall(1952) the personal differences between observers are not great but it is desirable, that in any series in which comparisons are to be made, readings should be made by the same person. Crocker and Tiver (1948) showed that under normal weather conditions and with analyses made at the 300 - 400 point level, the variation between different observers is little greater than between separate analyses made by the same individual. In their experience, the personal factor enters on days on which a strong wind blows. On such days it would be better to avoid using the point method, especially in grass which is a foot or more in height because in the swaying grass it is difficult to decide whether a grass should be counted as a hit or a miss. In this study, there were some difficulties in identifying a hit or a miss only in a case where many species clinging together. The height of the grasses also gave some problems in those sites whose cover was mainly tall grass species especially because most of the days were windy.

Davies (1931) makes a criticism that the total area examined is very small in proportion to the whole area under analysis, when the number of readings is high. This did not seem to be the case in this study because a large area of the park was covered, which could be representative of the whole park.

The data was split into sets, which finally gave out two degradation models for the park. This conclusion therefore supports the acceptance of the degradation models as appropriate and provides sound bases for condition assessments of vegetation in the Botsalano game reserve.

6.3 RECOMMENDATIONS

I would like to recommend that field work be undertaken during warmer months, viz; January, February and March. These are warmer and wetter months, during which most plant species have their flowers and leaves. Identification is much easier and saves time for the researcher. Different species flower at different times of the year, it would still be advisable to carry out several surveys representing different seasons.

Most vegetation communities have different species. The variation in species composition is related to variation in associated environmental factors which can usually be represented by environmental gradients. It is very important to carry out ordinations as the emphasis here is on individual samples or species. Their degrees of similarity to each other and on determining how the order of the individuals is correlated with underlying environmental controls (Kent & Coker:1992).

The range and choice of methods for ordination is a substantial problem for both researchers and students (Kent and Ballard:1988). Even now, there is no absolute agreement over which is the 'best' method that gives the least distortion to the data. In this study detrended correspondence analysis (DCA) was chosen because it mainly involves detrending. It is referred to as the removal of the 'arch effect' which is a problem in reciprocal averaging (RA). Gauch (1982) also concluded that DCA gives results at least as good and usually superior to other ordination techniques. DMOC which is a PCA ordination technique was used in the analysis.

A useful monitoring tool has resulted, which can be useful in informing management strategies in the park. Sample surveys can be used to determine trends in vegetation change and informed adjustments to stocking rates and types implemented. However, I still agree with Werner(1990) that increased interaction between the pure scientist and the land manager would be of mutual benefit to the understanding of natural systems and to the rangelands which are fundamental to the health of our country. It is also very important to apply basic ecological principles in management to ensure that long-term sustained productivity of rangelands.

It is therefore also recommended that the management of Botsalano Game Reserve apply some of the ecological and even economical principles to those areas which are already degraded, for

instance, there are areas in the park which have lost most palatable species and which are replaced by the unpalatable species, then the management can look for the seeds and re-seed the lost species, but also bearing in mind that if the seed bank for the desirable plants is exhausted, then the range will not naturally regenerate even if it is totally destocked unless additional re-seeding costs are incurred.

Werner (1990) also outlines the principle of succession that it involves a series of species replacements, fast growing weedy species replaced by slower growing but longer lived and strong competitive species. The management can thus put up strong control measures for herbivores not to get to the treatment areas by erecting a fence around the area. However, long-term planning is necessary to restore the degraded areas in the park.

Some restoration treatments such as the use of prescribed fire control woody weeds in degraded semi-arid woodlands, are already known to be cost effective (Burgess, (1988) , Hodgkinson et al. 1985)), whereas other treatments, such as the broad scale application of expensive herbicides to control shrubs, are uneconomical (Burgess:1986).

The results from this study also do reflect that the level of degradation decrease with distance away from water points. Using distance from water points seems a reasonable surrogate for a gradient in grazing pressure and this grazing gradient approach

is also being widely used in Australia as well (Landsberg et al.:1997). However, caution is also necessary because this measure may not reflect historical grazing pressures away from water points. Ludwig et al. (1999) also confirms that a decline in the density, cover and obstruction widths of vegetation patches close to water points indicates a loss of function, that is a decline in the ability of the landscape to retain vital resources because of excessive run-off losses of water, soil sediments, nutrients, and litter. Plant richness also decline near water, hence areas near water points can be viewed as 'sacrifice zones' because such areas will always be heavily impacted by stock (Andrew and Lange:1986).

