VEGETATION CHANGE OVER FIFTY YEARS IN HUMID GRASSLANDS OF KWAZULU-NATAL (ACOCKS'S SITES)

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DECLARATION

I, David John Marriott, hereby declare that this thesis comprises my own original work except where due reference is made to the contrary. This thesis has not been submitted for examination at any other university or academic institution.

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CONTENTS

ABSTRACT

Eighty three of Acocks's sites, originally surveyed about 50 years ago, were resurveyed in 1996 to determine the extent of grassland change in the humid grasslands of KwaZulu-Natal. Sites were relocated using 1:10 000 scale ortho-photos and present land cover was determined for each site. Forty six of the sites that were still under original grassland were further examined to determine present species composition. A survey method was designed that would emulate Acocks's data and comparisons were drawn between original and present species composition. These differences were then analysed together with some environmental variables to try to determine the factors which had the most influence on the change and which environment and management factors are related to the present variation in composition among sites.

Of the 83 sites, 26 had changed from natural vegetation to some other form of agriculture such as forestry or cultivation. Most of this change had occurred in the Natal Mistbelt Ngongoni Veld where large areas are forested. Cultivation is found predominantly in the communal areas where subsistence cultivation practices are employed.

The remainder of the sites had changed significantly in terms of their species composition. The most pronounced change had occurred in areas under communal tenure although significant changes had occurred in the commercially farmed areas. The direction of change was also more consistent towards species that commonly predominate in heavily grazed areas in the communal areas compared to the commercial areas. The exact reasons for this were unclear but this could possibly be attributed to heavier stocking rates in the communal areas.

Change in floristic composition was also more pronounced at lower altitudes where the mean annual rainfall is lower and the mean annual temperature higher. This could possibly be a result of the

vegetation at lower altitudes being less stable and thus less resistant to change.

Basal cover differed significantly between commercial and communally grazed sites. Lower basal cover was found in the communal sites where intensive grazing limits the growth of individual tufts. Number of species found at each site did not differ significantly between communal and commercially grazed sites.

This study was also a practical implementation of the resurveying of Acocks's sites and the original data set was found to be a useful baseline data set to determine coarse long-term changes in the vegetation.

1. INTRODUCTION

An ideal opportunity arose to determine long term change in South African vegetation by using Acocks's (1953) data and comparing it with data collected recently. Acocks's (1953) data sets were both consistent and reliable (Westfall *et al.* 1996) and covered the entire country with over 2700 sites which were said to be representitive of local vegetation in good condition (Acocks 1953; Westfall *et al.* 1996). Much of the resurveying of the original sites has not been attempted, however, and whether or not the data are worthy of use as a baseline set is a question which needs to be addressed. The study was, therefore, designed as an attempt to gain insight into long-term grassland compositional change using Acocks's data as a baseline. Little work has been done using Acocks's (1953) data set as a baseline due to technical difficulties associated with his methodologies. These will be discussed later.

Compositional change has been recognised as an intrinsic property of vegetation (Acocks 1955; Hellawell 1977) and may be caused by many factors which can be grouped in one of three main categories - vegetation, climate or anthropogenic induced change. This project is concerned with the anthropogenic and climatic influences as these both contain measurable variables which are easily quantified. Thus their effect on the vegetation can be measured.

The veld types examined included the Highland Sourveld, Natal Mistbelt Ngongoni Veld, Northern Tall Grassveld and Southern Tall Grassveld (Acocks 1953). These are some of the humid and sub-humid grasslands of KwaZulu-Natal. These grasslands support large numbers of livestock under both communal and commercial tenure and are thus of economic importance to the livestock industry. It is therefore important that these grasslands are sustainably utilised to ensure continued production. Owing to past management strategies of farmers in both communal and commercial areas, it can be expected that the grasslands may have changed in composition as a result of heavy utilization or they may have remained in a similar state to what they were 50 years ago where the veld has been "well managed." One of the hypotheses posed for this study was that grasslands under communal tenure have changed considerably more than grasslands under commercial tenure because of different management strategies. These are discussed later (Chapter 2). There is some controversy about this hypothesis (Tapson 1993) but there is a dearth of information on long-term grassland compositional change which supports either side of the argument. This study was designed, in part, to address this.

The second hypothesis posed was that change would have occurred to a greater degree in areas where the climate is less stable (*i.e.* where the temperatures are, on average, higher and the rainfall, on average, lower). Information supporting this hypothesis is available (Holling 1973; Friedel 1991; Laycock 1991).

The objectives of this study were, therefore, to:
1) determine the magnitude and direction of change in the study grasslands during the time since the original survey;
2) determine the environmental variables which have influenced this change; and
3) test the usefulness of Acocks's (1953) sites in determining long term changes in the vegetation.

2. THE INFLUENCE OF BIOCLIMATIC AND MANAGEMENT FACTORS ON GRASSLAND COMPOSITIONAL CHANGE: A LITERATURE REVIEW

2.1 Introduction

Change in grazing lands has been noted world-wide (Venter 1968; Tainton 1972; Downing 1974; Archer 1989; Gibson & Brown 1992); these have been ascribed to anthropogenic factors or impacts in many cases. There are three factors, vegetation succession, climate and man-imposed impact, which interact to determine the amount of change in the vegetation.

Vegetation may change via succession (Clements 1916) which is the tendency of vegetation to head towards a state of equilibrium, in terms of species composition, with the environment or via external forces. In other words succession may cause the vegetation to change in relation to environmental factors.

Climate influences the vegetation through determinants such as rainfall, temperature and irradiance. Vegetation is largely dependent on climate for its stability (Holling 1973). In drier climates, species shifts in vegetation communities are due largely to variabilities (especially rainfall) associated with arid climates. In the moister regions the reduced variabilities in climate create or encourage a more stable ecosystem (Holling 1973). In South Africa moisture is the main factor limiting plant growth (Tainton 1988) and the degree of fluctuation in the rainfall of any particular area is pertinent to the stability or resilience of the vegetation. Stability can be defined as the ability of an ecosystem to withstand disturbance or impact and resilience may be defined as the ability of an ecosystem to "bounce back" after disturbance or impact has already changed it (Holling 1973; Friedel 1991; Laycock 1991).

Man-imposed impact, through management factors such as grazing intensity and fire management, may have an important effect on the composition of a grass sward. With an increasing human population the effective management of the forage resources is imperative to optimise food production off the veld. Anthropogenic impact has been blamed for the deterioration of the grasslands in terms of soil erosion and reduced livestock production (McKenzie 1984). The effect of man's impact may differ depending on environmental factors to create a greater or lesser amount of change depending on the climatic conditions.

For the purposes of this review degradation is related to animal production and it is therefore defined as a decreased ability of the sward to maintain livestock (Tainton 1988). This degradation can happen with a change from palatable to unpalatable grass species or a high amount of soil erosion which in turn results in the invasion of relatively unpalatable species or species which have a low yield. Degradation may, or may not, be irreversible.

The objective of this literature review is to outline some bioclimatic and management factors to see what effect they have on the vegetation and how they could interact with each other to cause change in the humid and sub-humid grasslands of KwaZulu-Natal.

2.2 Management Factors

2.2.1 Grazing Impacts

The type of grazing can have a profound effect on the status of the vegetation (Tainton *et al*. 1978). Grazing systems in South Africa can be divided into three categories *viz*. rotational grazing, rotational resting and continuous grazing. Within each of these categories are a number of other factors which have to be taken into account such as stocking rate and burning regime. The vegetation status or, in this case, the degree of change (in terms of species composition) depends on the combination of these variables.

Species compositional change, due to management factors, may result in different communities depending on bioclimatic factors such as rainfall, temperature, light and soil type. The interaction of these factors may encourage species which are adapted to the new combination of factors.

Booysen (1969) examined the theory behind the different types of grazing systems. It is appropriate that these are understood before the problems of each system are looked at.

Rotational grazing was proposed in an attempt to minimise the amount of selective grazing in a sward. Selective grazing is the process whereby animals select for the more palatable plants or patches in the sward before they select the poorer quality ones (Booysen 1969). This can result in the domination of the sward by the less palatable species (Tainton 1972; Hatch & Tainton 1993; Lutge 1995). Selective grazing causes a decrease in sward palatability and thus a drop in production *per* hectare (Tainton 1972; Hatch & Tainton 1993) by encouraging an increase in species such as *Elionurus muticus* (Opperman *et al*. 1974) and *Aristida junciformis* (Venter 1968; Tainton 1972) that are relatively unpalatable to livestock.

Rotational grazing systems are very popular in the grasslands of KwaZulu-Natal. Booysen (1969) suggests that the reason why South Africa is one of the few countries which uses this approach is because of the variability in the palatability of species found in the grass swards. This is generally greater than that of other countries (*e.g.* USA and Australia).

In theory the way in which rotational grazing aims to overcome the problem of selective grazing is to heavily stock smaller camps so that the animals are forced to graze all of the species present to some degree before they are moved on to the next camp. In this way all the plants are grazed thus allowing them all to have equal competitive advantage during their rest period (Booysen 1969). This is known as High Utilization Grazing. The other form of rotational grazing is the High Production Grazing which is also designed to minimise the effects of selective grazing but the animals are taken out of the camps while there is still enough leaf material on the palatable plants to enable rapid regrowth. The palatable plants would, therefore, not be at too much of a disadvantage compared to the unpalatable species when the camp is left to rest (Booysen 1969).

Rotationally grazed areas, if overstocked, become increasingly selectively grazed resulting in the decline in the vigour of the desirable species and the relative increased vigour and competitive ability of the Increaser III grasses such as *Aristida junciformis* and *Elionurus muticus*. This once again results in the sward becoming dominated by these species (Tainton 1972; Morris *et al.* 1992).

Grasses which predominate in well managed veld are termed Decreasers. Increaser I species dominate veld which has been under-utilised and the opposite is true of Increaser II species. Increaser III species are those which invade a grass sward under selectively grazed conditions.

Tainton (1972) blamed overstocking for the encroachment of *Aristida junciformis* into many areas of the Tall Grassveld (Acocks 1953) of KwaZulu-Natal. This is one of the main problematic species as far as stock production is concerned. It has little forage value due to the high tensile properties of the leaves which animals find difficult to break (Tainton *et al.* 1976). Venter (1968), Edwards *et al.* (1980) and Tainton *et al.* (1976) all stated that it is an incredibly difficult species to eradicate using conventional management practices such as grazing and fire. *Aristida junciformis* has invaded large proportions of the mistbelt of KwaZulu-Natal (Acocks 1953) as well as heavily grazed communal areas in the Highland Sourveld (Acocks 1953). In the Tall Grassveld it is said to invade areas which have been selectively grazed (Tainton 1972).

The introduction of rotational grazing in areas which have been continuously grazed could also cause bush encroachment. In the Ciskei rotationally grazed areas have become encroached by *Acacia karroo* due to the opportunity for the seedlings to develop during the rest period (Forbes & Trollope 1991).

In the Tall Grassveld (Acocks 1953) Tainton *et al.* (1978) found that medium to lightly grazed (in terms of the local recommended stocking rates) rotational grazing systems maintained high veld condition scores.

Rotational resting is the process whereby the plants are left to rest for a full growing season. The value of resting veld has been recognised by many commercial farmers and it serves to allow the plants in the sward to regenerate their carbohydrate reserves and other physiological processes which may have been depleted during the periods of grazing (Booysen 1969; Tainton 1988). Camps which are not being rested are grazed rotationally or continuously. Not allowing the plants to rest could result in a decline in sward vigour and thus the invasion of undesirable species. This would be the result of the grazing animals' continual selection of the more palatable species which would deplete the plants' vigour and allow the less palatable species a competitive advantage. Morris *et al.* (1992) found invasion to happen in the Tall Grassveld (Acocks 1953) of KwaZulu-Natal where *Aristida junciformis* invades swards which have been continuously grazed and then left for a full season's rest. They speculated that this could be a result of decreased vigour of the palatable species. Tainton *et al.* (1978) found that rotationally rested camps under light utilization did not detrimentally affect the sward while medium and heavy use did.

Continuous grazing implies that the camp is grazed for an entire season at a time and given no rest during the growing season. This system requires the least management from the point of view of having to move cattle around and watching the veld to see when it is time to remove the animals. Continuous grazing has generally been denounced as a feasible grazing system in South Africa due to the lack of productivity which can be gained under good management practices. Morris *et al*. (1992) showed that under heavy continuous grazing "Mtshiki" species such as *Eragrostis curvula, Eragrostis plana* and *Sporobolus africanus* dominate the sward. These species, although containing little nutritive value relative to some other species such as *Themeda triandra*, tend to form a stable community and maintain a reasonable basal cover (McKenzie 1984). McKenzie (1984) found that many communally grazed areas in the Transkei, although under heavy stocking rates, still maintained a high proportion of "grazing/fire" climax species which are palatable to livestock. Booysen (1969) stated that under heavy continuous grazing swards may contain a high proportion of "climax" species but the vigour of the sward declines resulting in a decreased carrying capacity. Tainton *et al*. (1978) found that heavy continuous grazing had a detrimental effect on the veld condition. If stocking rates in these sourveld areas had to be reduced due to increased veld management awareness, the sward would become dominated by less desirable species due to increased selective grazing (Forbes & Trollope 1991).

Continuous grazing has in the past been considered to cause veld degradation but Booysen (1969) proposed that it was not continuous grazing *per se* but rather incorrect stocking rates applied in this manner that caused the damage. Booysen (1969) stated that heavy continuous grazing resulted in a decline in sward vigour and medium stocked continuous grazing resulted in selective grazing. Lightly stocked continuously grazed swards do, however, encourage *Aristida junciformis* invasion and Tainton *et al*. (1978) suggested that although the veld condition score was quite high, suggesting no detrimental change, it would decline sharply in the future owing to the apparent presence of *Aristida junciformis* in the sward.

In the Tall Grassveld (Acocks 1953), overgrazing results in swards dominated by Increaser II species such as *Eragrostis* *plana, Sporobolus africanus* and *Eragrostis curvula* (Morris *et al.* 1992). The grass community is, however, less stable than those found in higher rainfall regions (Tainton 1988) and bare trampled areas are often invaded by species such as *Cynodon dactylon, Eragrostis curvula, Eragrostis plana, Sporobolus africanus* and *Sporobolus pyramidalis*. If these areas are subsequently leniently grazed they become dominated by *Hyparrhenia hirta*. This sward may remain like this for many years before it becomes invaded by species such as *Themeda triandra* (Tainton 1988).

The impact of grazing on the KwaZulu-Natal grasslands may be summarised as follows. Heavy continuous grazing affects the sward by reducing the vigour of all the species, especially the desirable ones, resulting in the invasion of grazing tolerant species such as *Sporobolus africanus* and *Eragrostis plana*, otherwise known as Increaser II species. In some areas the proportions of palatable species are still quite high but their production is low, resulting in low livestock productivity. If the grazing pressure is lifted, invasion by Increaser III species tends to occur and the swards become dominated by species such as *Aristida junciformis* and *Elionurus muticus* (Morris *et al.* 1992).

Areas of veld under medium and heavily stocked rotational seasonal resting systems deteriorates due to the reduced vigour of the palatable plants, thus allowing the invasion of *Aristida junciformis*. This deterioration is worse than that in continuous grazing systems because invasion by *Aristida junciformis* occurs during the rest period, especially in spring, resulting in rapid deterioration. The same effect would occur in continuously grazed areas if the grazing pressure had to be lifted (Tainton *et al.* 1978).

In theory, rotational grazing is the system most likely to maintain the sward in a reasonable condition because uniform use of the vegetation is the objective, thus allowing all the plants to compete equally due to reduced selection of palatable species by livestock.

There are two broad categories of graziers in South Africa - communal and commercial graziers. These two categories differ in a number of ways but the fundamental difference lies in the approach of the farmers to animal production. Communal graziers, whose stock graze on communally owned land, strive for quantity of livestock as opposed to quality of livestock (Trollope 1985). This approach is due to the status associated with owning a large number of animals and the various uses communal farmers have for their livestock as opposed to communal livestock which are essentially used for meat and milk production. Livestock in communal areas are used for traditional ceremonies such as weddings, funerals and "lobola" and activities such as draught power for ploughing and transporting materials (Trollope 1985). The animals are also used for food products such as meat and milk. Commercial farmers, on the other hand, have to make their livestock production economically viable. This requires them to maintain sustainable grazing resources to ensure long term productivity of high quality animals produced off the veld. This could be seen as the production of quality as opposed to quantity of animals.

Grassland areas in South Africa have had a history of high grazing pressure. Large proportions of the land in the Ciskei and Transkei are utilized by grazing animals. Trollope (1976) estimated that 67% of the Ciskei was overstocked. In communally grazed areas of the Transkei and Ciskei the stocking rates are said to be 2.7 times the recommended stocking rates in some areas (McKenzie 1982). This heavy stocking intensity has impacted considerably on the vegetation (McKenzie 1984) but despite this there is no literature to support the fact that livestock numbers have declined. In fact animal numbers seem to be quite stable in these areas (Bembridge 1979; Tapson 1993). In the Ciskei (and probably in many other communally grazed areas) the veld degradation problem is further exacerbated because although there are certain recommended carrying capacities, these are for veld in good condition and the actual carrying capacity of the overstocked veld is far lower than these recommendations (Forbes & Trollope 1991).

Communal grazing lands are continuously stocked in most areas (Booysen 1969) and the more palatable plants, therefore, have little or no chance of rejuvinating vigour. The combination of the overstocking and the continuous grazing has resulted in vast areas of degraded veld and extensive soil erosion (Tainton 1972; Tshotyana 1986; McKenzie 1982; McKenzie 1984; Forbes & Trollope 1991).

Trollope (1985) proposed three basic factors which are responsible for the heavy stocking rates in the communal areas.

1) Socio economic factors: A large proportion of the people in the communal areas attempt to farm cattle due to the status associated with it and the other uses cattle fulfil in communal societies. This results in sub-economic units of land being available to most of the farmers because the same amount of land has to be divided up among many farmers. Compounding this effect is the high population growth in the rural areas which places even more pressure on the grazing lands, for two reasons. The first is that the demand for cattle increases with the increase in population and the second is that with increasing population more space is required for housing and cropping, thus reducing grazing area.

2) Incorrect land use: Trollope (1985) suggests that the majority of the population do not have the knowledge to be efficient farmers due to their lack of formal training in agriculture. In commercial grazing systems farmers have to manage an economically viable system otherwise they face bankruptcy or other associated problems. A system of natural selection exists, therefore, which ensures that only the farmers which manage to maintain their veld in a productive state can remain on the land. This is not the case in the communal areas. The lack of financial input on the

part of the grazier provides little incentive for the farmers to make the farming economically feasible. In the past rural communities have had much of their farming infrastructure such as fencing, watering points and dipping tanks supplied by the government. Commercial farmers have also had access to subsidies in the past. They do, however, have to provide much of their own funding for their operations. This once again poses the question of objectives: "Are the present veld management strategies employed by communal farmers effective in achieving their objectives and could their objectives be achieved using alternative strategies?"

3) Land tenure: There was, in the past, little negotiability of agricultural rights for buying and selling land in the communal areas (Trollope 1985). This allowed anybody who owned stock, free access to grazing lands thus imposing large grazing pressure on the land. Grazing rights in communal areas are often subject to the local chief's decisions. These rights have recently been revised under the new constitution regarding land tenure and many communal farmers now have the opportunity to own their land as individuals. It was in each stockman's interest to put his cattle on the lands for as long as possible to maximise his returns in terms of livestock numbers. Bembridge and Steyn (1987) found that general stock management strategies employed in communal areas (such as culling, selection, internal parasite control and supplemental feeding) were minimal if not non-existent in communal areas. This was attributed to lack of knowledge and access to expertise (Bembridge 1987).

Tapson (1993) suggested that many of the pre-conceived ideas about the extent of overgrazing in the communal areas may be a result of premature or ill-informed statements. He also suggested that the estimates of the stocking rates in the communal areas may be erroneous and exaggerated. The high stocking rates in the communal areas are more beneficial to the land-owners than stocking at the "optimum" stocking rates because of the different objectives of the communal farmers (Tapson 1993). Herd counts in

KwaZulu-Natal seem to have been stable or even increased slightly over the past 20 years and mortality has, in that time, been reduced (Tapson 1993). Is this an indication that the veld condition has not deteriorated? This question needs to be addressed with empirical evidence of which there appears to be a dearth at present.