It can also be believed that the existence of these severely degraded areas in the park is due to the ignorance of the past park managers who might have been ignorant about the long-term consequences by overstocking, however most managers now take care to avoid overstocking a range that is still in good condition.

Lindner (1990) suggested that if the range is already severely degraded, then the most profitable course of action will be to opportunistically graze the land whenever it manages to produce any forage, with the aim of totally degrading the range, this idea can be useful for Botsalano game reserve to totally degrade these areas with the sole purpose of may be building some chalets or camping sites for visitors. At the other extreme, Landner(1990) suggests again that range which is either in good

condition, or highly degraded, can be exploited on a sustainable basis by matching the stocking rate to the feed availability. This grazing management strategy will restore and preserve the range in good condition in perpetuity. Finally, for range which is moderately degraded there might be some value in de-stocking during seasons when there are good prospects for seedlings to become established.

Therefore de-stocking the game reserve and re-seeding it can be helpful to the existing condition of Botsalano Game Reserve, although the process of recovery is much slower than the process of degradation.

Since the park is also used to accommodate different groups of people who either go there for camping or hunting, restoring the severely degraded areas of the park especially those close to water points and roadways is likely to provide aesthetic and recreational benefits to tourists and other travellers in the area.

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APPENDIX A

TABLE 2

=====

HYDROMETER METHOD

=====

CLAY IN SOIL

=====

50 g soil in 1075 ml of distilled water

=====

HYDROMETER READING AFTER 8 HOURS

=====

(%)

HYDRO-
METER
READING

TEMPERATURE C

	17 C	18 C	19-20 C	21 C	22 C	23 C	24-25 C	26 C	27/28 C	29 C	30-31 C	32 C	33 C
-3	-	-	-	-	-	-	-	-	0	1	2	3	4
-2	-	-	-	-	-	-	0	1	2	3	4	5	6
-1	-	-	-	-	0	1	2	3	4	5	6	7	8
0	-	-	0	1	2	3	4	5	6	7	8	9	10
1	0	1	2	3	4	5	6	7	8	9	10	11	12
2	2	3	4	5	6	7	8	9	10	11	12	13	14
3	4	5	6	7	8	9	10	11	12	13	14	15	16
4	6	7	8	9	10	11	12	13	14	15	16	17	18
5	8	9	10	11	12	13	14	15	16	17	18	19	20
6	10	11	12	13	14	15	16	17	18	19	20	21	22
7	12	13	14	15	16	17	18	19	20	21	22	23	24
8	14	15	16	17	18	19	20	21	22	23	24	25	26
9	16	17	18	19	20	21	22	23	24	25	26	27	28
10	18	19	20	21	22	23	24	25	26	27	28	29	30
11	20	21	22	23	24	25	26	27	28	29	30	31	32
12	22	23	24	25	26	27	28	29	30	31	32	33	34
13	24	25	26	27	28	29	30	31	32	33	34	35	36
14	26	27	28	29	30	31	32	33	34	35	36	37	38
15	28	29	30	31	32	33	34	35	36	37	38	39	40
16	30	31	32	33	34	35	36	37	38	39	40	41	42
17	32	33	34	35	36	37	38	39	40	41	42	43	44
18	34	35	36	37	38	39	40	41	42	43	44	45	46
19	36	37	38	39	40	41	42	43	44	45	46	47	48
20	38	39	40	41	42	43	44	45	46	47	48	49	50
21	40	41	42	43	44	45	46	47	48	49	50	51	52
22	42	43	44	45	46	47	48	49	50	51	52	53	54
23	44	45	46	47	48	49	50	51	52	53	54	55	56
24	46	47	48	49	50	51	52	53	54	55	56	57	58
25	48	49	50	51	52	53	54	55	56	57	58	59	60
26	50	51	52	53	54	55	56	57	58	59	60	61	62
27	52	53	54	55	56	57	58	59	60	61	62	63	64
28	54	55	56	57	58	59	60	61	62	63	64	65	66
29	56	57	58	59	60	61	62	63	64	65	66	67	68
30	58	59	60	61	62	63	64	65	66	67	68	69	70
31	60	61	62	63	64	65	66	67	68	69	70	71	72
32	62	63	64	65	66	67	68	69	70	71	72	73	74
33	64	65	66	67	68	69	70	71	72	73	74	75	76
34	66	67	68	69	70	71	72	73	74	75	76	77	78
35	68	69	70	71	72	73	74	75	76	77	78	79	80
36	70	71	72	73	74	75	76	77	78	79	80	81	82
37	72	73	74	75	76	77	78	79	80	81	82	83	84
38	74	75	76	77	78	79	80	81	82	83	84	85	86
39	76	77	78	79	80	81	82	83	84	85	86	87	88
40	78	79	80	81	82	83	84	85	86	87	88	89	90

APPENDIX B

TABLE 1

=====

SAND IN SOIL

=====

(%)

HYDROMETER METHOD

=====

50 g soil in 1075 ml of distilled water

=====

HYDROMETER READING AFTER 4 MINUTES

=====

HYDRO- METER READING	TEMPERATURE C												
	17 C	18 C	19-20 C	21 C	22 C	23 C	24-25 C	26 C	27/28 C	29 C	30-31 C	32 C	33 C
-3	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
-2	-	-	-	-	-	-	100	99	98	97	96	95	94
-1	-	-	-	-	100	99	98	97	96	95	94	93	92
0	-	-	100	99	98	97	96	95	94	93	92	91	90
1	100	99	98	97	96	95	94	93	92	91	90	89	88
2	98	97	96	95	94	93	92	91	90	89	88	87	86
3	96	95	94	93	92	91	90	89	88	87	86	85	84
4	94	93	92	91	90	89	88	87	86	85	84	83	82
5	92	91	90	89	88	87	86	85	84	83	82	81	80
6	90	89	88	87	86	85	84	83	82	81	80	79	78
7	88	87	86	85	84	83	82	81	80	79	78	77	76
8	86	85	84	83	82	81	80	79	78	77	76	75	74
9	84	83	82	81	80	79	78	77	76	75	74	73	72
10	82	81	80	79	78	77	76	75	74	73	72	71	70
11	80	79	78	77	76	75	74	73	72	71	70	69	68
12	78	77	76	75	74	73	72	71	70	69	68	67	66
13	76	75	74	73	72	71	70	69	68	67	66	65	64
14	74	73	72	71	70	69	68	67	66	65	64	63	62
15	72	71	70	69	68	67	66	65	64	63	62	61	60
16	70	69	68	67	66	65	64	63	62	61	60	59	58
17	68	67	66	65	64	63	62	61	60	59	58	57	56
18	66	65	64	63	62	61	60	59	58	57	56	55	54
19	64	63	62	61	60	59	58	57	56	55	54	53	52
20	62	61	60	59	58	57	56	55	54	53	52	51	50
21	60	59	58	57	56	55	54	53	52	51	50	49	48
22	58	57	56	55	54	53	52	51	50	49	48	47	46
23	56	55	54	53	52	51	50	49	48	47	46	45	44
24	54	53	52	51	50	49	48	47	46	45	44	43	42
25	52	51	50	49	48	47	46	45	44	43	42	41	40
26	50	49	48	47	46	45	44	43	42	41	40	39	38
27	48	47	46	45	44	43	42	41	40	39	38	37	36
28	46	45	44	43	42	41	40	39	38	37	36	35	34
29	44	43	42	41	40	39	38	37	36	35	34	33	32
30	42	41	40	39	38	37	36	35	34	33	32	31	30
31	40	39	38	37	36	35	34	33	32	31	30	29	28
32	38	37	36	35	34	33	32	31	30	29	28	27	26
33	36	35	34	33	32	31	30	29	28	27	26	25	24
34	34	33	32	31	30	29	28	27	26	25	24	23	22
35	32	31	30	29	28	27	26	25	24	23	22	21	20
36	30	29	28	27	26	25	24	23	22	21	20	19	18
37	28	27	26	25	24	23	22	21	20	19	18	17	16
38	26	25	24	23	22	21	20	19	18	17	16	15	14
39	24	23	22	21	20	19	18	17	16	15	14	13	12
40	22	21	20	19	18	17	16	15	14	13	12	11	10