So far the rationale behind, and the impacts of, communal grazing have been discussed in the context of grazing strategy and stocking rates. The main effects of communal grazing are the degradation of the vegetation and the soil and this may be attributed to a combination of heavy stocking rates and a continuous grazing strategy.

The other aspect of grazing is commercial grazing which is not without its problems. Many commercial farmers use a rotational grazing system in the KwaZulu-Natal grasslands (pers. obs.) and, in thoery, this is said to cause the least amount of damage to the sward assuming that the correct stocking rates are applied (Booysen 1969).

Although in most commercial systems better veld management is applied due to the need to manage an economically viable operation, these systems, if not managed properly, also lead to detrimental changes in the species composition in the grass swards. Selective grazing tends to be more of a problem than overstocking in the sourveld areas under commercial grazing systems (Booysen 1969).

The problems discussed thus far generally result from overstocking and, with the appropriate stocking rates applied, there is no evidence that any grazing strategy has a detrimental effect on the species composition of the veld.

2.2.2 Fire

Fire is used as a management tool for a number of reasons. These include the removal of moribund material, a uniform defoliating agent, and the control of bush encroachment. The humid grasslands in this study were termed "fire climax grasslands" (Acocks 1953) meaning that they evolved under a regime of natural fires and the present species composition, therefore, requires fire to maintain it. Different species differ in their tolerance of fire (Tainton 1988) and therefore the manner in which fire is applied to the sward will affect the composition of the sward.

Fire can be applied in different seasons and at different temperatures depending on the objectives. "Hot" fires (those applied at times of the day or season when the herbage is dry giving rise to rapid intense burning) are often used for the control of bush encroachment and "cooler" fires (those burns applied when moisture content of the vegetation is relatively high thus limiting the rapid combustion of the vegetation) are often used to clean up moribund material while avoiding the destruction of the shoot apices of the grass plants.

Fire management differs between communal and commercial areas. Communal farmers tend to burn in summer (TM Everson pers. com. University of Natal, Private Bag X01, Pietermaritzburg, 3201) as opposed to commercial farmers which nowadays tend to burn in spring or winter. The burning strategy in communal areas tends to be random burning of small patches (TM Everson pers. com.) but the reason for this is unclear. It could possibly be to encourage fresh growth in areas where the plants have become moribund (which is unlikely in communal areas) or where the plants are unpalatable and can only be grazed when the growth is fresh (*e.g. Aristida junciformis* dominated areas). In commercial areas burning strategy is often done on a rotational system to fit in with the rotational grazing or resting strategy.

Everson and Tainton (1984) conducted an experiment on burning and mowing of the Highland Sourveld (Acocks 1953) with the following objectives:

1) to maintain high water quality and the preservation of the soil;
2) to maintain high faunal and floral diversity and
3) to prevent the extinction of any component species.

Although they only tested burning in winter and spring at various intervals some interesting results were shown. In plots which were protected from burning the proportions of species such as *Themeda triandra, Heteropogon contortus* and *Trachypogon spicatus* all decreased with a corresponding increase in the proportions of species such as *Tristachya leucothrix, Alloteropsis semialata* and *Harpochloa falx*. The important grazing grasses thus decrease under conditions of under-defoliation and are replaced by grasses which are less useful in terms of their animal production potential (Everson & Tainton 1984).

Frequent defoliation (*i.e.* annual winter burns and annual spring burns with light mowing) resulted in a high proportion of Decreaser species relative to Increaser species. Decreaser species are species considered to be indicative of veld under well managed conditions whereas Increaser species are species which increase in abundance under conditions of under- or over-utilization (Tainton *et al.* 1978). In the plots burnt less frequently, or after spring burning with no mowing, the Increaser I species began to dominate at the expense of the more agriculturally important species (*i.e.* Decreaser species).

None of the treatments allowed for the increase of the Increaser II and III species because there was no over utilization of the sward.

One of the aspects they discussed was the concept of species shifts. The species which became dominant in any treatment were already present in the sward but could be quite rare. In other words, under conditions of underutilization species such as

Alloteropsis semialata and *Harpochloa falx*, although relatively rare in a well managed sward, become dominant because the underutilized conditions suit their growth conditions more than species which dominate and thrive under well managed conditions. This implies that invasion did not necessarily occur but there were just shifts in composition.

They concluded that to maintain a sward that has a high proportion of Decreaser species (important grazing species), burning in the Highland Sourveld (Acocks 1953) should occur more often than biennially. In grazing systems, however, where the sward is already being defoliated by livestock, this is not usually possible because there would not be enough material in the sward to burn. In such cases, biennial burning would be sufficient.

Edwards (1969) conducted a study on burning regimes in a similar environment (Giants Castle Nature Reserve). He looked at the effect of burning frequency and season and examined the effects of these burning regimes on the relative proportions of palatable and unpalatable species. His study differed from Everson and Tainton's (1984) in that the effect of autumn and summer burns was also examined. The burns which yielded the highest proportions of palatable grass species were the biennial spring and the annual winter burns. The least number of palatable species were found under the alternate autumn-winter and biennial autumn burns. Unpalatable species had high proportions in the triennial spring and biennial summer burns and low proportions in the annual winter and alternate autumn winter burns.

The question arises, "which species are unpalatable in the different burns?" Extrapolating from Everson and Tainton's (1984) work it would be fair to assume that the unpalatable species mentioned in the triennial spring burn would equate to some of the Increaser I species (species which increase in abundance in under-utilized conditions). Looking at these results one can see that the autumn burning is likely to decrease the palatability of the sward. HKS Agriland (1988) suggested that burning in summer encourages the invasion of wire grasses which would include species such as *Aristida junciformis, Elionurus muticus* and *Diheteropogon filifolius*. Similar effects would be found in autumn due to the stress imposed on the plants by fire when they are trying to translocate carbohydrate reserves to their stem bases and root systems.

Thus far it has been said that either winter or spring burns would be the most beneficial to the veld by maintaining high proportions of Decreaser species. As far as soil erosion is concerned the most suitable is the spring burn due to the decreased risk of soil erosion from wind and rain (Edwards 1969; HKS Agriland 1988). Everson (1985) showed that, in the Highland Sourveld (Acocks 1953), burning biennially in spring rendered the soil more susceptible to erosion than annual winter burns because the soil is exposed to most of the spring rains before the grass recovers whereas the veld burnt in winter recovers quickly in spring thereby avoiding erosion by most of the spring rains. To burn in winter or spring would therefore depend on the main erosion factor of the area. In areas where the main erosion factor is water or rainfall, burning in winter would be advocated and in areas where wind is an important erosion agent, burning in spring would be advocated.

Other objectives of burning have included the encouragement of certain woody species (*e.g. Protea* woodlands in the KwaZulu-Natal Drakensberg). Mentis *et al.* (1974) suggested a summer burning regime for this purpose because a summer burn is not as detrimental to woody plants as it is to grasses due to the reduced intensity of the fire in summer compared to a winter burn. It was, therefore, proposed that a biennial summer burn should be applied (Mentis *et al.* 1974).

Morris *et al.* (1992) found that the introduction of periodic spring burns to variously managed grazing areas encouraged the sward to tend towards a *Themeda triandra* domain from one which was dominated by Increaser II species. The only exceptions were the heavily utilized, rotationally rested and continuously grazed camps. These treatments did not respond to a rest and burning regime but remained stable communities dominated by *Aristida junciformis*.

From the above evidence it can be seen that fire can advantage or disadvantage the manager depending on how it is used. Burning objectives have to be clearly outlined before the burning regime is implemented. Autumn and summer burns generally act to the long-term detriment of the stockmen whereas they might aid in certain nature conservation objectives. Spring and winter burns are the best for grazing animals production. The omission of fire in the fire climax grasslands of KwaZulu-Natal can only act to the detriment of the stockman because the veld becomes dominated by species which are not fire tolerant and in these veld types these are generally species which are less palatable (Edwards 1969; Everson & Tainton 1984). Even in the case of correct management where fire is omitted, the sward becomes selectively grazed and dominated by Increaser III species.

Although this study does not take the different burning regimes into account, it must still be realised that fire may contribute considerably to the composition of the grass sward. The above evidence shows that fire has a powerful effect on the sward - both on its own and in combination with other defoliation factors such as grazing. It cannot, therefore, be ignored as a contributing factor in the determination of vegetation change.

2.3 Bioclimatic Factors

Although climatic changes can change vegetation either very rapidly (in the case of floods or some other major perturbation) or slowly (in the case of global climatic change) these aspects are not pertinent to this study. The climatic influences that are important in this study are those which influence the sensitivity of the grasslands to change resulting from anthropogenic factors.

2.3.1 Temperature

Plant survival depends largely on the fluctuation of temperatures as opposed to the mean annual temperature (Tainton 1988). It is for this reason that certain species are found only in some areas. The range of temperature between seasons tends to increase with increasing altitude (Phillips 1969; Tainton 1988). Species such as *Harpochloa falx, Alloteropsis semialata* and *Rendlia altera* are found in areas with low mean annual temperatures and high inter-seasonal range of temperatures. In areas with a lower range, and generally higher mean annual temperatures, species such as *Urochloa mosambicensis, Panicum maximum* and *Bothriochloa insculpta* are found (Tainton 1988). This is essentially a gradient from the Highland Sourveld (Acocks 1953) to the Lowveld (Acocks 1953). There is, however, not much difference between the inter-seasonal temperature range between the humid and sub-humid grasslands of KwaZulu-Natal and the species composition of these grasslands is thus very similar.

2.3.2 Moisture

Rainfall is the main climatic factor which influences the distribution of vegetation in South Africa (Tainton 1988). This is because in most areas in South Africa moisture is a limiting factor for plant growth (Tainton 1988). Where moisture is not limiting, temperature generally is limiting (*e.g.* montane grasslands in the Drakensberg mountains). Evaporation losses are generally high in South Africa (Schulze 1982). It can be assumed that species which are found at lower altitudes in the KwaZulu-Natal grasslands have adapted to lower moisture regimes due to the correlation between altitude and rainfall (see Chapter 5). This is only relevant to the inland grasslands and coastal grasslands may have different characteristics. The negative correlation between altitude and temperature would also influence the species distribution due to the relatively higher amount of evaporation which would occur at lower altitudes where the temperatures are higher. The combination of rainfall and temperature is, therefore, of importance when discussing the distribution of grass species. Roberts (1971) named species which are generally found at lower altitudes. These include *Aristida congesta* subsp. *barbicollis, Cynodon dactylon* and *Eragrostis chloromellas*. He did, however, state that these species were probably a result of overgrazing rather than simply altitude. The intermediate grass species (*i.e.* species which are found throughout the grassland types in a high proportion of the sward) include *Brachiaria serrata, Cymbopogon excavatus* and *Hyparrhenia hirta* (Roberts 1971) and the higher altitude grasslands have species such as *Andropogon appendiculatus, Eragrostis racemosa, Eragrostis capensis, Helictotrichon turgidium, Melinis nerviglumis* and *Melinis repens*. Apart from a few exceptions the humid grasslands in KwaZulu-Natal are similar in terms of their species composition despite their climatic differences. One does find, however, that certain species will prefer certain climatic regions but this does not exclude other species from the sward. The differences between the Veld Types (Acocks 1953) occur in their relative abundances of species and in terms of their "climax" vegetation. The woody components of the grasslands differ considerably especially between the humid and sub-humid grasslands. The Highland Sourveld and the Natal Mistbelt Ngongoni Veld (Acocks 1953) have a temperate forest climax vegetation with species such as *Podocarpus latifolius, Halleria lucida* and *Kiggelaria africana* (Acocks 1953) dominating the forest community whereas the Tall Grassveld areas (Acocks 1953) have more of a savanna climax vegetation with *Acacia sieberana* and *Acacia nilotica* present.

2.3.3 Soils

This section in itself could cover a wide variety of topics such as erodibility, nutrient status and moisture retention ability. This review, however, outlines the important factors which may affect the production and compositional change of a grass sward. For this purpose I consider it important to look at the erodability potential of soils because certain grass species are associated with eroded or shallow soils (Gibbs Russell *et al.* 1991). The other aspect to look at is the moisture retention ability of soils because some grass species are associated with wet soils whereas other species are associated with dry soils (Gibbs Russell *et al.* 1991).

The nutrient status of the soils may also affect species distribution. In the higher altitude areas, owing to the higher rainfall, the soils are relatively deficient of nutrients as a result of leaching. The drier areas have less of a leaching effect and the soils in these regions could be expected to have a higher nutrient status (Phillips 1969).

Phillips (1969) outlined certain soil characteristics which exist in the various study regions. The first region is the Coast Hinterland which equates approximately to the mist belt area described by Acocks (1953). The soils in this region have the potential for erosion although, if correctly managed, they can be very productive for many agricultural crops. Inadequate drainage is also a problem and the soils tend to be quite infertile due to the high moisture in the region.

The second region is the Highland to Submontane region (Phillips 1969). This is approximately equivalent to Acocks's (1953) Highland sourveld. The soils are leached of most of their nutrients and tend to be quite acidic. Erosion is most prevalent on the steeper slopes but they generally can withstand a fair amount of anthropogenic pressure before they begin to erode.

The third is the Upland Moist region (Phillips 1969). This could be considered a combination of the Highland Sourveld and Southern Tall Grassveld (Acocks 1953). This region is slightly drier than the previous two groups and the soils are more susceptible to erosion if not carefully managed. Drainage tends to be a problem due to the plinthite which is common in these areas.

The fourth is the Upland Drier region (Phillips 1969). This area is similar to the Tall Grassveld (Acocks 1953) areas. The climate is somewhat drier than any of the previously mentioned regions. The base status of these soils is higher due to the lower rainfall and the large amounts of Dolerite parent material found here. The soils are difficult to conserve and to cultivate. Duplex soils are common and these are particularly prone to moisture stress and erosion by wind and water. Under heavy grazing pressure or poor cultivation which exposes the soil for too long, the soils are very easily eroded by wind and rain (Phillips 1969).

Thus, one would expect the Tall Grassveld (Acocks 1953) areas under heavy grazing, to contain large proportions of species which are adapted to shallow or eroded soils. This is due to these soils being particularly susceptible to erosion. In the other study grasslands the soils are not as susceptible to erosion hazards and as a result one would expect to find, under heavy grazing conditions, species which need not necessarily be adapted to shallow or eroded soils. Under extreme grazing conditions, however, species adapted to shallow or eroded soils would still be present in the sward.

2.4 Conclusion

Climatic factors affect the species distribution in combination with man-imposed impacts. Climatic and management factors combine to create a specific environment and the species which are best adapted to that environment colonise the area and succession develops until the local conditions are unsuitable for further development (Clements 1916). The combination of factors such as temperature and rainfall may encourage species which are either adapted to dry or moist conditions. Generally the species composition in the humid grasslands of KwaZulu-Natal is similar in terms of species presence since there is not enough climatic variation to allow a totally different vegetation type to colonise. The species' relative abundances, however, may differ depending on how the individual species are adapted to the microclimate of the area.

There are two factors which account for the distribution of species *viz*. climate and land use. Land use may be the important factor in deciding the distribution of species if the impact is intense enough. For example, burning at the "wrong" time of year has been shown to affect the species composition and imposing the incorrect stocking rates on the veld can also have detrimental effects. What happens then is that the species become distributed in relation to the land use as opposed to the bioclimatic variables. This is especially true in the humid grasslands where, as mentioned before, the species distribution is quite similar. The effect of climate cannot be overruled because the drier warmer areas tend to be more sensitive to change, so one would expect, given the same land use intensity, to find greater change in the drier areas than the moister areas of the grasslands *i.e.* the interaction between perterbation and climate is important. The same impact may have a different effect in different environments.

3. OVERALL LAND COVER CHANGE

3.1 Introduction

A large proportion of the grasslands in KwaZulu-Natal has been aforested or cultivated (Scott-Shaw *et al.* 1996). This is especially evident in the more humid areas which are suitable for crops such as pine trees, gum trees and sugar cane. Not only does this have consequences for the livestock industry but it also has implications for hydrology, soil and biodiversity conservation. The objective of this chapter is to outline the extent of loss of KwaZulu-Natal grassland to agricultural cultivation practices and forestry by examining proportions of the original grassland sites surveyed by Acocks (1953).

The original sites (Acocks 1953) were all grassland which was considered to be in good condition and representative of the grassland which was described (Acocks 1953). An ideal opportunity, therefore, existed to determine what percentage of these sites was still under natural grassland and what percentage of the sites had, in the last 50 years, been aforested, cultivated or settled. Although this study in no way claims to give accurate figures of the extent of the gross land-use change, it provides an indication of the trend of such change.

3.2 Methods

The 83 sites in the humid and sub-humid grasslands of KwaZulu-Natal were relocated using 1:10 000 orthographic photographs. The sites were those originally used by Acocks (1953) in the classification of the grasslands. Acocks (1953) selected the sites on the basis that they were representative of the local vegetation. The coordinates of each site (Appendix 1) were obtained *via* the Range and Forage Institute from the original maps which were used by Acocks (1953). The land-use for each site was visually determined upon examination of the ortho-photographs. The dates of the ortho-photos varied but most of them were produced around the mid to late 1980's.

The categories of land cover were natural grazing, forestry, cultivation and settlements and these could easily be distinguished by examining the ortho-photos. These different land cover categories were also apportioned to the respective veld types (Acocks 1953) to examine which veld types had undergone the greatest degree of land cover change.

3.3 Results

3.3.1 Present land cover

Table 3.1 shows the percentages of the different land cover types as measured in 1996 and the trend appears to be that large proportions of the KwaZulu-Natal grasslands have been afforested. Cultivation has also taken up quite a lot of the grassland. Settlement, however, has taken up very little of the grassland. This may be due to the fact that Acocks's sites were originally quite far away from settled areas. In some cases grassland is still present near rural settlements.

Table 3.1: Percentage of sites presently under certain land use practices.

Present land use	% land use
Natural grassland	69
Forestry	17
Cultivation	12
Settled	2

Certain Bioclimatic Groups were more prone to gross land use change (*e.g.* forestry and cultivation) owing to their wetter climates and the nature of their soils (Phillips 1969). From the results shown in Table 3.2 it is evident that the climates which are suited to plantations are those of the moist areas *e.g.* Natal Mistbelt Ngongoni Veld and the Highland Sourveld (Acocks 1953).

The Northern Tall Grassveld (Acocks 1953) was the most prone to other forms of cultivation and in some of the higher altitude sites in this veld type forestry was also evident (pers. obs.) although it was not adequately described by the results. The veld type which had the least disturbance as far as cultivation is concerned was the Southern Tall Grassveld (Acocks 1953). This is probably due to the unsuitability of the climate and soils for cultivation (Phillips 1969). In the past this area was, however, extensively cultivated (Acocks 1953) to the detriment of the landscape. Soil erosion is very prevalent in this veld type.

Table 3.2: Division of study sites into land cover categories.

Veld type	Land use	No. sites	% sites/ veld type
Southern tall grassveld	Veld	31	86
	Forestry	1	3
	Cultivated	3	8
	Settled	1	3
Total		36	100
Northern tall grassveld	Veld	7	70
	Forestry	1	10
	Cultivated	2	20
	Settled	0	0
Total		10	100
Highland sourveld	Veld	18	69
	Forestry	3	12
	Cultivated	4	15
	Settled	1	4
Total		26	100
Natal mistbelt Ngongoni veld	Veld	1	9
	Forestry	9	82
	Cultivated	1	9
	Settled	0	0
Total		11	100

It is clear from the above table that the Ngongoni Veld has largely been taken over by forestry. Cultivation appears to be fairly uniform in terms of percentages across the veld types.

3.3.2 Present grassland tenure

Grassland utilization in KwaZulu-Natal can be divided into three main categories *viz.* communal grazing, commercial grazing and nature reserves. Commercial grazing generally takes the form of cattle grazing although there are still areas of sheep grazing. Communal grazing usually encompasses a variety of livestock types *viz*. cattle, sheep, goats and equines.

Table 3.3: Percentage of grassland sites presently in each of three land use categories.

Grassland use type	No. sites	% land use
Commercial grazing	34	60
Communal grazing	21	36
Game reserves	2	4

The above results show sites which have not been changed from a grassland to any other form of agriculture since the original survey (Acocks 1953).

3.4 Discussion

The most noticeable result from this survey was the amount of afforestation which had occurred in the Natal Mistbelt Ngongoni Veld (Acocks 1953). It was not clear, however, how many of the sites were originally situated in communal or commercial areas thus it is difficult to say which land-use type was more prone to change in agricultural practice. This may have contributed to bias in the results. The other grasslands all had a small percentage of forestry. In terms of the conservation of biodiversity and the conservation of grazing lands this has important implications. In the Mistbelt areas grazing has in the past resulted in the invasion of many of the grasslands by the unpalatable *Aristida junciformis* (Acocks 1953) resulting in reduced livestock productivity. The replacement of grassland by monospecific stands of plants, such as pine or gum trees, reduces the biodiversity of that area which is contrary to many nature conservation objectives. The habitats for many species in the immediate surrounds may also be affected by the reduced availability of water and the increased soil erosion which could result from the introduction of plantations.

Cultivation has also occurred in all of the veld types and apart from the Mistbelt areas this is often in the form of subsistence cropping (pers. obs.) which tends to occur on a small scale. In the Mistbelt areas sugar cane is taking up large areas owing to the suitability of the climate (Phillips 1969). The results of this study were corroborated by Scott-Shaw *et al.* (1996) where the percentages of the veld types in KwaZulu-Natal which were in conserved areas and still under original vegetation cover, were discussed. They stated that much of the grassland area, especially in the Mistbelt, had been transformed to forestry or cultivation.

The two settlements described here are both urban in nature (Table 3.2). They are settlements situated near large towns. This may be indicative of urban expansion to some degree.

Although there seems to have been a definite change of land use practice in KwaZulu-Natal, there are still vast areas of grassland which are utilized for grazing purposes. It is, therefore, of importance to us to know how these grasslands are changing in terms of species composition so that they can be effectively managed. Forestry has taken over quite extensive areas of both southern and northern KwaZulu-Natal where bioclimatic conditions are suitable. Settlement is also expanding into the grassland areas but this is to be expected with an ever increasing population. It is also important for us to know what proportion of our grasslands are being given over to other agricultural practices in the long term so that we can assess the long term potential of these grasslands.

4. DEVELOPMENT OF A TECHNIQUE FOR RESURVEYING ACOCKS'S SITES: A PILOT SURVEY

4.1 Introduction

In the case of this survey it was important that the method determined would adequately determine a reliable median distance between plants and also give a measure of frequency to emulate the measurements taken by Acocks (1953).

A technique of measuring the parameters which Acocks (1953) used to assess the vegetation needed to be developed to ensure compatability of the data from the original survey (Acocks 1953) with the follow up survey. Since the survey was to be conducted in the grasslands of KwaZulu-Natal, it was considered necessary to use methods which have been designed for use in grasslands.

Acocks (1953) collected his data by visual means. Once he had selected a site, he recorded all the species in the area and gave them an abundance value based on the median inter-plant distance. This was a density measure. Due to the patchy nature of grass swards, and species not assuming random distribution, he also gave them a "locality" symbol which related to the extent to which each species was localised. This was a frequency parameter. He relied on his intuition to assess a plant's abundance and no apparatus were used to take measurements. It was, therefore, necessary to develop a method which would emulate his methods and still give reliable measures of the plant abundances.

Westfall & Panagos (1988) developed a method of surveying Acocks's sites but this was based on canopy cover of the plants to determine density. This was seen as an inappropriate method because canopy cover varies considerably in grasslands depending on the length of time since the sward had last been grazed or burnt.

Research on quadrat size and number has been conducted in the past (Wiegert 1962; Brummer *et al* 1994). The size of the quadrat is important because it has been found that species measurements are subject to a certain amount of variability depending on the the size (Anderson & Marcus 1993). Variation in the data obtained, depends on the size and shape of the quadrats used (Brummer *et al* 1994).

The objectives of this pilot study were to design a repeatable method which could be used to:
i) measure species frequency (locality); and
ii) measure species density.

4.2 Method

Two sites were chosen on the basis of three criteria. These were:
i) the site had to be homogeneous in terms of the vegetation. In other words, the site could not extend into a forest or a wetland as this would increase the amount of variation in the data;
ii) the vegetation had to be in good condition (*i.e.* the species richness had to be high. This was a subjective decision) and
iii) the sites had to be situated in two veld types.
The reasons for these criteria were to minimise sampling inefficiency and to encompass likely variation between grassland types. The vegetation had to be in good condition as Acocks (1953) sampled vegetation in good condition.

The first site selected was situated on the research farm "Ukulinga" (29°37'S 30°22'E) and the second site was situated in the Dargle on the side of the Nhlozane mountain (29°29'S 29°54'E). These sites were situated in the Southern Tall Grassveld and Highland Sourveld respectively (Acocks 1953).

Since plants in a grassland are generally not randomly distributed, it was decided to use a quadrat to determine the frequency (extent to which the plants are "localised") and density of plants. The optimum size and number of quadrats had, therefore, to be determined to ensure accurate measures of species density and inter-plant spacing.

A nested quadrat approach was adopted to assess the relative efficiencies of four different sized square quadrats in determining the frequency of all species in the sward (Figure 4.1). These sizes were worked out on an area basis (*viz.* $0.25m^2$, $0.50m^2$, $0.75m^2$ and $1.00m^2$). This equated to quadrats of sizes 0.5m x 0.5m, 0.71m x 0.71m, 0.87m x 0.87m and 1.00m x 1.00m respectively.

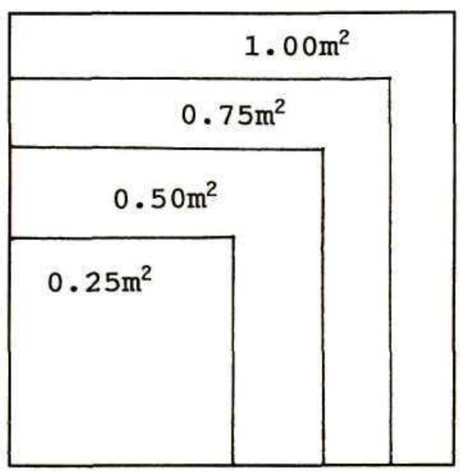

Figure 4.1. Diagrammatic representation of the nested quadrats used for the pilot survey.

Fifty quadrats of each size were placed at ten metre intervals along a transect of 500 m length. If, however, the vegetation at the site was not homogenous for a transect length of 500 m, the transect was divided into two halves and two 250 m transects were surveyed.

Each species (including forbs and sedges) within each quadrat was recorded. Although all species were recorded, there were relatively few forb and sedge species possibly due to the time of sampling so numbers of species recorded consist mainly of the grasses. The number of new species for each quadrat size was determined for each quadrat number. In this way the number of species recorded could be determined for each quadrat size for all 50 quadrats.

The procedure for measuring inter-plant spacing for each species is detailed in Chapter 5. These measurements were taken at each quadrat for all the species present in the quadrat.

4.3 Results

The graph of the Southern Tall Grassveld (Figure 4.2) showed that a total of 39 species were recorded. The only two quadrats which reached this level were the 0.75 m^2 and 1.00 m^2 quadrats.

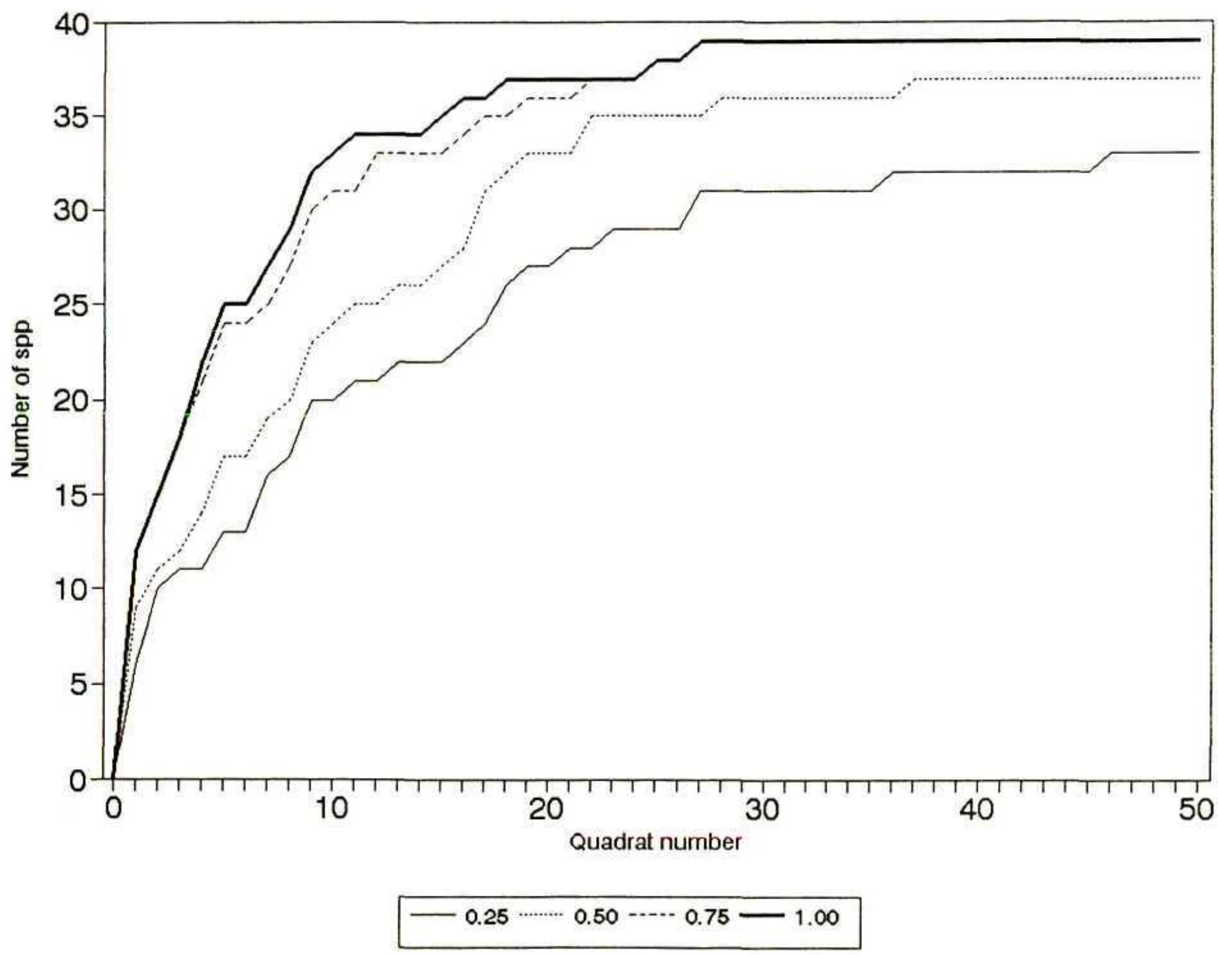

Figure 4.2. Graphical depiction of the number of quadrats required for each quadrat size to attain a plateau of number of species recorded in the Southern Tall Grassveld (Acocks 1953) (The numbers in the legend refer to size in m^2 of each quadrat.)

The Highland Sourveld (Acocks 1953) site yielded similar results in terms of the number of quadrats required for each quadrat size to reach their respective asymptotes although the total number of species recorded was slightly higher, with 45 species being recorded (Figure 4.3).

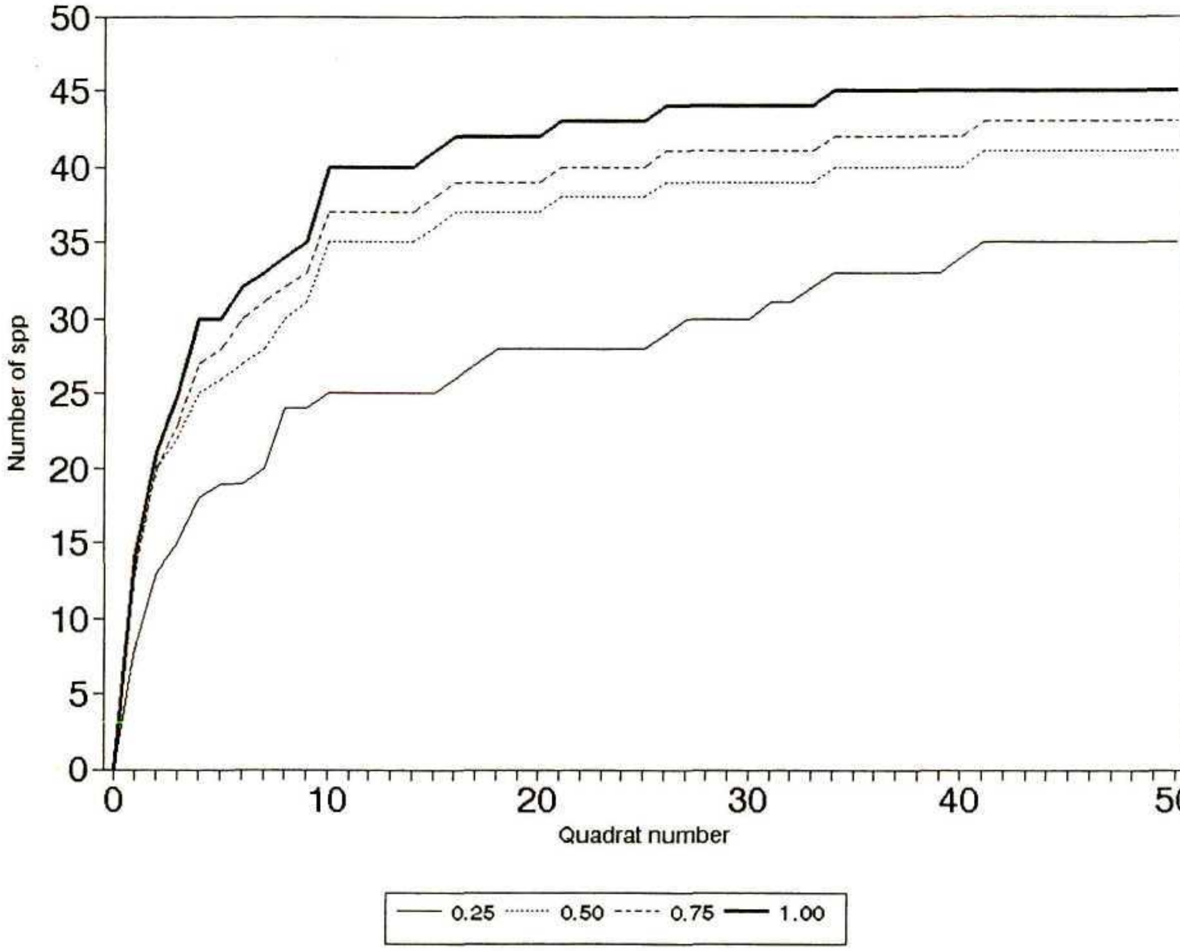

Figure 4.3. Graphical depiction of the number of quadrats required for each quadrat size to attain a plateau of number of species recorded in the Highland Sourveld (Acocks 1953) (The numbers in the legend refer to size in m^2 of each quadrat.)

From the graphs it was clear that the 1.00 m^2 quadrat levelled off a lot sooner than the smaller quadrats, especially the 0.25m^2 quadrat. At both of the sites the 1.00 m^2 quadrat reached its plateau after approximately 15 quadrats whereas the 0.25 m^2 quadrats at both sites only reached their plateaux after approximately 40 quadrats. This was expected because it would take a greater number of smaller quadrats to cover the same total area and thus record the same number of species. This was particularly evident in the case of the rarer species (*i.e.* species which were seldom encountered, even in the larger quadrats). In some cases species which were encountered only once were more likely to have been recorded in the larger quadrats and thus the graph of these quadrats could always be expected to be above the curves of the smaller ones. This was once again to be expected because of the total area covered up to that point.

It would be useful to examine a few percentages of species recorded for each quadrat at different stages to draw comparisons between the efectiveness of each quadrat size in obtaining total numbers of species recorded (Tables 4.1 & 4.2).

Table 4.1. Number of species recorded for each quadrat size as a percentage of the total recorded by the 1.00 m^2 quadrat for the same number of quadrats (Highland Sourveld)

	Quadrat number						
Quadrat size (m^2)	1	5	10	20	30	40	50
0.25	57	63	63	67	68	76	78
0.50	93	87	88	88	87	89	91
0.75	93	93	93	93	93	93	95
1.00	100	100	100	100	100	100	100

Table 4.2. Number of species recorded for each quadrat size as a percentage of the total recorded by the 1.00 m^2 quadrat for the same number of quadrats (Southern Tall Grassveld)

	Quadrat number						
Quadrat size (m^2)	1	5	10	20	30	40	50
0.25	50	52	61	73	79	82	85
0.50	75	68	73	89	92	95	95
0.75	100	96	94	97	100	100	100
1.00	100	100	100	100	100	100	100

The results shown in these tables are clearly illustrated by Figures 4.2 and 4.3.

Another useful way in which to view the data is to tabulate percentages for each quadrat number of the total number of species recorded at each site (Tables 4.3 & 4.4).

Table 4.3. Number of species recorded, after various numbers of quadrats, as a percentage of the total number of species recorded in the Highland Sourveld site

	Quadrat number						
Quadrat size (m^2)	1	5	10	20	30	40	50
0.25	16	42	56	62	67	76	78
0.50	29	58	78	82	87	89	91
0.75	29	62	82	87	91	93	96
1.00	31	67	89	93	98	100	100

Table 4.4. Number of species recorded, after various numbers of quadrats, as a percentage of the total number of species recorded in the Southern tall grassveld site

	Quadrat number						
Quadrat size (m^2)	1	5	10	20	30	40	50
0.25	15	33	51	69	79	82	85
0.50	23	44	62	85	92	95	95
0.75	31	62	79	92	100	100	100
1.00	31	64	85	95	100	100	100

The results for Tables 4.3 and 4.4 are clearly depicted by Figures 4.4 and 4.5.

The efficiency of using more quadrats decreases as the number of quadrats used increases. For the 0.25m^2 quadrat the asymtote was approached gradually (Figures 4.4 & 4.5) and therefore it would be necessary to use a large number of these quadrats to gain the same amount of information that would be obtained by using a few of the 1.00m^2 quadrat. This would prove to be too time consuming. The 1.00m^2 quadrat would allow the asymptote of recorded species to be reached sooner but this could make the estimates of inter-plant distances unreliable owing to a lack of replicates of each species.

The ideal would, therefore, be to use a smaller quadrat which ensures a larger sample size of inter-plant distances which then allows a species list of the dominant and sub-dominant species.

The numbers of quadrats required for each quadrat size were determined from figures 4.2 and 4.3 and were tabulated (Table 4.5).