APPENDIX C : LIST OF IDENTIFIED SPECIES

1. *Anthepora argentea*
2. *Aristida barbicollis*
3. *Heteropogon contortus*
4. *Aristida congesta*
5. *Bulbostylis burchellii*
6. *Pogonarthria squarrosa*
7. *Brachiaria negropedata*
8. *Melinis repens*
9. *Eragrostis echinochloidea*
10. *Eragrostis trichophora*
11. *Digitaria eriantha*
12. *Aristida scabrivalvis*
13. *Trichoneura grandiglumis*
14. *Eustachys paspaloides*
15. *Aristida diffusa*
16. *Anthepora pubescens*
17. *Cymbopogon validus*
18. *Diheteropogon amplexans*
19. *Eragrostis superba*
20. *Elionurus muticus*
21. *Andropogon eucomus*
22. *Themeda triandra*
23. *Pentarrhinum insipidum*
24. *Eragrostis rigidior*
25. *Eragrostis gummiflua*
26. *Ischaemum afrum*
27. *Urochloa mosambiensis*
28. *Aptosimum lineare*
29. *Mundulea sericea*
30. *Cyperus longus*
31. *Kyphocarpa angustifolia*
32. *Indigofera melanadenia*
33. *Oenothera tetraptera*
34. *Chloris virgata*
35. *Digitaria velutina*
36. *Compositae*
37. *Eragrostis heteromera*
38. *Walafrida densiflora*
39. *Schkuhria pinnata*
40. *Alternanthera pungens*
41. *Rhynchelytrum repens*
42. *Gnaphalium filagopsis*
43. *Eragrostis biflora*
44. *Eragrostis plana*
45. *Cynodon dactylon*
46. *Tagetes*
47. *Eragrostis junciformis*
48. *Schmidtia pappophoroides*
49. *Eragrostis chloromelas*
50. *Setaria ingrassata*
51. *Brachystelma cupulatum*
52. *Monocymbium cerasiiforme*

The following codes are used :

----- indicates that the data is unavailable
 = indicates that the day average is unreliable due to missing data.
 AVE is the day average.

Note :

AVE will only be for the days that appear on the report.
 This value can be wrong if only a part of the year's data is extracted.