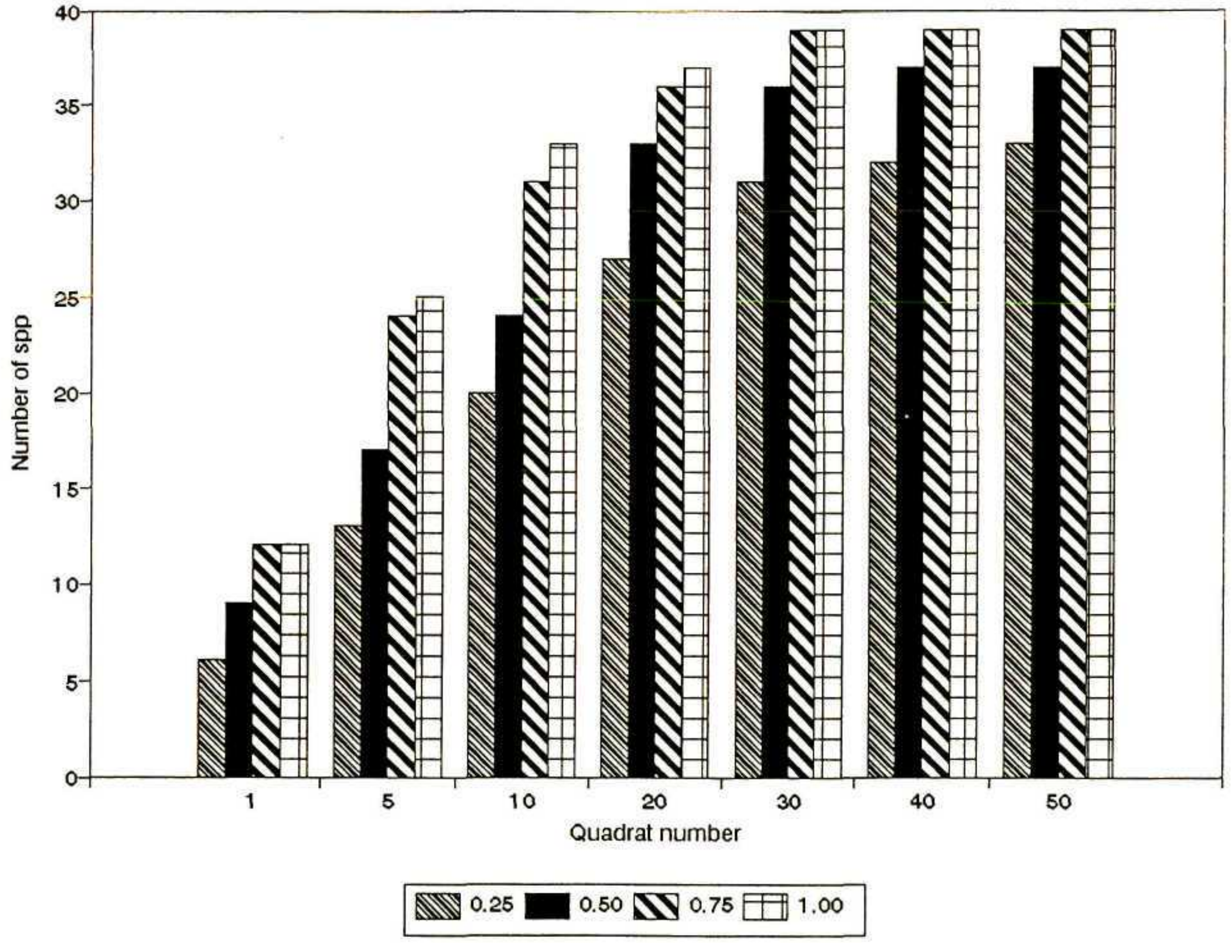

Figure 4.4. Number of species recorded for each quadrat size (m^2) in relation to number of quadrats (Southern Tall Grassveld).

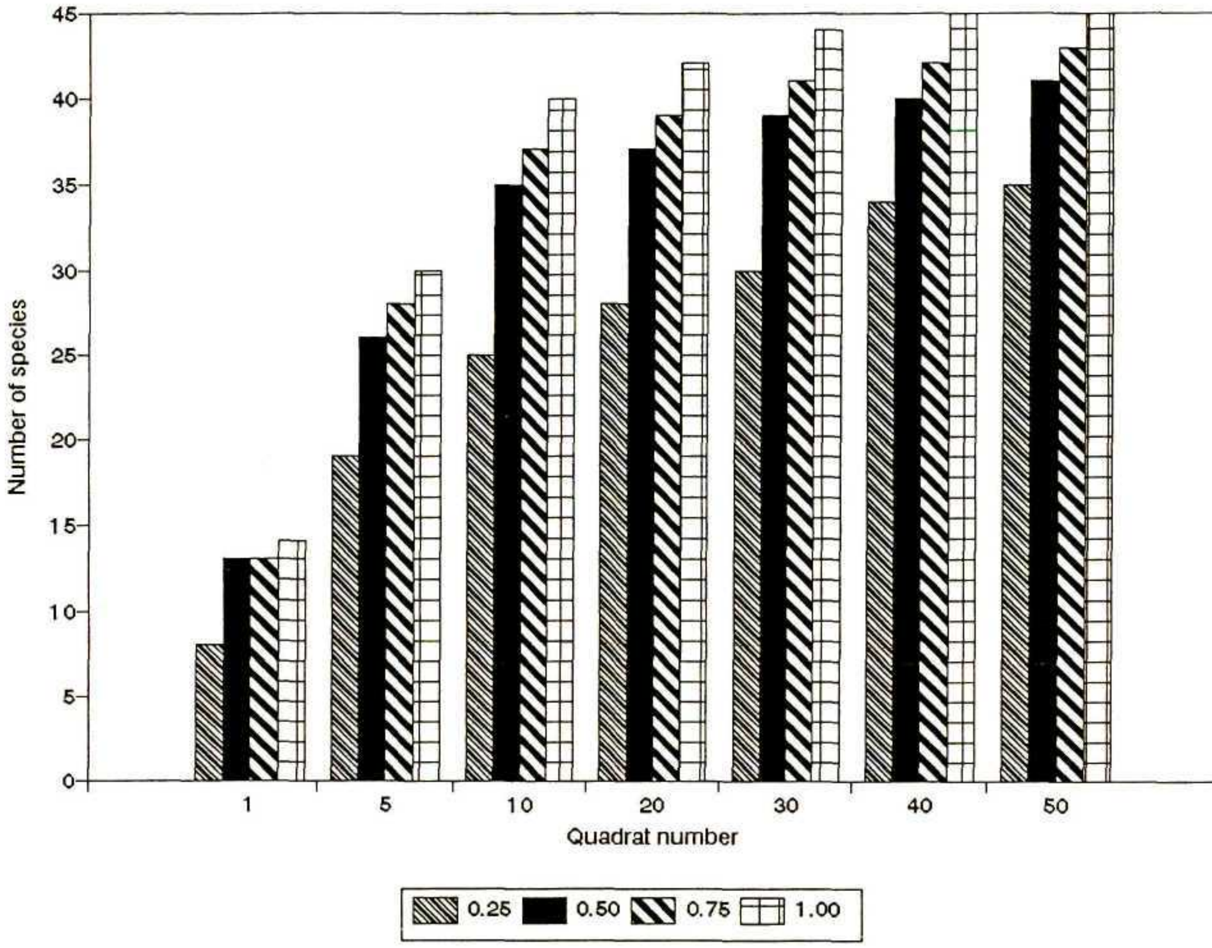

Figure 4.5. Number of species recorded for each quadrat size (m^2) in relation to number of quadrats (Highland Sourveld).

Table 4.5. Required number of quadrats of each size required to obtain a 90% of maximum species list at a site

	Quadrat size (m^2)			
	0.25	0.50	0.75	1.00
Number of quadrats	50	30	20	15

Scrutiny of the data revealed that the optimum size quadrat for the assessment of inter-plant spacing and frequency was $0.50m^2$. This required the sampling of 30 quadrats to gain a species list of approximately 90% of the species recorded at each site. Those species that were not recorded tended to be the rarer species for which estimates of their inter-plant spacings were in any event unreliable.

These values equated to 15m^2 total sampling area for each quadrat. This value is very similar to that shown by Brummer *et al.* (1994) where they estimated a necessary total sampling area for the sampling of standing crop of grassland vegetation in the United States of America (USA) as being 14.4m^2 for all quadrat sizes.

4.4 Discussion

Sampling efficiency has been recognised as an important factor in determining quadrat size and number (Wiegert 1962; Brummer *et al* 1994). Implied in this statement is the time which it takes to collect the necessary data. Thus it was considered important to optimise the number and size of the quadrats to obtain the necessary data and to minimise the time of sampling. This was particularly important in this survey because the sites were situated far apart, and the travelling between them, together with the accurate relocation of them was time-consuming.

Brummer *et al.* (1994) found that increasing quadrat size decreased the amount of variance in individual species measures found in the sward. Although they were chiefly concerned with biomass of individual species within the quadrats, the principles behind eliminating sward variability remain the same. The way to combat this increasing variation with decreasing quadrat size is to increase either the number of quadrats or the quadrat size (Brummer *et al.* 1994). For the purposes of this survey, it was necessary to limit the size of the quadrat to a maximum of 1.00 m^2 so that sufficient replications could be measured to gain a reasonable measure of the median distance between plants of the same species.

Brummer *et al.* (1994) also noted that square quadrats had a lower variance than rectangular ones. Square quadrats are also the most efficient for estimating density when the square is approximately the same size as the vegetation patches (Wiegert 1962; Brummer *et al.* 1994 citing Risser 1984). Owing to the nature of the proposed survey, however, it was impracticable to determine the approximate size of patches and therefore another method of overcoming the variability in the sward, due to patchiness, had to be determined. This will be explained later in the thesis (Chapter 5).

From the pilot survey it was decided to use the 0.50 m^2 quadrat with 30 placings giving a total sampling area of 15 m^2, which would allow a reliable estimate of the inter plant spacings for the common species. If a species occurred in all the quadrats, it would have 30 measures of its nearest neighbour which would allow an accurate measure of its median distance. This, however, was not always likely to be the case, yet even if the species occurred in only half of the quadrats, thus being a relatively common species, the median distance would still be determined from a fairly robust sample of 15 measurements.

The 0.50 m^2 quadrat would also have allowed a species list of approximately 90% of the total species collected by a quadrat of 1.00 m^2. For assessing the extent of change, this would have been adequate since the main species used to assess change are the common ones.

5. PRESENT SPECIES DISTRIBUTION OF THE STUDY GRASSLANDS IN RELATION TO ENVIRONMENTAL AND LAND-USE FACTORS

5.1 Introduction

The species which constitute a grass sward may be considered a result of the environmental factors influencing that area (Chapter 2). These environmental factors may be divided into bioclimatic factors and management factors.

i) Bioclimatic factors include, among others, rainfall, temperature, soil characteristics, aspect and slope. Plant growth depends on moisture availability, nutrient status of the soils and photosynthetic potential. The bioclimatic variables, therefore, may combine to either enhance or inhibit the growth potential of the plants (Tainton 1988).

Certain species are adapted to certain combinations of the bioclimatic variables (Acocks 1953; Tainton 1988; Acocks 1990) so varying species and proportions of species may be found in a given area depending on the climatic influences and on the physiological ability of the species to compete under the prevalent conditions (Tainton 1988).

ii) Management factors: Grazing is the factor which this study looks at predominantly in terms of the management of the grasslands, which may vary from broad grazing regimes such as communal and commercial grazing. Within each of these groups the intensity of the grazing is dependent on the managers of the lands. Thus within commercial grazing, for example, one would find a variety of stocking intensities which could lead to a number of different herbaceous communities and likewise with communal grazing lands. Communal grazing lands have, however, been severely overgrazed in the past, resulting in severe veld degradation in terms of botanical composition (Forbes & Trollope 1991; Trollope 1985; McKenzie 1984). This degradation may vary between bioclimatic regions. The direction of change may be affected by the bioclimatic region given similar management factors. This is because the vegetation adapts to the local bioclimate and a management influence which is imposed on the vegetation may affect the vegetation in a number of ways. One tends to find species which are relatively unacceptable to animals replacing more acceptable species under conditions of heavy utilization (Tainton 1988).

The objectives of this chapter are to provide a description of the grasslands in the study in terms of their grass species composition and to determine which environmental variables have had the greatest influence on this distribution. This will provide a background for the examination of the change over the last 50 years.

5.2 Study Area

Of the 57 Acocks sites which were still grassland, 11 were inaccessible leaving 46 that were able to be resurveyed. The 46 sites were situated in four veld types (Acocks 1953), Highland Sourveld, Natal Mistbelt Ngongoni Veld, Northern Tall Grassveld and Southern Tall Grassveld. The study encompassed a wide range of mean annual temperature (MAT), altitude and mean annual precipitation (MAP) (Table 5.1). Thirty of the sites were under commercial grazing systems and the remaining 16 were under communal tenure. The sites were not situated evenly among veld types but the two dominant veld types (Highland Sourveld and Southern Tall Grassveld) were well represented (Table 5.2).

Table 5.1. Range in climatic variables over the 46 sites

	Minimum	Maximum
MAP (mm)	671	1132
Altitude (m)	650	2094
MAT (°C)	14.1	19.0

Table 5.2. The number of sites situated in each veld type

Veld type	Number of sites
Highland Sourveld	20
Natal Mistbelt Ngongoni Veld	2
Northern Tall Grassveld	5
Southern Tall Grassveld	19

The veld types have different species compositions which are generally related to climate (Acocks 1953). With increasing altitude the mean annual precipitation increases and the mean annual temperature decreases. The soils in the different veld types are also, to some extent, related to climate.

The Natal Mistbelt Ngongoni Veld (Acocks 1953) falls into Bioclimatic Group 2 (Phillips 1969). The rainfall is quite high and the temperatures are relatively low compared with the Tall Grassveld (Acocks 1953) areas (Phillips 1969). Soils in these areas include mainly unstructured erodable soils such as the Hutton and Clovelly forms and they tend to be highly leached. The Highland Sourveld (Acocks 1953) also contains highly leached soils due to the high rainfall with similar soils forms present. Under heavy utilization the soils can erode (Phillips 1969).

The Tall Grassveld areas (Acocks 1953) consist of highly erodable soils such as the Estcourt, Bonheim and Milkwood forms (Phillips 1969). These areas are generally poor cropping areas due to the erodability of the soils and the fluctuation in the moisture available to plants. The rainfall in these areas is generally lower than that found in the other study veld types (Acocks 1953).

The northern most site was situated at 27°14′44"S and the southern most site at 30°34′05"S. Since KwaZulu-Natal has a general drop in altitude from the Drakensberg towards the coast, the range in longitude coordinates may also be significant. The eastern most site was situated at 31°15′27"E and the western most site at 29°03'58"E. These were the sites which registered the highest and lowest temperatures respectively.

5.3 Methods

The sites were relocated using the method described in Chapter 3.

At each site 30 quadrats of size 0.71 m x 0.71 m (0.50m^2) were placed at ten metre intervals along a transect of 300 m length. Within each quadrat the following measurements were taken:
1) the presence of each species (nomenclature for each species follows Gibbs Russell *et al.* 1991) and
2) the distance, to the nearest centimetre, from each species to its nearest neighbour of the same species within the top right hand quadrant, up to a maximum distance of one metre (Figure 5.1). If a species had more than one representative within the bounds of the quadrat, the plant closest to the centre was chosen as the representative for that species. The quadrant was centred on each representative species and from there the distance was measured to the nearest neighbour of the same species within the top right hand quadrant.

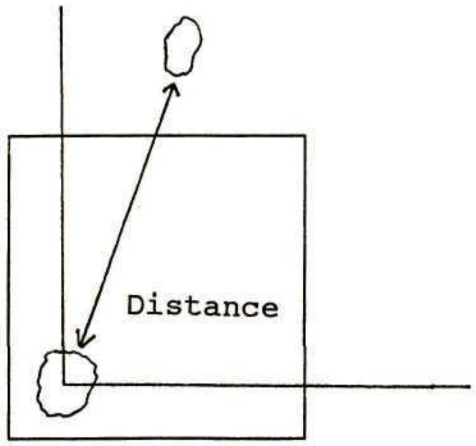

Figure 5.1. Diagrammatic representation of the method used to measure inter-plant spacing.

This gave measurements which would facilitate the calculation of frequency of each species as well as the density of each species. These could then be combined to calculate an abundance rating for each species, using the formula:

$$A = (151 - D) \times (q/Q) \qquad (5.1)$$

where A = abundance,

D = median distance (cm) between plants of the same species,

q = number of quadrats in which the species was found,

Q = maximum number of quadrats in which the species could have been found (*i.e.* 30).

The median distance was used instead of the mean distance because it was assumed that Acocks (1953) used medians since he did not actually measure the distances between plants but rather he assessed visually the approximate distance between them. Medians are also better estimates in data with skewed distributions.

The above formula was created to assign higher values to the common species and lower values to the less common species. This was so that the ordination could distinguish between common and uncommon species. A value of 150 cm was assigned to species whose median distance between plants was greater than one metre. In the equation, therefore, to ensure that no species had an abundance rating of zero, the median distance value was subtracted from 151.

The following environmental variables were recorded for each site:

1) aspect and slope, obtained from the ortho photos. The slope was calculated by determining the mean distance between contour lines at the site on the ortho photo;

2) MAT, obtained from the Department of Agricultural Engineering (University of Natal);

3) MAP and altitude, obtained from the Computing Centre for Water

Research (University of Natal); and
4) present land use (either communal or commercial grazing).

The environmental variables were combined to create variables which were considered to have more relevance to plant growth. Mean annual precipitation was divided by the MAT to derive an index of plant available moisture called "maptemp" whose units were recorded as mm $°C^{-1}$. The rationale behind this was that at a high rainfall and a low temperature, less evaporation would occur relative to areas with lower rainfall and higher temperatures. Thus the amount of moisture available to the plant would be greater, allowing for a greater growth potential.

A measure of radiation (J m^{-2} day^{-1}) for each site for the September to March period of the year was read off graphs (Schulze 1976) using the aspect and slope values for each site. This period was chosen because it is the growing season for the humid grasslands in KwaZulu-Natal.

Radiation was combined with "maptemp" to create a variable called "rad*mt". The idea behind this was that at higher levels of radiation, more energy is available for photosynthesis thus increasing the growth potential of the plants. Therefore with high levels of moisture, lower temperatures and high amounts of radiation, plant growth should be enhanced. The variable "rad*mt" could, therefore, be considered to be an index of the potential for plant growth.

Two other interactive terms were used in the modelling and these involved the interaction between the communal grazing and "maptemp" to form a variable called "C*mt", and between the commercial grazing and the "maptemp" to create a variable called "B*mt". This was to examine the interaction between environment and land-use.

Correspondence Analysis (CA), using CANOCO (Ter Braak 1988), was performed on the species-by-sites matrix to examine their distribution. Plots of the main ordination axes were then drawn up and the environmental variables overlaid.

The environmental variables and the species-by-sites matrix (Appendix 2) were analyzed using Canonical Correspondence Analysis (CCA) (Ter Braak 1986). This was done using the CANOCO package (Ter Braak 1988). Canonical correspondence analysis uses a system of ordination and regressions to examine the effects of the environmental variables on the species distribution. Thus the ordination axes in CCA are linear combinations of the environmental variables. Plots of the first three axes were then drawn up using the species scores and the sample scores which are linear combinations of the environmental variables.

A Monte Carlo re-randomization test (Ter Braak 1988), using 99 permutations, was conducted to examine whether the measured environmental variables had a significant effect on the species distribution.

A *t*-test was conducted to compare the number of species found in the communal areas and the commercial areas.

Only the re-survey data were used in these analyses as it was a descriptive exercise as opposed to a comparative exercise, therefore the original data were not required.

5.4 Results

Both axes 1 and 2 in the CA accounted for a large amount of the variation in the species data (Table 5.3). A total of 39% of the species variation was accounted for by the first four axes. Of this a total of 32% was captured by the first three axes. For the species-environment relation, a total of 67% was captured by all four axes while 59% was captured by the first three axes.

Table 5.3: Summary of the Correspondence analysis

Axes	1	2	3	4
Eigenvalues	0.481	0.325	0.255	0.233
Species-environment correlations	0.578	0.563	0.216	0.406
Cumulative % variation (species data)	14.4	24.2	31.8	38.8
Cumulative % variation (species-environment data)	34.2	56.2	58.7	66.9

The *t* values of the CA indicated which of the measured variables were significant in their effect on the species distribution (Table 5.4) and the correlations between the environmental variables and the species axes (Table 5.5) indicated the degree to which each variable influenced the distribution of the species along the axes. The cumulative fit percentages (Table 5.6) showed the species which had most of their variation accounted for by the first two axes. These species could, therefore, be used to interpret the effects of the environmental variables on the species distribution.

Table 5.4: Table of *t* values of the regression coefficients for the CA output (significant values ($P<0.05$) indicated in bold)

Environmental variable	Axis 1	Axis 2	Axis 3	Axis 4
Communal grazing (C)	0.96	**3.23**	0.23	-1.85
Commercial grazing (B)	0	0	0	0
Radiation*maptemp (rad*mt)	1.27	0.42	0.86	-0.55
Communal*maptemp (C*mt)	**-2.50**	**-3.48**	-0.76	1.06
Commercial*maptemp (B*mt)	**-2.40**	-0.73	-0.89	-0.56

Table 5.5. Correlation coefficients of the environmental variables for the first four axes of the CA analysis (significant values (P<0.05) indicated in bold)

Environmental variable	Axis 1	Axis 2	Axis 3	Axis 4
Communal grazing (C)	0.2793	-0.1285	0.1616	-0.0128
Commercial grazing (B)	-0.2793	0.1285	-0.1616	0.0128
Radiation*maptemp (rad*mt)	**-0.4253**	-0.1966	-0.0432	-0.3006
Communal*maptemp (C*mt)	0.2345	-0.2068	0.1533	0.0068
Commercial*maptemp (B*mt)	**-0.3894**	0.0865	-0.1662	-0.1085

Table 5.6: Cumulative fit per species as a fraction of variance of each species' variance for CA axis 1 and 2

Species	Axis 1 (%)	Axis 2 (%)
Sporobolus africanus	50.2	73.0
Tristachya leucothrix	49.4	49.6
Hyparrhenia hirta	40.6	43.6
Cymbopogon excavatus	34.4	35.0
Themeda triandra	32.0	33.6
Heteropogon contortus	26.1	30.8
Eragrostis curvula	24.8	29.4
Alloteropsis semialata	24.6	25.7
Aristida congesta subsp. *barbicollis*	22.7	60.1
Bothriochloa insculpta	15.3	62.4
Eragrostis plana	8.0	56.5
Aristida congesta subsp. *congesta*	13.9	41.0
Tragus berterionianus	8.3	32.7
Paspalum notatum	6.9	26.7
Paspalum scrobiculatum	14.0	20.3

The first CA axis was a grazing gradient with the interaction terms communal*maptemp (C*mt) and commercial*maptemp (B*mt) being significant (Table 5.4). The most highly correlated variables along axis 1 were the radiation*maptemp and commercial*maptemp interactions. This indicated that a low scoring species would be found predominantly under a higher moisture regime and under commercial land use (Figure 5.3). Species with low eigen scores along axis 1 included *Tristachya leucothrix, Alloteropsis semialata, Themeda triandra* and *Heteropogon contortus*. Species which scored high along axis 1 were those species which would generally be found under communal land use. Species which had high scores included *Sporobolus africanus, Cymbopogon excavatus, Eragrostis curvula* and *Aristida congesta* subsp. *barbicollis* (Figure 5.2).

Axis 2 could also be interpreted as a grazing gradient but it was predominantly concerned with the relationship between communally grazed sites and their situation in dry or moist sites (Figure 5.3). Species which scored low along axis 2 were those that were found in communally grazed sites under moist conditions. These included *Sporobolus africanus, Eragrostis plana, Paspalum notatum* and *Paspalum scrobiculatum*. The species which had high scores along axis 2 were those which were communally grazed but existed under drier conditions. These included *Bothriochloa insculpta, Aristida congesta* subsp.*congesta, Aristida congesta* subsp. *barbicollis* and *Tragus berteronianus* (Figure 5.2).

Two of the species had large amounts of their variation accounted for by both axes, *Sporobolus africanus* and *Aristida congesta* subsp. *barbicollis* (Table 5.6). This indicated that these species reacted strongly to both the environmental variables and the land-use variables. Both these species occurred in areas which were heavily utilised (*i.e.* communal grazing areas). *Sporobolus africanus* occurred in moister environments and *Aristida congesta* subsp. *barbicollis* occurred in the drier regions (Figure 5.2).

The environmental variables showed no significant effect on the species distribution along axes 3 and 4 (Table 5.4). These axes were, therefore, excluded from the interpretation.

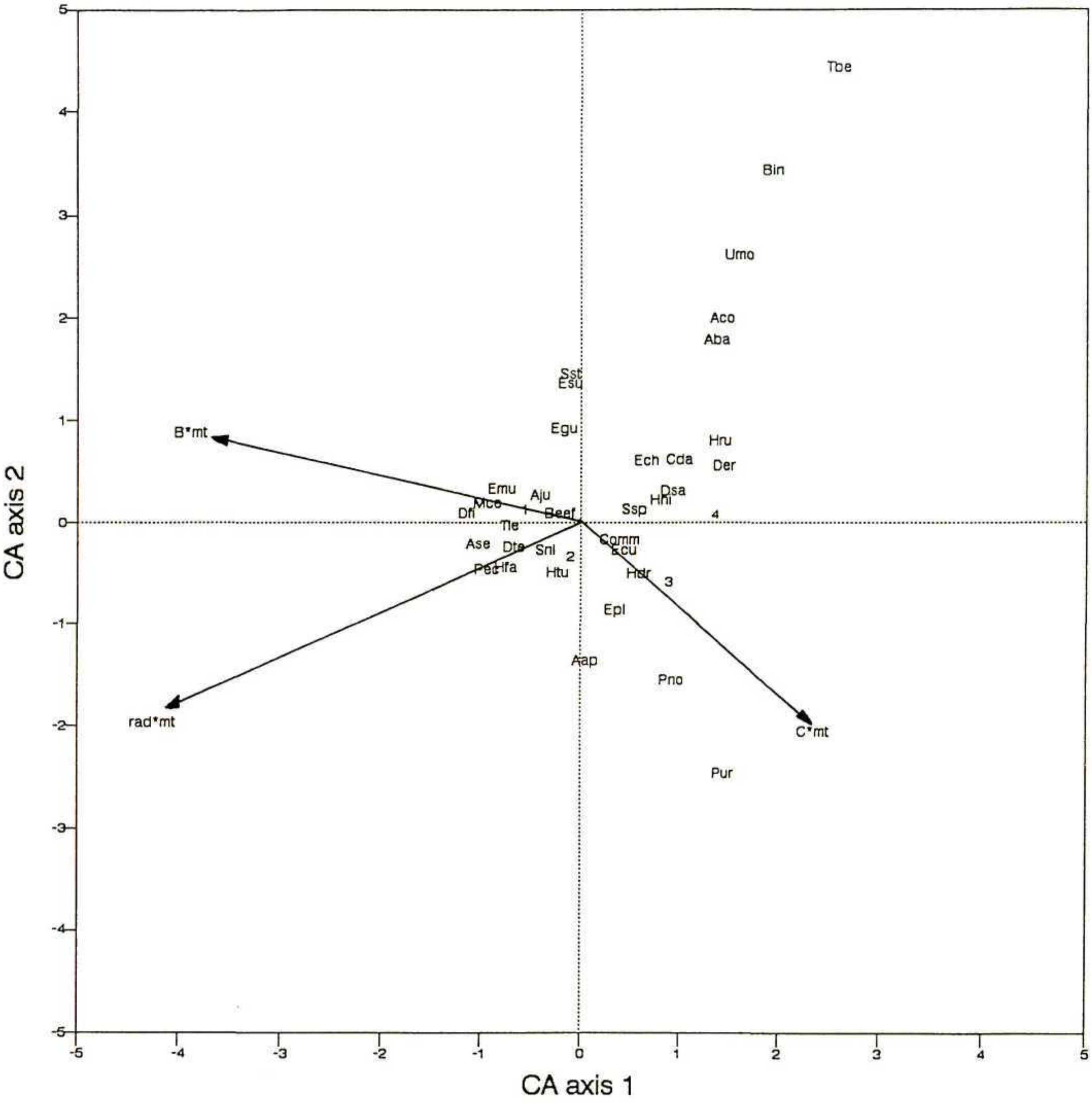

Figure 5.2. Ordination of species along CA axes 1 and 2 with environmental variables overlaid.

Key: 1-*Brachiaria serrata*, *Cymbopogon validus*, *Diheteropogon amplectens*, *Eragrostis capensis*, *Eragrostis racemosa*, *Heteropogon contortus*, Microchloa caffra, *Sporobolus pyramidalis*, *Themeda triandra*, Tragus racemosa, *Trachypogon spicatus;* 2-*Panicum aquinerve*, *Hyparrhenia tamba*; 3-*Chloris gayana*, *Paspalum dilatatum*, *Paspalum scrobiculatum*, *Sporobolus africanus;* 4-*Cymbopogon excavatus*, *Melinis nerviglumis*, *Melinis repens*, *Urochloa panicoides*; Aap-*Andropogon appendiculatus*; Aba-*Aristida congesta* subsp. *barbicollis*; Aju-*Aristida junciformis*; Ase-*Alloteropsis semialata*; Asch-*Andropogon schirensis*; Bin-*Bothriochloa insculpta*; Cda-*Cynodon dactylon*; Cma-*Cymbopogon marginatus*; Dfi-*Diheteropogon filifolius*; Dsa-*Digitaria sanguinalis*; Dtr-*Digitaria tricholanoides*; Ech-*Eragrostis chloromelas*; Ecu-*Eragrostis curvula*; Emu-*Elionurus muticus*; Epl-*Eragrostis plana*; Esu-*Eragrostis superba*; Hdr-*Hyparrhenia dregeana*; Hfa-*Harpochloa falx*; Hhi-*Hyparrhenia hirta*; Mce-*Monocymbium ceresiiforme*; Pna-*Panicum natalensis*; Pno-*Paspalum notatum*; Sni-*Setaria nigrirostris*; Ssp-*Setaria sphacelata*; Sst-*Sporobolus staphianus*; Tle-*Tristachya leucothrix*; rad*maptemp-radiation*maptemp; C*mt-communal*maptemp; B*mt-commercial*maptemp; Beef-centroid of commercial sites; Comm-centroid of communal sites.

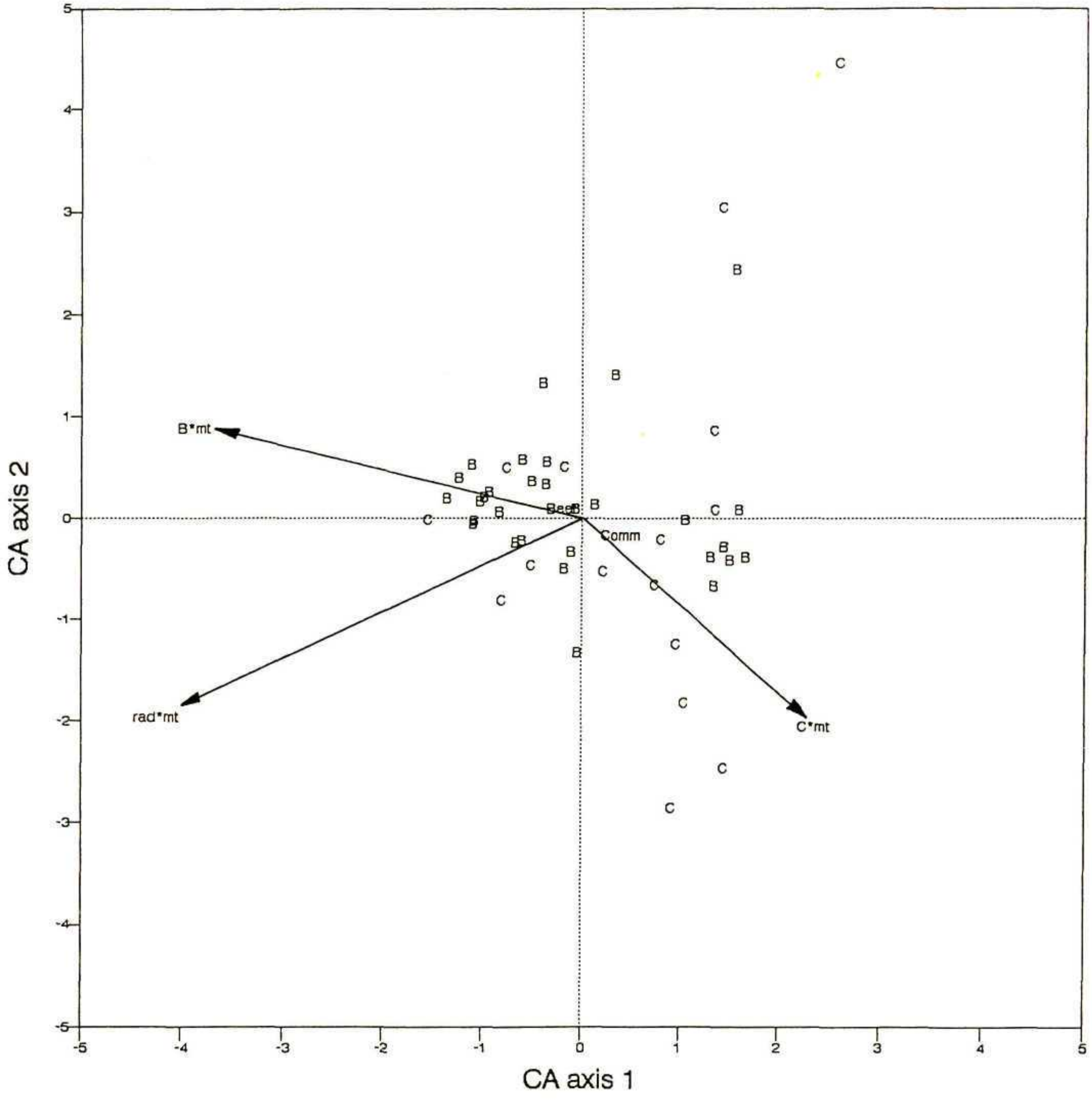

Figure 5.3. Ordination of sites along CA axes 1 and 2 with environmental variables overlaid.

Key: C-communal sites; B-commercial sites; rad*maptemp-radiation*maptemp; C*mt-communal*maptemp; B*mt-commercial*maptemp; Beef-centroid of commercial sites; Comm-centroid of communal sites.

The Canonical correspondence analysis (CCA) accounted for a total of 14% of the species variability within the first four axes (Table 5.7). Axis 1 accounted for 7% and axis 2 accounted for a further 3%. This figure was considerably lower than the variance accounted for by the CA due to the fact that some of the variation could not be accounted for by the environmental variables. The amount of variation in the species data accounted for by the CA was approximately 2.7 times that accounted for by the CCA for the first four axes. This meant that the CA fit was far better than the CCA although the variation of the species-environment relation was far higher in the CCA. This meant that some important environmental variables had been omitted from the analysis.

Although the amount of variation accounted for by the CCA was considerably lower than the CA, the Monte Carlo test revealed that the environmental variables used in the CCA accounted for a significant amount of the variation ($P<0.01$) both on the first axis and on the overall ordination.

Table 5.7: Summary of the Canonical correspondence analysis

Axes	1	2	3	4
Eigenvalues	0.235	0.097	0.088	0.048
Species-Environment correlation	0.775	0.602	0.697	0.616
Cumulative % variation (species)	7.1	10.0	12.6	14.1
Cumulative % variation (species-environment relation)	50.2	70.9	89.7	100.0

The *t* values of the regression coefficients showed significance on the first three axes (Table 5.8). On CCA axis 1 communal grazing (C), radiation*maptemp (rad*mt), communal*maptemp (C*mt) and commercial*maptemp (B*mt) were all significant. The most significant along axis 1 was the communal*maptemp interaction. Along axis 2 the only significant regression coefficients were communal grazing and the communal*maptemp interaction. Along axis

3 the only significant variable was communal grazing. Although axis 4 showed significant effects of three of the variables, this was merely a result of the total variation accounted for by the first four axes totalling 100%. This was because there were only four variables presented in the ordination and therefore the total variation was divided between four axes. The most important factor in the CCA was the effect of grazing type which showed that this was the most important factor determining the distribution of the species in the grasslands.

Table 5.8. Table of *t* values of the regression coefficients for the CCA output (significant values indicated in bold)

Environmental variable	Axis 1	Axis 2	Axis 3	Axis 4
Communal grazing (C)	**3.06**	**-3.87**	**2.35**	1.27
Commercial grazing (B)	0	0	0	0
Radiation*maptemp (rad*mt)	**2.19**	-0.36	-0.01	**-4.79**
Communal*maptemp (C*mt)	**-5.66**	**2.69**	-0.49	**2.03**
Commercial*maptemp (B*mt)	**-3.98**	-0.95	1.02	**4.12**

Owing to the high correlations of environmental variables on the first three axes (Table 5.9), it was deemed necessary to plot two sets of biplots. The first set was CCA species and sites axes 1 and 2 and the second set was CCA species and sites axes 1 and 3.

Table 5.9. Correlation coefficients of the environmental variables for the first four CCA axes (bold value significant (P<0.05))

Environmental variable	Axis 1	Axis 2	Axis 3	Axis 4
Communal grazing (C)	0.1550	0.2198	**0.6336**	0.0179
Commercial grazing (B)	-0.1550	-0.2198	**-0.6336**	-0.0179
Radiation*maptemp (rad*mt)	**-0.5301**	-0.2876	0.0411	-0.3374
Communal*maptemp (C*mt)	0.0721	0.2764	**0.6160**	-0.0057
Commercial*maptemp (B*mt)	-0.3021	-0.3348	**-0.5094**	-0.0430

The cumulative fit of species showed the species which had a large amount of their variation accounted for and thus the species which could best be used for the interpretation of the ordination diagrams (Table 5.10).

Table 5.10. Cumulative percentages for species which had more than 15% of their variation accounted for by the first three CCA axes

Species	CCA axis 1	CCA axis 2	CCA axis 3
Aristida congesta subsp. *barbicollis*	35.5	40.4	43.9
Alloteropsis semialata	15.1	15.2	17.4
Bothriochloa insculpta	21.2	25.7	29.6
Cymbopogon excavatus	25.7	26.1	26.6
Eragrostis racemosa	4.2	16.6	18.6
Heteropogon contortus	6.0	18.1	18.2
Hyparrhenia hirta	18.6	19.2	21.5
Hyparrhenia rufa	9.4	11.0	16.2
Monocymbium ceresiiforme	7.2	25.3	25.5
Sporobolus africanus	3.0	10.9	16.9
Tragus berteronianus	8.8	11.8	15.0

From the correlations it was evident that axis 1 was a gradient describing growing conditions with low scoring species existing in areas which have a high moisture regime and high radiation values (*i.e.* high radiation*maptemp values) and species with high scores existing in areas with low radiation values and low moisture values Figure 5.4a and b). To a lesser degree the commercial*maptemp interaction was correlated with axis 1. The species found with low axis 1 scores would, therefore, be those which would be found predominantly in wetter areas under a commercial grazing system. Species which have low axis 1 scores include *Alloteropsis semialata* and *Monocymbium ceresiiforme*. Species with high scores along axis 1 include *Bothriochloa insculpta, Cymbopogon excavatus, Aristida congesta* subsp. *congesta* and *Hyparrhenia hirta*.

Axis 2 was a grazing gradient with the only significant regression arrows being those of the communal grazing and the communal*maptemp interaction (Table 5.8). High scoring species along axis 2 were those which are found under conditions of high growing potential for the plants (*i.e.* high radiation*maptemp values) in communal areas (*e.g. Sporobolus africanus, Digitaria sanguinalis, Paspalum notatum, Paspalum scrobiculatum* and *Eragrostis plana*). Low scoring species were those under communal grazing in drier areas where plant growth potential is lower (*i.e.* low radiation*maptemp values). The species include *Tragus berteronianus, Bothriochloa insculpta, Aristida congesta* subsp. *barbicollis* and *Hyparrhenia rufa* (Figure 5.4a).

The regression arrow of the radiation*maptemp interaction was close to the regression arrow of the commercial*maptemp interaction (Figures 5.4a and 5.5a). This indicated that the effect of these two variables on species distribution was very similar. On the other hand the communal*maptemp interaction regression arrow was very dissimilar to the radiation*maptemp arrow indicating that the effect of communal grazing on the species distribution was independent of radiation*maptemp.

Communal grazing was the only significant variable along axis 3 (Table 5.8) and the correlation with axis 3 was also quite high (Table 5.9). The species plot (Figure 5.4b) showed that positively scoring species were those found predominantly in communally grazed areas (*e.g. Sporobolus africanus, Tragus berteronianus, Bothriochloa insculpta, Eragrostis plana* and *Eragrostis curvula*). Species with negative scores were those found predominantly in commercially grazed areas (*Trachypogon spicatus, Hyparrhenia hirta, Themeda triandra* and *Monocymbium ceresiiforme*). The site ordination of axis 3 showed a clear distinction between the commercial and communal sites (Figure 5.5b). As previously mentioned the main variable influencing the distribution along axis 1 was the interaction between radiation*maptemp (*i.e.* environmental conditions for growth). Figure 5.5b showed that at low values of radiation*maptemp (*i.e.* warm dry areas) the dispersion between the commercial and communal sites is much greater than at high values of radiation*maptemp. This implies that warmer drier areas are more susceptible to the effects of grazing than cooler wetter areas.

The CA showed that the most important factors influencing the distribution of species in ordination space were those which involved the environmental conditions for plant growth. The same was shown by the CCA but the CCA also showed that in the hotter drier areas with low radiation the difference between commercial and communally grazed areas was greater than in cooler moister areas with high radiation.