0508047 0	NAPIKENG WO											
	MAXIMUM TEMPERATURE											
	1997											
	TIME 08h00											
DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
01	31.3	29.4	27.1	24.6	24.4	16.2	14.9	22.3	25.3	31.8	22.6	28.0
02	31.7	31.9	28.9	21.6	26.9	17.3	16.9	23.1	26.2	30.5	29.0	35.7
03	30.1	30.5	26.8	32.5	24.4	19.0	19.4	22.3	25.7	31.4	32.4	31.7
04	28.8	31.5	29.3	21.9	23.7	20.1	21.2	25.1	25.8	32.2	33.0	32.3
05	29.6	31.3	22.2	25.6	24.5	20.8	18.7	18.4	24.5	32.9	33.5	33.1
06	30.4	30.0	27.1	20.3	20.9	21.8	17.4	16.6	25.2	34.9	34.3	31.8
07	31.1	28.8	24.2	17.8	18.4	23.5	15.4	19.6	18.0	34.4	36.5	32.1
08	30.8	29.5	28.9	20.4	20.7	24.6	15.2	23.2	21.8	28.9	33.8	34.5
09	29.1	28.8	30.4	17.1	21.2	23.6	15.2	23.5	15.6	26.0	32.5	34.1
10	30.2	28.8	24.4	22.3	21.6	23.9	18.2	22.5	16.9	26.4	29.1	37.2
11	26.1	31.4	28.9	23.4	21.8	22.2	19.7	23.9	17.1	29.6	25.8	36.0
12	23.2	27.8	26.2	24.9	22.1	12.6	20.3	24.6	19.3	30.1	29.7	36.2
13	22.6	31.5	22.1	22.5	22.2	16.0	19.8	25.9	19.9	28.0	31.3	35.9
14	28.3	29.8	25.8	21.4	22.7	16.6	19.5	26.2	19.4	22.0	34.0	35.6
15	29.8	27.9	23.9	23.7	23.1	20.0	20.5	24.3	19.6	26.0	31.8	31.4
16	30.1	31.1	24.3	25.0	22.7	19.4	19.7	25.0	23.4	20.9	29.1	34.9
17	34.7	34.0	24.8	16.0	22.7	21.6	20.3	25.3	24.1	18.6	24.9	29.3
18	23.6	28.5	22.8	28.3	23.0	16.2	22.3	26.1	27.3	22.1	22.7	30.1
19	28.2	33.2	23.4	26.3	23.4	18.2	17.5	27.6	27.2	22.5	26.7	28.8
20	30.1	32.4	23.9	21.2	24.0	17.1	21.5	27.8	30.2	25.1	32.3	30.1
21	24.7	34.4	25.0	24.8	24.5	21.1	24.6	26.0	31.2	27.4	29.8	34.1
22	26.3	34.9	26.7	26.1	21.6	23.1	23.5	25.3	32.5	30.3	25.2	34.0
23	29.8	35.2	25.2	19.1	17.4	22.3	23.2	26.9	34.2	31.8	28.5	32.5
24	29.9	28.0	27.0	20.0	19.5	23.2	25.0	25.0	28.9	33.4	32.4	28.8
25	29.0	30.4	24.9	21.3	16.3	22.7	20.2	25.0	31.6	33.9	28.5	32.8
26	29.0	30.5	21.9	24.4	17.4	24.1	23.8	27.2	30.0	32.0	29.7	34.1
27	29.6	29.0	21.3	27.5	14.8	24.3	21.1	26.7	31.3	26.3	26.7	35.4
28	28.0	24.8	23.3	23.0	12.0	26.0	16.8	25.2	34.0	23.6	29.2	33.2
29	30.0		24.2	21.7	13.3	13.1	21.4	25.1	35.6	24.0	30.7	32.4
30	31.1		24.7	22.7	15.6	11.3	18.7	26.0	31.4	28.9	29.6	29.5
31	32.2		26.8		16.2		20.0	24.2		29.6		25.5
AVR	28.6	30.5	25.3	22.9	20.7	20.0	19.7	24.3	25.7	28.2	29.8	32.6

0508047 0	NAFIXENG WO					MAXIMUM TEMPERATURE				1998	TIME 0800		
DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
01	25.4	30.9	34.1	30.1	28.9								
02	24.0	33.5	30.2	30.3	28.9								
03	20.6	33.1	29.5	29.6	29.7								
04	26.3	32.3	31.0	30.5	29.1								
05	28.7	33.9	33.3	31.2	30.0								
06	25.2	32.9	34.2	30.8	29.8								
07	28.5	34.6	32.9	32.4	30.1								
08	31.9	36.1	26.7	29.7	27.3								
09	30.7	34.2	31.5	26.3	23.9								
10	25.1	33.4	32.9	28.5	17.0								
11	28.7	32.2	32.7	29.5	17.8								
12	28.6	33.9	27.8	26.2	19.2								
13	31.0	29.9	26.7	27.4	21.8								
14	28.7	30.8	24.7	29.4	21.5								
15	28.9	27.5	26.8	29.3	20.8								
16	31.2	29.5	29.1	27.9	22.8								
17	32.5	21.0	30.9	26.3	21.4								
18	34.1	24.9	32.6	25.2	20.9								
19	31.2	23.7	28.6	25.3	21.5								
20	30.3	26.6	30.9	25.2	23.2								
21	32.2	28.8	32.3	25.6	24.7								
22	31.1	31.6	31.1	27.1	23.0								
23	31.5	32.9	31.2	28.5	23.7								
24	32.4	30.9	31.2	30.2	24.7								
25	27.3	30.1	32.2	29.0	25.4								
26	29.3	25.8	29.8	28.7	24.9								
27	31.9	29.4	22.2	29.4	25.2								
28	31.1	32.0	25.7	30.6	20.3								
29	31.2		29.3	30.5	21.2								
30	29.8		26.9	28.5	22.1								
31	30.7		28.1		23.5								
AVE	29.3	30.5	29.9	28.5	24.0								

Report Complete

APPENDIX E

The following codes are used :

- indicates that the data is unavailable
- = indicates that the day average is unreliable due to missing data.
- AVE is the day average.