The dispersion of communally grazed sites in ordination space was greater than the commercial sites on both sets of analyses. This is important because it indicates that under heavy utilization, the grasslands may tend towards a number of different communities. This may be due to climatic variation or a number of other factors which were not measured in this study such as fire management and stocking intensity.

Although the CCA and CA were different in the amounts of the variation which they accounted for, they both showed valuable results which were similar.

The *t*-test used to compare number of species in communal areas to number of plants in commercial areas yielded non-significant results ($P>0.05$). Species richness in both types of grazing were on average the same.

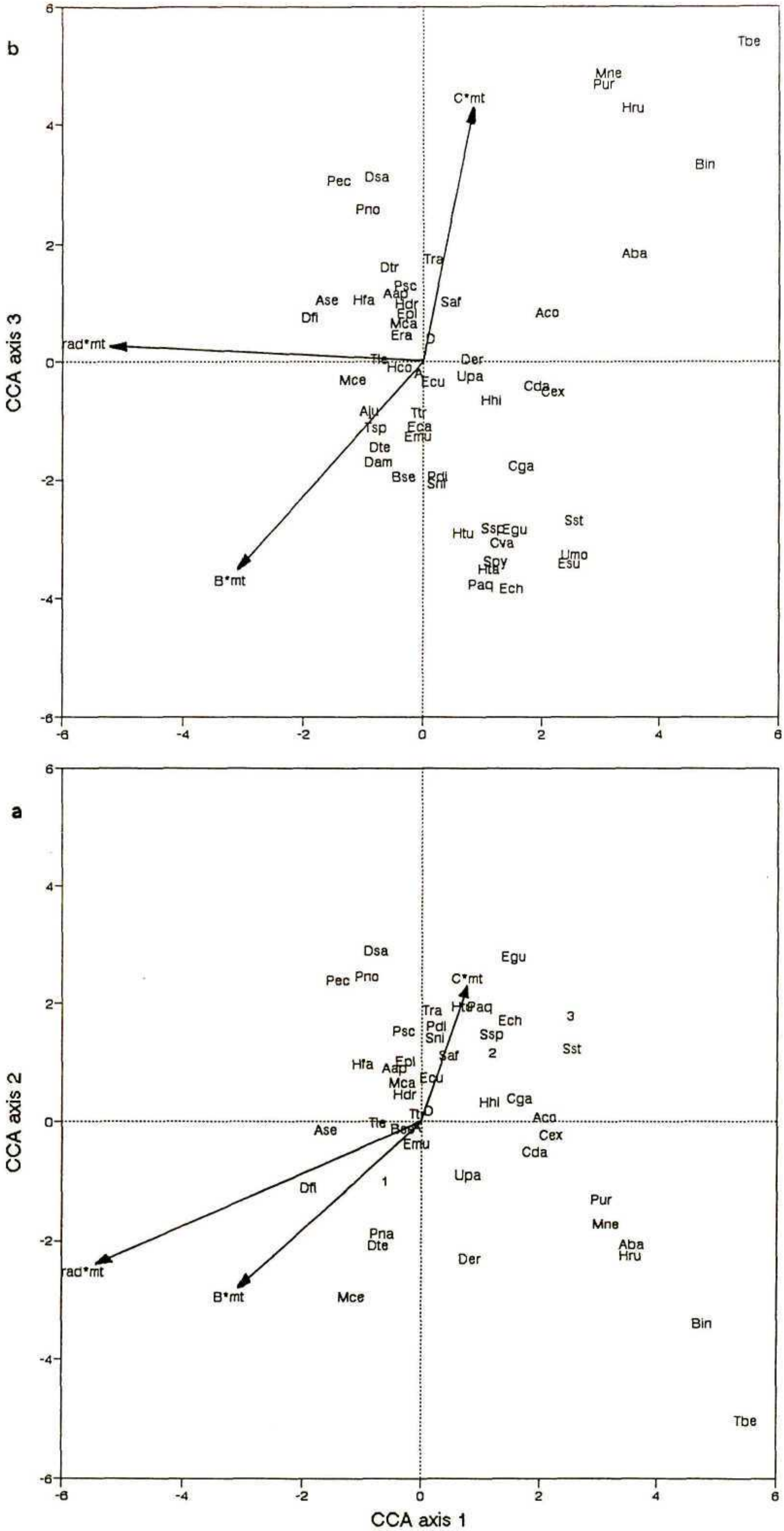

Figure 5.4. Ordination of species along CCA axes 1, 2 and 3 (key overleaf)

Key: 1-*Aristida junciformis*, *Diheteropogon amplectens*, *Digitaria tricholonoides*, *Eragrostis racemosa*, *Heteropogon contortus*, *Trachypogon spicatus*; 2-*Cymbopogon validus*, *Hyparrhenia tamba*, *Sporobolus pyramidalis*; 3-*Eragrostis superba*, *Urochloa mosambicensis*; Aap-*Andropogon appendiculatus*; Aba-*Aristida congesta* subsp. *barbicollis*; Aco-*Aristida congesta* subsp. *congesta*; Aju-*Aristida junciformis*; Ase-*Alloteropsis semialata*; Asch-*Andropogon schirensis*; Bin-*Bothriochloa insculpta*; Bse-*Brachiaria serrata*; Cda-*Cynodon dactylon*; Cex-*Cymbopogon excavatus*; Cga-*Chloris gayana*; Cma-*Cymbopogon marginatus*; Cva-*Cymbopogon validus*; Dam-*Diheteropogon amplectens*; Dfi-*Diheteropogon filifolius*; Dsa-*Digitaria sanguinalis*; Dtr-*Digitaria tricholanoides*; Eca-*Eragrostis capensis*; Ech-*Eragrostis chloromelas*; Ecu-*Eragrostis curvula*; Emu-*Elionurus muticus*; Epl-*Eragrostis plana*; Era-*Eragrostis racemosa*; Esu-*Eragrostis superba*; Hdr-*Hyparrhenia dregeana*; Hco-*Heteropogon contortus*; Hfa-*Harpechloa falx*; Hhi-*Hyparrhenia hirta*; Hru-*Hyparrhenia rufa*; Hta-*Hyparrhenia tamba*; Mca-*Microchloa caffra*; Mce-*Monocymbium ceresiiforme*; Pdi-*Paspalum dilatatum*; Pna-*Panicum natalensis*; Pno-*paspalum notatum*; Psc-*Paspalum scrobiculatum*; Saf-*Sporobolus africanus*; Sni-*Setaria nigrirostris*; Spy-*Sporobolus pyramidalis*; Ssp-*Setaria sphacelata*; Sst-*Sporobolus staphianus*; Tbe-*Tragus berteronianus*; Tle-*Tristachya leucothrix*; Tsp-*Trachypogon spicatus*; Ttr-*Themeda triandra*; Umo-*Urochloa mosambicensis*; Upa-*Urochloa panicoides*; rad*mt-radiation*maptemp; C*mt-communal*maptemp; B*mt-commercial*maptemp; A-centroid of commercial sites; D-centroid of communal sites.

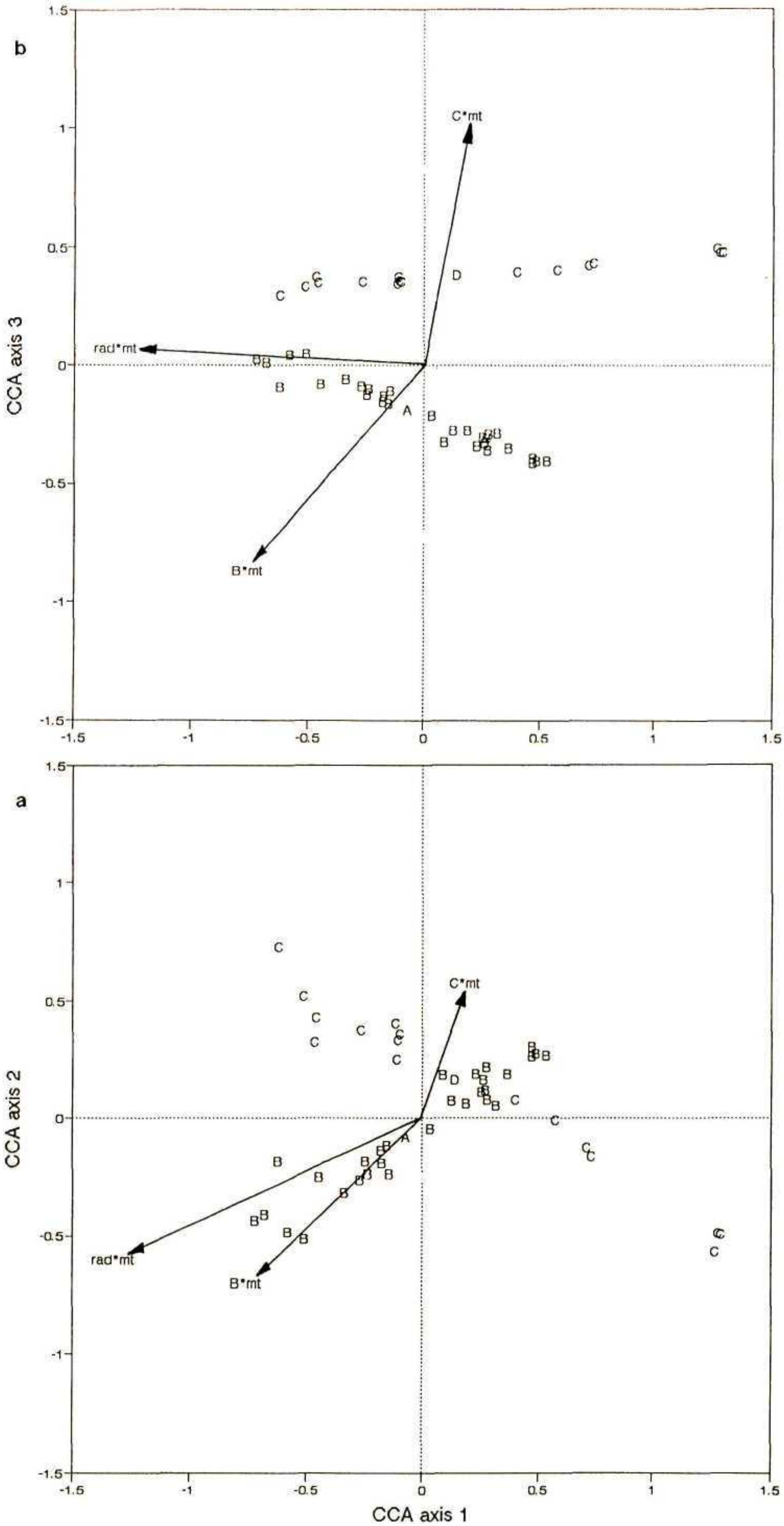

Figure 5.5. Ordination of sites along CCA axes 1, 2 and 3 indicating the environmental variables and the centroids of the sites.

Key: C=communal sites; B=commercial sites; rad*maptemp=radiation*maptemp; C*mt=communal*maptemp; B*mt=commercial*maptemp; A-centroid of commercial sites; D-centroid of communal sites.

5.5. Discussion

Many of the environmental factors which affect plant distribution in the study grasslands were not measured. Had all such variables been measured, a lot more of the variation may have been accounted for. This implies that, although the variables measured in this study accounted for some of the variation, there are other environmental variables which contribute to species distribution.

The results of this study were to be expected. Similar results have been found by many other authors (Booysen 1969; Tainton 1972; Tainton *et al.* 1978; McKenzie 1984; Forbes & Trollope 1991; Morris *et al.* 1992). The effect of intensive grazing practices on grassland composition has been shown to either create a sward dominated by "Mtshiki" species in the case of communal grazing or else species which invade as a result of selective grazing (*e.g. Aristida junciformis, Elionurus muticus*) in the case of commercial grazing.

The grasslands are fairly similar in their composition throughout the study area apart from the occasional species which may occur in the hotter drier areas as opposed to the cool moist areas and *vice versa*. These species tend to be in the minority though. The dominant species are those which tend to be present in all of the veld types regardless of the bioclimatic conditions. These include *Themeda triandra, Tristachya leucothrix, Hyparrhenia hirta, Eragrostis curvula, Eragrostis plana* and *Sporobolus africanus*.

The difference between bioclimatic regions is noticeable when the grazing intensity is high. The effect of grazing tended to have a greater effect on species composition than the effect of climate, especially in the drier hotter areas. This was probably because the vegetation is less stable in drier areas (Tainton 1988). In cooler moister areas the difference between communal and commercial land-use was less pronounced because the vegetation tends to be more stable (Tainton 1988).

Under communal grazing conditions the spread of the sites in ordination space is wide compared to the spread of the commercially grazed sites. This spread is partly dependent on the climatic variables measured and probably dependent on other variables which were not measured in this study. The species composition of the sites also influences the amount of spread within the communal or commercial grazing categories. The overlap between commercial sites in terms of species composition is great and this is shown in the ordination diagrams. The communal sites, however, are more spread out thus showing that the overlap in species composition is considerably less than in commercial areas. Species restricted to dry areas included *Bothriochloa insculpta, Tragus berteronianus, Aristida congesta* subsp. *barbicollis* and *Urochloa mosambicensis*. Species restricted to moister cooler regions included *Paspalum notatum* and *Paspalum urvillei*.

From the results in this study it was evident that grazing has had a profound effect on the species distribution of the study grasslands relative to the climate. The next chapter will attempt to determine whether the grasslands have changed and, if so, whether the same factors which contributed to the distribution of species are instrumental in the change.

6. COMPOSITIONAL CHANGE IN THE HUMID GRASSLANDS OF KWAZULU-NATAL OVER THE LAST FIFTY YEARS

6.1 Introduction

The definition of change in the present context is the alteration of the species composition of the grass sward. Change due to grazing impacts is often evident by a change in species composition (Morris *et al.* 1992) in the humid grasslands of KwaZulu-Natal. This change may or may not be to the detriment of stock production.

The magnitude of the change could be dependant on the intensity of the sward use and certain climatic variables which may render the sward more susceptible to change. In communal areas the grazing is generally very intense (McKenzie 1984; Trollope 1985; Forbes & Trollope 1991) resulting in a decreased carrying capacity of the veld and a decline in animal production (McKenzie 1984). The changes resulting from intensive grazing may not always be reversible (Venter 1968; Tainton 1972; Friedel 1991; Morris *et al.* 1992) and in areas where this is the case it is not always the answer to remove livestock from the lands as it is possible that this would result in a worse situation.

It is, however, not strictly accurate to assume that all change within a grassland occurs due to grazing intensity even though at certain intensities of grazing this may be the overriding factor. Other environmental factors also contribute to change. These include altitude, aspect, slope, soil type, rainfall and temperature. Although these factors alone would not contribute to drastic change (except in the case of major perturbations), they may influence the sensitivity of the grassland to change (Holling 1973; McKenzie 1982).

The direction of change may depend on the land use. Tainton (1972) showed that selective grazing encourages the invasion of *Aristida junciformis* and Morris *et al.* (1992) showed that intensive grazing ultimately encouraged the invasion of "Mtshiki" species in the sward and when grazing pressure was reduced these swards became invaded by *Aristida junciformis*. Acocks (1953) and McKenzie (1984) noted that heavy utilization in the communal areas resulted in swards with a high proportion of "climax" species present but with low vigour. The nature of these changes is different even though the direction of the change in terms of successional theory may be the same.

The sites in this study were divided into two grazing regimes (*viz*. present communal and commercial grazing) as this was considered to be the most important aspect to look at in terms of change. Obviously, if drastic change had occurred due to climatic change nothing could then be done about it. If it was discovered, on the other hand, that drastic change had resulted from grazing pressure this study could possibly influence the decisions of the relevant authorities to implement the correct procedures.

The objectives of this study were to:
1) detect if change had occurred in the composition of the humid grasslands of KwaZulu-Natal since the original survey by Acocks (1953);
2) determine the magnitude of the change;
3) determine which habitats are more sensitive to change; and
4) determine the direction of the change in terms of species composition.

6.2 Methods

6.2.1 Data collection

The study sites were relocated using the methods described in Chapter 3.

The following environmental variables were determined for each site (for details see Chapter 5):
1) aspect and slope;
2) mean annual temperature (MAT);
3) mean annual precipitation (MAP);
4) altitude;
5) land-use; and
6) soils (obtained from land type maps produced by Cedara Agricultural Development Institute, Pietermaritzburg). The soils data were separated into three categories depending on their moisture-retention status. Category 1 consisted of soils which were shallow and thus had little moisture-retention ability; category 2 consisted of soils which had some drainage impediment in the form of plinthite in the profile; and category 3 consisted of soils which were freely drained thus allowing for deep infiltration of moisture. An ordinal scale of moisture-retention ability was thus created, indicating degree of drainage.

The same quadrat method as described in Chapter 5 was used to measure frequency and inter-plant spacing for each species. For details refer to Chapter 5.

From the two measurements taken (Chapter 5) it was possible to obtain a measure of the species's frequency and its median inter-plant spacing.

6.2.2 Data analysis

To collate the two field measurements the following equation was used:

$$P = D\ (Q/q) \qquad (6.1).$$

where

P = median distance adjusted for frequency

D = median distance between plants of the same species

Q = maximum number of quadrats in which the species could have occurred (*i.e.* 30), and

q = number of quadrats in which the species did occur.

The abundance of each species was then assigned a rank based on its P value. The smaller the P value, the greater the abundance of the species.

Acocks's (1953) data were collected using visual methods. He assigned symbols representing their inter-plant spacing and the degree to which each species was "localised" to each species. This was to assign an abundance value to each species. These symbols were often the same for many species at any one site implying that those species had the same abundance. These symbols could be ranked from the most to the least abundant species.

It was decided to use ranks because abundances indicated in the follow-up data were not considered to be numerically comparable with the original data but the consistency of the original data made it possible to use ranks. In other words the species with the most abundant symbol in the original data could be compared with the species with the lowest P value (*i.e.* highest rank) in the follow up survey. This was the only way which the two data sets could be compared.

The ranks were compared using a gamma rank correlation coefficient (Siegel & Castellan 1988). Gamma is computed as the difference between the probability that the rank ordering of the two species agree. The probability of ties is also taken into account.

From the data it is calculated as:

$$\text{Gamma} = \frac{\text{Number of agreements} - \text{number of disagreements}}{\text{Number of agreements} + \text{number of disagreements}} \qquad (6.2)$$

This was used as a measure of similarity between the original and follow up survey for each site. This coefficient uses the same background as the Kendall's tau (Siegel & Castellan 1988) but it copes better with ties. Acocks's data had many ties and it was therefore necessary to use an equation which was appropriate. Correlations between environmental variables and gamma coefficients were calculated. Gamma values range from -1 to 1 where -1 implies total dissimilarity between sites and 1 means that the sites are exactly the same.

Gamma coefficients were compared between land uses (*i.e.* communal or commercial grazing) using a two tailed *t*-test (Steel & Torrie 1980) for samples of different sizes. This was to see if there was a significant difference in the amount of change between grazing regimes. An analysis of variance (Steel & Torrie 1980) was conducted on the land-type data to see if they differed in their mean Gamma values. Linear regressions were conducted on the other enviromental variables to examine if any of them had a significant effect on the amount of change.

Three multiple regressions were run to examine specific models which were hypothesised as causes of change. The models were constructed to take into account all the measured environmental variables in a way that was considered to be biologically sound. The first model was as follows:

Gamma = landuse + landuse*maptemp + maptemp*soils*rad (6.3)

Where: Gamma = coefficient of similarity,

landuse = communal or commercial grazing,

maptemp = MAP/MAT ($mm.^{o}C^{-1}$),

soils = land type ,

rad = Radiation - graphically determined using slope and aspect ($10^{6}J.m^{-2}.day^{-1}$).

Owing to the high correlation between altitude, temperature and rainfall, the "maptemp" variable was introduced as a surrogate measure for altitude. This model involved one main effect variable, one first order interaction and one second order interaction. The term landuse*maptemp was designed because it was presumed that where the moisture regime (*i.e.* maptemp) was higher, the effect of the land use would be less. The term "maptemp*rad*soils" was a measure of the plants' growth potential. The rationale behind this term was that in areas of high moisture, low temperature (combined to form "maptemp"), high radiation (rad) and soils which had a free drainage system, the plants would have a better growth potential.

The second multiple regression model was as follows:

Gamma = Landuse + altitude + radiation + soils (6.4).