Note :

AVE will only be for the days that appear on the report.
This value can be wrong if only a part of the year's data is extracted.

0508047 0	MAPIKENG WD											
	MINIMUM TEMPERATURE											
	1997											
	TIME 08h00											
DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
01	15.5	11.9	15.8	14.8	8.2	0.7	- 1.0	7.5	5.8	14.6	16.6	14.8
02	16.2	12.9	19.1	10.1	9.0	1.6	0.8	6.2	7.1	15.2	15.4	18.1
03	17.8	16.8	17.4	13.9	7.1	0.5	0.7	1.3	14.1	14.3	16.6	12.6
04	17.9	18.1	18.0	13.4	4.7	5.1	3.2	5.0	7.6	14.4	20.0	13.9
05	17.6	17.1	16.0	11.1	6.4	2.5	3.9	11.9	9.7	15.8	18.1	17.7
06	17.5	19.8	17.4	11.2	10.5	5.4	4.6	- 1.5	12.8	15.9	16.1	15.9
07	16.7	17.5	18.1	2.9	10.7	6.1	1.5	1.4	13.1	14.0	20.7	17.5
08	18.8	16.9	17.2	4.8	9.0	6.3	- 0.2	2.6	12.1	13.2	22.0	15.7
09	18.1	15.6	17.9	0.8	6.9	9.8	6.7	5.5	10.6	10.4	21.0	19.8
10	18.0	16.5	17.5	6.2	5.9	6.5	4.7	4.4	11.4	11.7	20.4	20.4
11	18.3	19.0	17.0	8.2	7.0	9.5	3.8	5.2	12.0	13.7	16.6	20.3
12	16.9	19.3	17.8	8.6	6.0	2.2	3.1	6.8	10.9	11.8	13.7	17.3
13	17.1	17.1	17.1	10.0	5.3	0.4	3.7	4.9	10.9	13.9	15.2	19.3
14	15.8	14.2	2.9	9.0	5.7	0.2	1.0	7.2	8.0	12.9	15.7	17.6
15	16.0	16.3	14.8	8.6	5.7	1.1	1.7	9.2	7.3	10.9	15.6	18.9
16	18.5	15.5	13.4	9.8	4.2	1.8	2.8	8.7	6.9	9.2	16.1	19.5
17	16.9	17.5	13.0	11.5	4.2	- 1.7	1.6	6.0	10.1	8.4	8.6	20.4
18	16.3	18.9	14.7	12.9	6.6	1.5	3.2	7.4	11.4	7.7	5.9	10.5
19	16.7	19.5	15.5	12.7	7.4	- 2.3	10.1	9.5	11.2	8.8	6.6	15.8
20	18.4	19.8	12.1	14.3	8.5	4.1	8.8	7.6	14.3	10.6	9.9	14.7
21	17.3	17.7	10.8	10.6	9.9	4.6	7.7	5.6	11.0	11.0	13.0	16.2
22	18.5	19.7	13.2	13.3	7.5	5.6	6.6	6.2	12.6	14.1	8.1	19.5
23	18.3	15.8	16.0	14.1	9.3	6.0	7.9	2.8	13.5	15.9	6.3	17.2
24	18.3	16.1	14.3	4.6	9.3	6.7	7.5	7.2	10.3	14.7	12.9	16.2
25	19.8	18.8	14.7	6.5	9.2	5.6	2.6	10.3	10.1	17.8	15.7	17.8
26	18.0	16.9	14.2	8.9	7.3	5.1	5.3	9.9	13.5	17.9	12.7	21.2
27	17.9	16.9	14.9	11.9	5.6	5.3	8.6	11.7	14.4	8.8	14.6	18.9
28	15.8	14.8	14.5	7.6	3.3	7.3	3.3	10.2	16.1	11.9	16.0	20.1
29	16.2		14.8	4.3	1.4	4.0	2.2	10.0	15.0	13.5	14.8	19.8
30	16.9		15.0	4.2	0.4	2.7	8.8	11.3	16.9	13.6	15.2	16.1
31	16.3		13.0		1.1		9.0	11.1		11.5		19.7
AVE	17.3	17.0	15.1	9.6	6.5	3.6	4.3	6.8	11.3	12.9	14.6	17.5