The third model to be fitted was the same as the previous one but maptemp replaced the altitude variable thus:

Gamma = Landuse + maptemp + radiation + soils (6.5).

The direction of change had to be determined using individual species. It was decided to examine this aspect using only the most abundant species in the original and follow-up sites so that gross changes could be examined as opposed to small changes which could easily be the result of seasonal fluctuations, imprecise measurements or noise. The process was as follows:

1) The top five ranked species of the original and the follow up sites were extracted. In the cases where ties in the original data made this impossible, the top six to nine ranked species were extracted.

2) The five species were then assigned new ranks of 5 - 1 for the purposes of conducting Correspondence Analysis (CA). The most abundant species would score 5 and the fifth most abundant species would score 1. If a species was rare in one of the surveys but common in the other it would gain the appropriate

rank for the site in which it was common and would be assigned a value of 0.01 for the site in which it was rare. This was merely to indicate its presence.
3) In the case of ties where, for example, three species tied for the top rank in the original survey, the three top species in the follow up survey were also tied to ensure comparability of the data. These species would, therefore, all be assigned the rank 5.

Thus three scenarios could have occurred *viz.* a site where the top five species contained no ties (Table 6.1), a site where either the original or the follow up survey could have yielded one or two ties but the total number of species from each temporal site which could have been used, remained five (Table 6.2) or a site where either the original or follow up survey could have yielded numerous ties resulting in the use of more than five species (Table 6.3).

Table 6.1. Example of site with no ties in the top five ranks

Spp	Original site rank	Follow up site rank	Original site rank for CA	Follow up site rank for CA
Themeda triandra	1	7	5	0.01
Tristachya leucothrix	2	-	4	-
Digitaria eriantha	3	1	3	5
Hyparrhenia hirta	4	12	2	0.01
Heteropogon contortus	5	2	1	4
Sporobolus africanus	8	3	0.01	3
Eragrostis curvula	-	4	-	2
Eragrostis racemosa	10	5	0.01	1

Table 6.2: Example of method of ranking a site with one tie in the top five ranks

Species	Original site rank	Follow up site rank	Original rank for CA	Follow up rank for CA
Themeda triandra	1.5	1	5	5
Trachypogon spicatus	1.5	9	5	0.01
Tristachya leucothrix	3	4	4	3
Aristida scabrivalvis	4	-	3	-
Monocymbium ceresiiforme	5	3	2	4
Harpochloa falx	-	2	0.01	5
Heterpogon contortus	-	5	-	2

Table 6.3: Example of method of ranking species for each site showing a site with a large number of ties

Species	Original site rank	Follow up site rank	Original rank for CA	Follow up rank for CA
Themeda triandra	2.5	6	5	4
Heteropogon contortus	2.5	3	5	5
Digitaria tricholanoides	2.5	12	5	0.01
Tristachya leucothrix	2.5	2	5	5
Eragrostis racemosa	6	4	4	5
Microchloa caffra	6	17	4	0.01
Elionurus muticus	6	5	4	4
Hyparrhenia hirta	11	1	0.01	5
Eragrostis curvula	13	7	0.01	4

The newly assigned rank values for use in the CA were analysed by means of partial correspondence analysis (CA) by using the CANOCO package (Ter Braak 1988). Effects of the environmental variables were partialled out so that the temporal changes could be isolated.

6.3 Results

Significant correlations were detected between MAP, MAT and altitude. Mean annual temperature was negatively correlated with altitude and mean annual precipitation was positively correlated with altitude. Mean annual precipitation was negatively correlated with mean annual temperature (Table 7.4). From this it was decided to create another variable called "maptemp" (Chapter 5).

The rationale behind maptemp was discussed in Chapter 5. "Maptemp" was highly correlated with altitude (r=0.681) and therefore could not be used in the same multiple regression as the altitude variable. It was, however, a reasonable substitute for altitude and could be used to explain biological differences.

Table 6.4: Correlation matrix of the measured variables (bold numbers are significant (P>0.05)).

	LU	Alt	MAP	MAT	Asp	Slp	soils	G
LU	1.00							
Alt	-0.25	1.00						
MAP	-0.14	**0.44**	1.00					
MAT	0.21	**-0.86**	**-0.44**	1.00				
Asp	-0.05	0.18	-0.01	-0.25	1.00			
Slp	-0.09	0.15	-0.03	-0.30	0.06	1.00		
soils	-0.20	0.16	-0.10	-0.13	-0.29	-0.06	1.00	
G	**-0.47**	**0.42**	0.19	-0.21	0.21	-0.13	-0.20	1.00

Key: LU = landuse

Alt = altitude

MAP = mean annual precipitation

MAT = mean annual temperature

Asp = aspect

Slp = slope

soils = soils

G = gamma

Variables which had an effect on the vegetation change over the

50 years were altitude (*F*=0.013) (Figure 6.1) and land use (*P*=0.014) (Figure 6.2). These were shown by the linear regressions and the *t*-test respectively. None of the other environmental variables had any effect on the vegetation change.

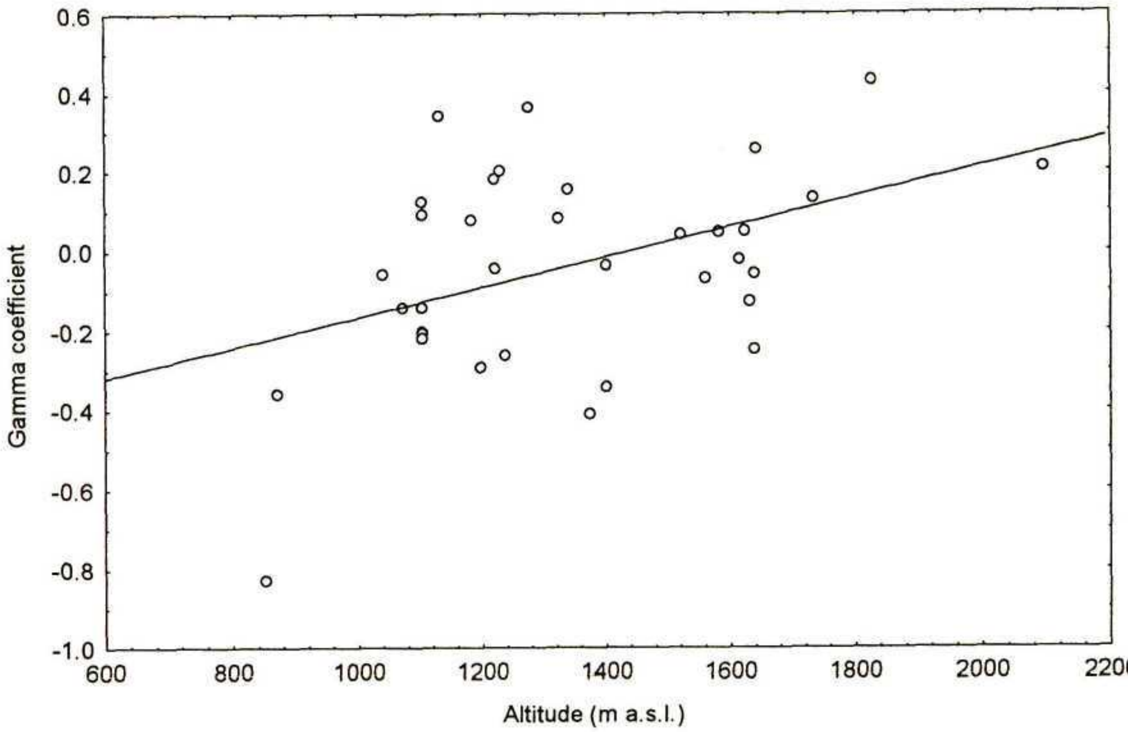

Figure 6.1. Relationship between Gamma and altitude.

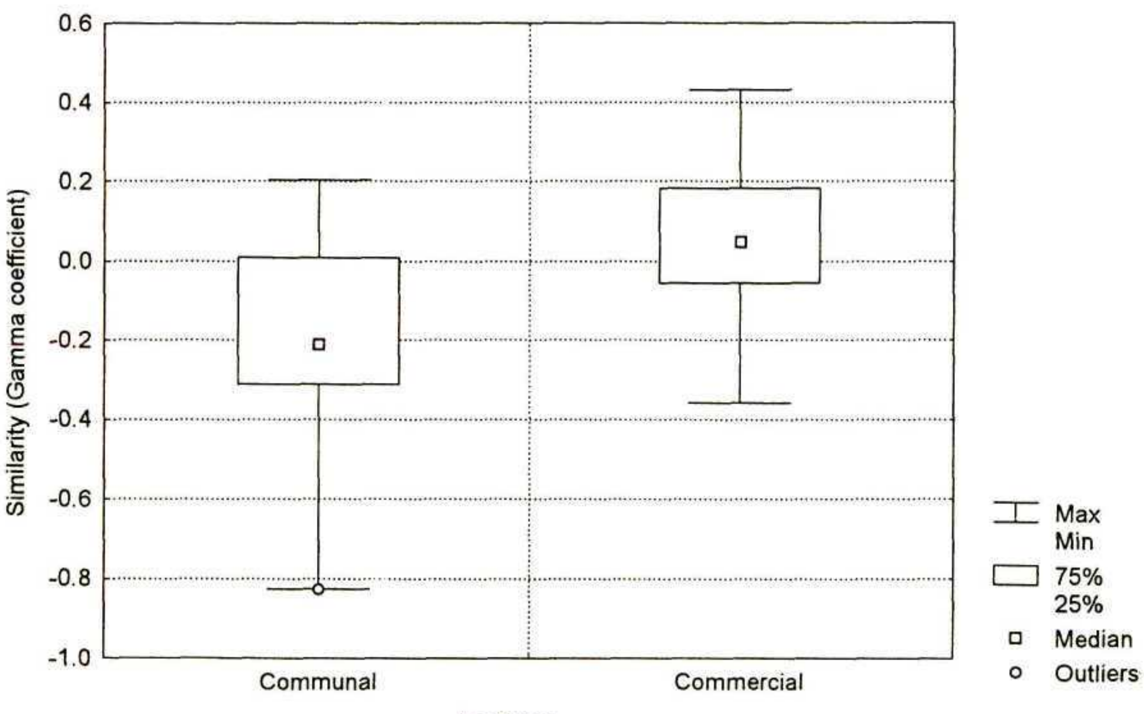

Figure 6.2. Relationship between Gamma and grazing type.

The first multiple regression model results (Eqn. 6.3) (Table 6.5) were significant overall (F=0.035; R^2=0.19) but none of the terms were significant (P>0.05). Much of the variation was not accounted for and it was thus deemed necessary to simplify the model to try to gain a better fit and to try to isolate the environmental variables which were affecting vegetation change.

Table 6.5. Multiple regression results of model 6.3

	Estimate	s.e.	*t*	*t* prob.
Constant	-0.267	0.245	-1.09	0.284
maptemp	0.006	0.004	1.32	0.196
Landuse C	0.519	0.552	0.94	0.354
maptemp* Landuse	-0.015	0.011	-1.38	0.179
Soils*evap	0.000	0.000	0.23	0.818

The second multiple regression was significant (F=0.004; R^2=0.31) (Table 6.6) and showed that altitute and land use affected the change. The effect of altitude could not be fully explained biologically. It could, however, be explained to some extent by the maptemp variable. The altitude variable was, therefore, replaced by the maptemp variable.

Table 6.6. Multiple regression results of model 6.4

	Estimate	s.e.	*t*	*t* prob.
Constant	-1.478	0.671	-2.20	0.035
Landuse C	-0.160	0.081	-1.98	0.057
Altitude	0.000	0.000	2.35	0.026
Radiation	0.041	0.022	1.85	0.074
Soils	-0.049	0.047	-1.05	0.304

This regression was also significant (F=0.028; R^2=0.20) but the only variable that showed any significance was the landuse (P=0.025) (Table 6.7). Landuse, therefore, was shown to affect the amount of change in both of the simplified models.

Table 6.7. Multiple regression results of model 6.5

	Estimate	s.e.	*t*	*t* prob
Constant	-1.114	0.725	-1.54	0.135
Landuse C	-0.120	0.085	-2.36	0.025
maptemp	0.003	0.004	0.79	0.435
Radiation	0.036	0.024	1.53	0.137
Soils	-0.032	0.054	-0.59	0.560

Although the regressions accounted for only little of the variation, they were all significant, thus showing some trend. The main variables which emerged as significant were the altitude and the grazing regime (landuse). None of the interaction terms was significant in any of the regressions. The term maptemp, although it was a substitute for altitude, could not account for as much variation as altitude.

There was less change recorded for grasslands that were under commercial utilization and at higher altitudes. None of the other measured environmental variables affected the amount of change. In other words, land use and altitude appeared to have an overriding effect on the amount of change experienced by the grasslands.

The partial CA revealed the change in each of the sites over time with the effects of the environmental factors removed from the analysis. Some striking trends were revealed. The species which had a great amount of their variation accounted for (*i.e.* greater than 20% for the first two axes) could comfortably be used to describe the trends (Table 6.8).

Table 6.8. Cumulative percentages of species for which more than 15% of their variation was accounted for by partial CA axes 1 and 2

Species	Axis 1	Axis 2
Sporobolus africanus	60	60
Eragrostis curvula	26	36
Tristachya leucothrix	24	33
Hyparrhenia hirta	21	22
Eragrostis plana	19	34
Elionurus muticus	19	20
Heteropogon contortus	17	33
Digitaria sanguinalis	15	25
Aristida barbicollis	15	50
Themeda triandra	15	15
Bothrichloa insculpta	6	59
Cynodon dactylon	4	30
Microchloa caffra	0.4	16
Chloris gayana	9	16
Eragrostis chloromelas	4	15

The species for which a large amount of variation was captured by the first axis include *Sporobolus africanus, Eragrostis curvula, Tristachya leucothrix* and *Hyparrhenia hirta* and the species whose variation was captured predominantly by axis 2 include *Eragrostis curvula, Microchloa caffra, Aristida congesta* subsp. *barbicollis* and *Heteropogon contortus*. These species were the most useful in interpreting the CA species ordination (Figure 6.3).

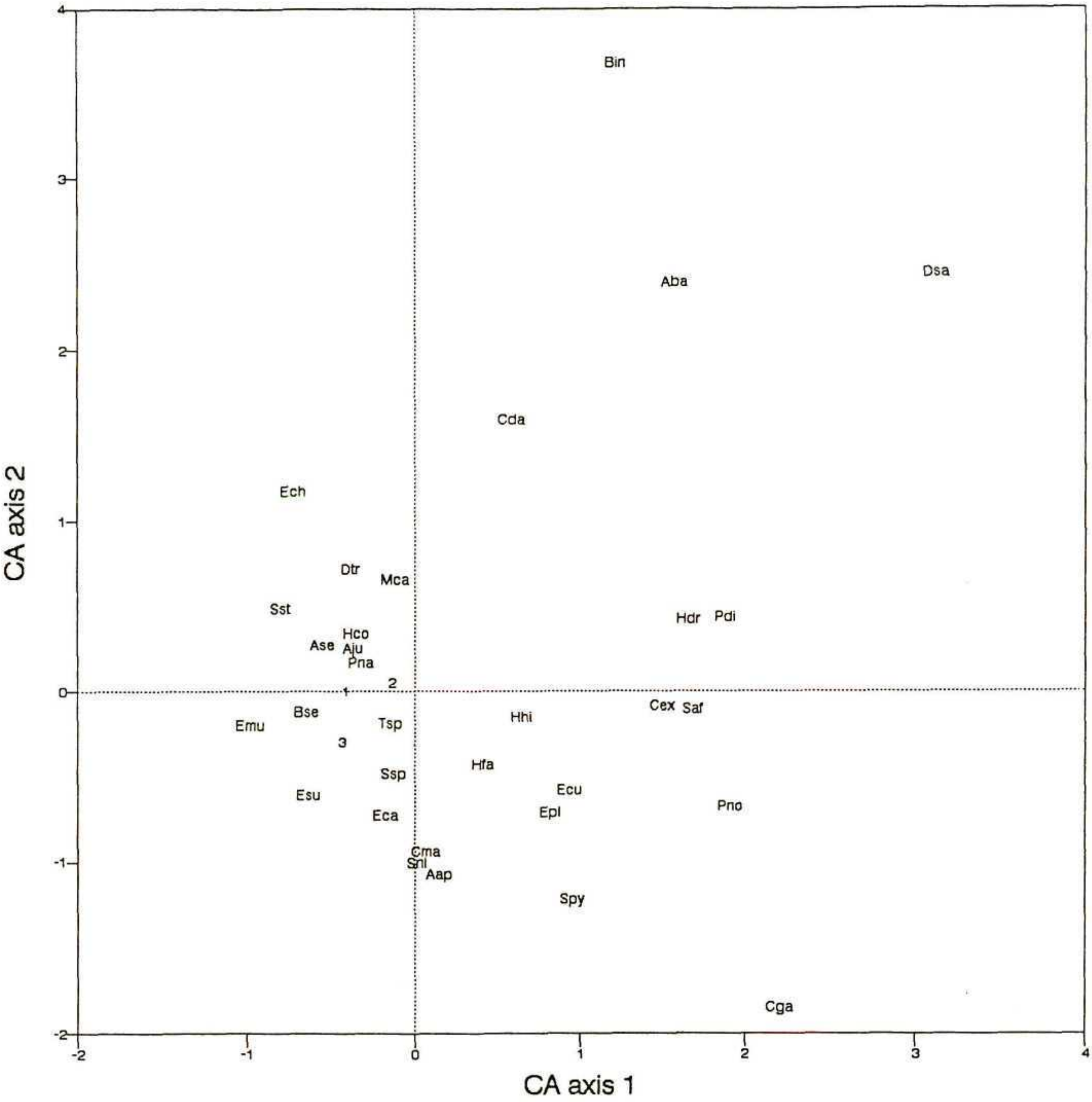

Figure 6.3. Ordination of species along partial CA axis 1 and 2.

Species key: 1-*Andropogon schirensis, Eragrostis racemosa, Themeda triandra*; 2-*Diheteropogon filifolius, Monocymbium ceresiiforme;* 3-*Diheteropogon amplectens, Tristachya leucothrix;* Aap-*Andropogon appendiculatus*; Aba-*Aristida congesta* subsp. *barbicollis*; Aco-*Aristida congesta* subsp. *congesta*; Aju-*Aristida junciformis*; Ase-*Alloteropsis semialata*; Bin-*Bothriochloa insculpta*; Bse-*Brachiaria serrata*; Cda-*Cynodon dactylon*; Cex-*Cymbopogon excavatus*; Cga-*Chloris gayana*; Cma-*Cymbopogon marginatus*; Dsa-*Digitaria sanguinalis*; Dtr-*Digitaria tricholanoides*; Eca-*Eragrostis capensis*; Ech-*Eragrostis chloromelas*; Ecu-*Eragrostis curvula*; Emu-*Elionurus muticus*; Epl-*Eragrostis plana*; Esu-*Eragrostis superba*; Hco-*Heteropogon contortus*; Hdr-*Hyparrhenia dregeana*; Hfa-*Harpechloa falx*; Hhi-*Hyparrhenia hirta*; Mca-*Microchloa caffra*; Pdi-*Paspalum dilatatum*; Pna-*Panicum natalensis*; Pno-*paspalum notatum*; Psc-*Paspalum scrobiculatum*; Saf-*Sporobolus africanus*; Sni-*Setaria nigrirostris*; Spy-*Sporobolus pyramidalis*; Ssp-*Setaria sphacelata*; Sst-*Sporobolus stapfianus*; Tbe-*Tragus berteronianus*; Tsp-*Trachypogon spicatus*; Umo-*Urochloa mosambicensis*; Upa-*Urochloa panicoides*.

The species whose variation was largely accounted for by axis 1 were distributed along a large proportion of the axis. Of these species *Sporobolus africanus, Eragrostis curvula, Hyparrhenia hirta, Eragrostis plana, Digitaria sanguinalis* and *Aristida congesta* subsp. *barbicollis* all had high scores. *Tristachya leucothrix, Elionurus muticus, Heteropogon contortus* and *Themeda triandra* all had low scores. The species with high axis 1 scores are generally those associated with heavy utilization whereas the species with low axis 1 scores are generally those which are associated with moderate use with the exception of *Elionurus muticus* which is associated with selective grazing (Tainton *et al.* 1976).