0508047 0 MAFIKENG WO		MINIMUM TEMPERATURE								1998			TIME 08h00	
DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC		
01	17.9	18.8	17.1	15.8	9.9									
02	16.7	16.7	13.1	15.8	10.7									
03	14.6	16.8	10.9	13.5	10.0									
04	14.6	14.4	13.2	13.7	12.6									
05	16.9	16.2	16.4	14.4	10.5									
06	18.3	20.4	16.3	12.8	10.9									
07	17.5	19.5	17.5	12.9	10.2									
08	17.1	20.2	17.9	14.8	9.4									
09	19.4	17.7	17.6	13.4	7.6									
10	10.0	20.4	14.4	14.6	3.2									
11	11.4	19.5	15.4	15.2	0.5									
12	16.8	18.4	15.4	14.5	2.5									
13	15.5	20.4	13.8	13.9	2.2									
14	16.9	14.4	13.0	13.2	3.5									
15	15.6	20.0	15.4	13.8	0.1									
16	16.5	18.1	14.3	15.0	0.2									
17	19.8	15.4	15.3	13.4	4.9									
18	20.3	15.7	15.9	10.7	3.9									
19	16.3	14.5	18.1	10.2	2.8									
20	18.0	15.8	17.1	9.3	4.1									
21	16.7	15.1	18.0	10.2	3.1									
22	18.7	17.8	17.8	10.7	3.8									
23	18.2	16.4	17.0	13.6	6.4									
24	17.5	17.8	15.7	12.3	5.1									
25	15.9	17.3	16.0	13.7	7.5									
26	17.2	17.9	18.8	12.1	5.1									
27	18.0	15.4	14.8	10.7	5.1									
28	17.6	16.6	15.4	9.3	8.4									
29	18.0		16.4	10.4	0.6									
30	15.0		16.5	10.8	3.2									
31	18.7		15.8		5.3									
AVG	16.8	17.4	15.8	12.8	5.5									

Report Complete

TOT = 52,3 mm
YEAR/JAAR TOT = 873,8 mm

JAN 1998

1= 38,6 mm 2= 3,9 mm 3= 5,0 mm 6= 46,2 mm 7= 4,8 mm 8= 0,4 mm 13= 4,9 mm 14= 0,0 mm
18= 8,7 mm 20= 10,8 mm 21= 0,5 mm 22= 0,2 mm 23= 7,5 mm 29= 13,6 mm 30= 14,0 mm
TOT = 159,1 mm

FEB 1998

7= 1,0 mm 13= 20,4 mm 16= 1,1 mm 17= 55,0 mm 20= 0,0 mm
TOT = 77,5 mm

MAR 1998

6= 0,0 mm 7= 7,9 mm 8= 4,0 mm 11= 11,7 mm 12= 9,9 mm 13= 15,8 mm 25= 1,6 mm 27= 30,3 mm
28= 0,4 mm 30= 17,5 mm
TOT = 99,1 mm

APR 1998

11= 1,6 mm 12= 0,3 mm 16= 5,3 mm
TOT = 7,2 mm

MAY 1998

TOT = 0,0 mm
YEAR/JAAR TOT = 342,9 mm

Report complete / Verslag voltooi

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PERSON RECORDING: -----
SITE POSITION/DESCRIPTION:

COMMENTS: (Distance to cultivation, recent burn in area, rockiness, shrub density, site distance from drinking pt, fenceline contr., under big tree, protected/open

APPENDIX H

SPEARMAN'S RANK CORRELATION COEFFICIENT FOR MODEL A

SITE NO.	BIOMASS VALUE	RANK	DEGRADATION GRADIENT	RANK	DIFF. (d)	DIFF ² (d ²)
1	250.96	15	15	7	8	64
5	261.12	20	19	15	5	25
6	255.60	18	18,2	11	7	49
11	219.12	11	18,5	12	1	1
13	202.56	6	48	22	16	256
15	60.96	1	89,5	26	25	625
16	226.16	12	36	21	9	81
21	276.00	24	18,7	13	12	144
22	209.52	9	17,2	8	1	1
23	195.04	5	20	17	12	144
24	254.08	16	17,5	10	6	36
25	265.44	22	17,3	9	13	169
26	213.52	10	7	4	6	36
27	258.16	19	7,5	5	14	196
33	170.00	3	74	24	21	441
34	142.24	2	62	23	21	441
35	190.00	4	80	25	21	441
40	276.80	25	19,2	16	9	81
41	261.68	21	18,8	14	7	49
49	208.24	8	22	18	10	100
50	203.76	7	22,3	19	12	144
51	269.12	23	25	20	3	9
61	232.32	13	2	2	11	121
63	277.12	26	0	1	25	625
67	239.92	14	8	6	8	64
70	254.08	<u>16</u>	<u>2.2</u>	<u>3</u>	<u>13</u>	<u>169</u>
						4512

$$r = 1.0 - \frac{6 \times d^2}{n^3 - n}$$

Where d = difference between paired ranks

n = number of pairs of observations

$$r = 1.0 - \frac{6 \times 4512}{26^3 - 26}$$

$$= 1.0 - \frac{27072}{17550} = -0.543$$

Significance testing

The r_s value must be tested for significance using the t statistic and table available in most statistical books.

Thus,

$$t = r_s \sqrt{\frac{n-2}{1.0 - r_s^2}}$$

$$t = -0.543 \sqrt{\frac{26-2}{1.0 - 0.295}}$$

$$t = -0.543 \sqrt{\frac{24}{0.705}} = -3.17$$

The value of t has to exceed 2.49 in a one-tailed test at the level of 0.01 level. The t value for this model is -3.17, negative correlation between biomass and degradation gradient is highly significant.

APPENDIX I

SPEARMAN'S RANK CORRELATION COEFFICIENT FOR MODEL B

SITE NO	BIOMASS VALUES	RANK	DEGRADATION GRADIENT	RANK	DIFF. (d)	DIFF. ² (d ²)
7	273.32	25	14, 5	20	5	25
11	219.12	16	3	3	13	169
13	225.76	17	14, 2	17	0	0
28	85.76	2	70	25	23	529
29	90.00	3	56, 4	23	22	484
30	238, 72	21	15	21	0	0
31	70.56	1	60	24	21	441
32	100.40	4	55, 8	22	18	324
38	200.80	13	14, 3	18	15	225
39	193.04	10	14, 4	19	9	81
42	162, 16	5	3, 1	5	0	0
43	246, 08	24	4	9	15	225
44	193, 76	11	6	11	0	0
45	229.28	18	2	2	16	256
46	203, 44	14	4, 1	10	4	16
47	168.88	6	3, 6	7	1	1
48	174.40	9	13, 5	16	7	49
52	198.24	12	7	12	0	0
53	241.36	23	3	3	20	400
54	171, 44	8	0	1	7	49
55	238.56	20	3, 5	6	14	196
59	170.72	7	13	14	7	49
60	229.29	19	3, 7	8	11	121
65	246.24	22	13, 2	15	7	49
66	216, 32	15	12	13	2	<u>4</u>
						3693

$$r = 1.0 - \frac{6 \times 3693}{25^3 - 25}$$

$$= 1.0 - \frac{29262}{17550} = -0.263$$

Significance testing

$$\begin{aligned}
 t &= r_s \sqrt{\frac{n-2}{1.0-r_s^2}} \\
 &= -0.262 \sqrt{\frac{25-2}{1.0-0.069}} \\
 &= -0.262 \sqrt{\frac{23}{0.931}} = -1.30
 \end{aligned}$$

This model has the t value -1.30, the negative correlation between biomass and degradation gradient is once again significant.