Species with high scores along axis 2 included *Digitaria sanguinalis*, *Aristida congesta* subsp. *barbicollis, Bothriochloa insculpta, Cynodon dactylon, Microchloa caffra* and *Eragrostis chloromelas*. The species with low scores along axis 2 included *Eragrostis curvula, Eragrostis plana* and *Heteropogon contortus*. The species with high scores on axis 2 are those generally associated with drier areas whereas the species with low scores on axis 2 are those species which tend to occur in moister areas (Chapter 5). All the species which could explain axis 2 are generally associated with heavy utilization (Chapter 5) (Tainton *et al.* 1976).

The sites ordination was separated into two separate figures namely commercially and communally grazed sites for clarity. The trajectories indicate the direction of change from the original to the follow-up surveys. The commercially grazed sites (Figure 6.4) showed no consistent trend in the direction of their trajectories. Seven of the 23 sites had a reasonable trend from low to high axis 1 scores. Three of the sites had long trajectories in the opposite direction. The rest of the trajectories tended to lie along axis 2 in either direction. The length of the trajectories was also important as these represented the amount of change relative to other sites.

The communally grazed sites ordination (Figure 6.5) showed some consistent direction in the trajectories. The amount of change was significantly higher (*P*=0.014) in the communal sites than the commercial sites which would explain the length of the trajectories in the ordination diagram. All but one of the 12 trajectories had strong tendencies along axis 1 from low to high scores. Some of the trajectories tended towards high scores on axis 2 and the majority of the sites tended towards low scores on axis 2. Interpreting this with respect to species, the trajectories which headed towards high axis 2 scores were increasing their proportions of species like *Aristida congesta* subsp. *barbicollis*, *Cynodon dactylon* and *Bothriochloa insculpta*. The majority of the sites, however, tended towards low axis 2 scores implying that the proportions of species like *Eragrostis plana*, *Eragrostis curvula* and *Sporobolus africanus* increased in those sites. The only site which did not tend positively along axis 1 had a strong trajectory along axis 2 and the tendency along axis 1 was weak.

The other important aspect to note is the distribution of the commercial sites as opposed to the communal sites. From the overall distribution of the two sets of sites (Figures 6.2 & 6.3) it could be seen that the spread of the commercial sites was far smaller than that of the communal sites. This emphasises once again the relative length of the trajectories between the two land use types.

In conclusion, the change was accounted for by land use and altitude. The change in communal areas was far greater than the change in commercial areas. The direction of change in terms of species composition was also far more consistent in communal areas than in commercial areas.

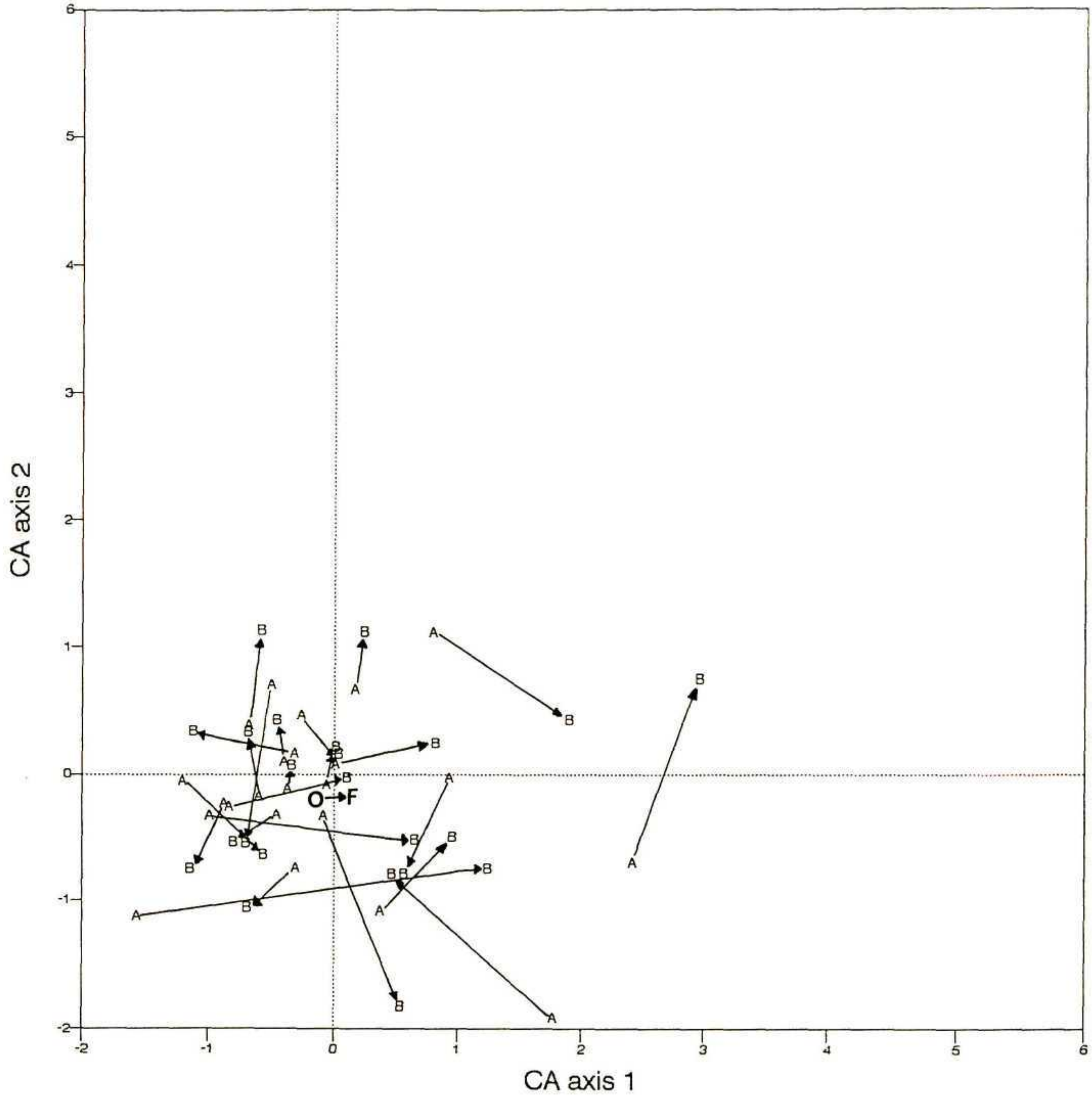

Figure 6.4. Ordination of original (A) and follow-up (B) commercially grazed sites along partial CA axes 1 and 2. Centroids of original sites (O) and follow-up sites (F) also indicated.

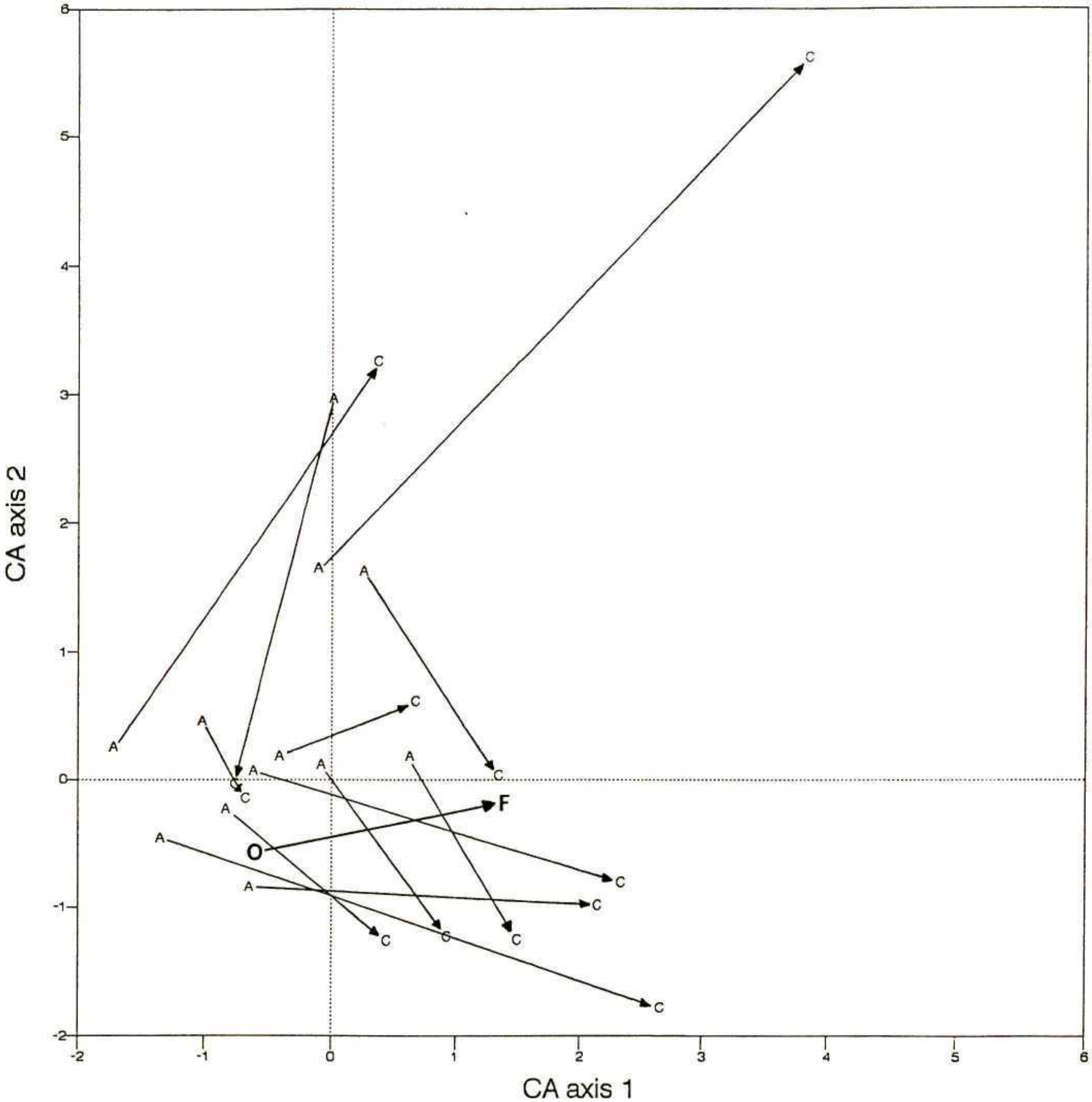

Figure 6.5. Ordination of original (A) and follow-up (C) communally grazed sites along partial CA axes 1 and 2. Centroids of original sites (O) and follow-up sites (F) also indicated.

6.4 Discussion

With increased moisture in the environment there tends to be less variability in the factors that encourage growth in plants (Holling 1973). With decreased variability in the climate the vegetation is also subject to less variability and thus it evolves to become a stable community. This kind of system is more resistant to change but when it does change it is less inclined to return to its original state than a grazed site in a less moist area (Holling 1973; Friedel 1991; Laycock 1991). In other words, when a "threshold" is crossed the vegetation then tends towards another community. This was also found to happen in the Southern Tall Grassveld (Acocks 1953) by Morris *et al.* (1992). The species which increase in their proportions in the sward are different in the drier areas to those which invade in the wetter areas. In the drier areas species such as *Bothriochloa insculpta, Tragus berteronianus* and *Aristida congesta* subsp. *barbicollis* increase in abundance, whereas in the moister regions species such as *Paspalum notatum* and *Paspalum urvillei* increase in abundance.

From the results it is evident that communal grazing has had a profound effect on the amount of change which has occurred over the last 50 years. The only environmental variable which affected the change was the altitude, which is difficult to quantify in terms of biologically important variables. The only way that this could be accounted for to some extent was by using the surrogate variable "maptemp" which related the increasing altitude to a corresponding decrease in mean annual temperature and an increase in mean annual precipitation. The amount of change decreased as altitude increased (not markedly however). This result has been corroborated by authors when the stability and resilience of ecosystems have been discussed (Holling 1973; McKenzie 1982; Westoby *et al.* 1989; Laycock 1991; Friedel 1991). In areas where the climatic variation is not as pronounced the vegetation is less inclined to change in response to anthropogenic impacts than vegetation in areas where climatic variation is pronounced. In areas where the climatic conditions are subject to a large amount of variability, the vegetation adapts and is also subject to changes depending on the prevailing climatic conditions (Westoby *et al*. 1989). Therefore in the grasslands of KwaZulu-Natal, where climatic variation is not too pronounced (Phillips 1969), change would be a result of intensive land use as opposed to annual climatic variation. However, as the grasslands tend towards drier areas the climate becomes more variable and the change in such areas would be expected to be greater.

The intensive grazing of the communal areas has resulted in a large proportion of "Mtshiki" species dominating those swards. This has been found in a number of studies (Morris *et al*. 1992; Tainton *et al*. 1978). *Aristida junciformis* was found predominantly in the commercially grazed areas. This could be interpreted as being the result of selective grazing in these areas. Since the communal grazing areas are so heavily grazed, all the component species tend to be defoliated to some extent thus reducing the vigour of the entire sward. This is the principle behind High Utilization Grazing (Booysen 1969).

The communal sites changed more than the commercial sites. The trajectories depicted in the communal and commercial grazing ordination diagrams showed that the communal sites had all changed a lot whereas the commercial sites, although there had been change, had far shorter trajectories. The commercial grazing trajectories were also in a number of different directions indicating that change was not in a uniform direction. This meant that some of the commercially grazed sites were improving and some deteriorating in terms of species composition. The communal grazing trajectories were all heading in one direction indicating that they had all undergone enough change to be heading towards a different vegetation community. These communities differed in species composition depending on the growing conditions, primarily moisture. Most of the sites had increased proportions of *Eragrostis curvula, Sporobolus africanus* and *Eragrostis plana*. The sites which were situated in drier regions increased their proportions of *Aristida congesta* subsp. *barbicollis* and *Tragus berteronianus*. The wetter sites increased in proportions of *Paspalum notatum* and *Paspalum dilatatum*. These drastic changes may imply that at high utilization levels the sward may cross some sort of a "threshold" whereafter the sward tends towards a different community. This was not, however, measured. This concept of the threshold has been discussed by other authors (Morris *et al*. 1992; Laycock 1991) and has been described by Hurd & Wolf (1974) as the "cup and ball" theory. According to Laycock (1991) it would be difficult to get sites which have undergone drastic change, or crossed a threshold, back to their original state. This has been shown by Tainton (1972), Morris *et al*. (1992) and Tainton *et al*. (1978) all of whom implied that it would be difficult to revert this vegetation to its original state through the use of standard management practices like fire and grazing. This may be because the species present in a heavily grazed sward are adapted to heavy grazing pressure and species which dominate a "well managed" sward may not be able to compete strongly enough with the present species to regain dominance.

7. DIFFERENCE IN BASAL COVER BETWEEN COMMUNAL AND COMMERCIALLY GRAZED AREAS

7.1 Introduction

Basal cover of grasslands refers to the amount of soil area which is occupied by the basal area of plants in the sward. It has been recognised as a relatively stable quantitative attribute of grassland vegetation compared to crown cover which is affected by grazing, burning and growing conditions (Morris & Muller 1970). It has been used in South Africa to assess the effects of long term utilization on veld (Morris & Muller 1970). A decrease in basal cover exposes the soil rendering it more susceptible to erosion.

The reasons why it is an important measure is that it decreases in conditions of under- or over-utilization (Tainton 1988). Under utilization encourages plants to become moribund causing the demise of the tuft centres as well as the shading out of new tillers that may potentially establish between the tufts (Tainton 1988). The result of this is a few tufts of large diameter but spaced far apart leading to a low basal cover. Over-utilization decreases the overall basal cover because, although new tillers don't senesce due to over-shading, they don't have an opportunity to establish properly because they are too heavily grazed before they can develop proper root systems and reserves to cope with heavy grazing. What would be found in this scenario is a lot of very small tufts that haven't had much opportunity to develop beyond a certain size but situated quite close together.

One would, therefore, expect to find a low basal cover in commercially grazed areas that are seldom burnt and very lightly utilised (Tainton 1988) or communal areas where grazing management is not properly controlled in terms of stocking rates, fire and other management factors (Forbes & Trollope 1991) resulting in very heavy utilization. In areas where veld management has been good (*i.e.* burning has been regular and stocking rates have been correctly adhered to) the basal cover would be high. This situation would most likely be encountered in the commercial sector in the humid grasslands under study.

The objective of this study was to determine whether the basal cover differed between areas under commercial and communal grazing regimes.

7.2 Methods

The location of the sites was discussed in Chapter 3.

One hundred distance (strike points to nearest tuft) and tuft diameter readings were taken at each site using the spike point method (Hardy & Tainton 1993). This entailed systematically placing 100 points with a spike and measuring the distance to the closest plant from the point of strike and the average diameter of the basal area of that plant. These values were then put into the equation derived by Hardy and Tainton (1993) to estimate basal cover:

$$BC = 19.8 + 0.39(D) - 11.87(\ln D) + 0.64(d) + 2.93(\ln d) \quad (7.1)$$

where D = mean distance to the tuft;
d = mean diameter of the tuft.

The results were analysed using two-tailed *t*-tests to examine possible differences between communal and commercial areas for:
1) mean distance to tuft;
2) mean diameter of tufts; and
3) mean basal cover of swards.

To avoid a type II error in the results a rigorous significance level of $P<0.01$ was set. This was because the measurements used in the *t*-tests were estimates of the basal cover and not exact measurements for each site.

7.3 Results

The *t*-tests revealed no significant difference of distance between the spike and plants. Although there was no significant difference between mean diameter of plants there was a tendency for the plants in the communal areas to be an average of 1 cm smaller (P=0.057). The mean tuft size in communal areas was estimated to be 4 cm whereas in the commercial areas the mean tuft size was 5 cm. The results of the basal cover estimates, however, showed a highly significant difference ($P<0.001$) between communal and commercial areas. In the communal areas the mean basal cover was estimated to be 15% (SE=2.53; n=16) whereas in the commercial areas the estimate was 20% (SE=2.43; n=29).

7.4 Discussion

Le Roux and Morris (1977) showed that basal cover did not respond to different cutting and burning treatments. They did not, however, have very rigorous cutting treatments which would have simulated the levels of grazing in the communal areas. Their experiment ran for only seven years and this may not have been sufficiently long to record definite changes.

The results of this study showed that there is a significant difference in the basal cover estimates of communal and commercial areas. These results corroborate the statement of Tainton (1988) which maintained that heavy utilization decreased basal cover by decreasing the size of each tuft.

In areas where the basal cover is low, the soils are less protected from erosion by wind and water. Tapson (1993) suggested that the amount of evidence supporting the hypothesis that communal grazing results in soil loss is limited, and that soil loss amounts may be over-estimated in communal areas. It stands to reason, however, that with a decreased plant cover in an area, the soil will be more exposed to erosion agents.

The amount of water runoff would also be higher since there is a low amount of basal cover to trap this water thus limiting the amount of water able to penetrate the soil thus leaving less moisture available to the roots of the plants. This would, in turn, decrease the growing potential of the plants. Primary productivity could, therefore, be reduced thereby lowering the forage availability for livestock.

The measurements of basal cover were merely estimates, so that the difference between communal and commercial areas had to be highly significant for there to be no doubt that there was a difference. The results of this study showed this.

8. DISCUSSION

8.1 Land cover change

Various forms of agriculture have taken over substantial areas of grassland in KwaZulu-Natal (Scott-Shaw *et al.* 1996). The extent to which natural grasslands have been lost to other forms of agriculture varies greatly according to veld type. Forestry has increased largely in the Natal Mistbelt Ngongoni Veld (Acocks 1953) probably due to the suitable climatic conditions in the area. High rainfall and deep soils (Phillips 1969) in this area are the criteria which are sought by foresters. Cultivated crop land does not seem to have encroached to any great extent on the grasslands. The cultivated areas are generally those in communal areas. This is probably due to the increasing population and its need to produce more food for subsistence purposes. In fact the Southern Tall Grassveld (Acocks 1953) has had a drop in the amount of commercial cultivation (pers.obs.) possibly due to the increased environmental awareness that these areas are unsuitable for cropping. This is borne out by many areas constituting "old lands." Typically *Hyparrhenia hirta* dominates such communities.

8.2 Species distribution in the study grasslands

The results of Chapter 5 showed that the main factors influencing the present distribution of species in the grasslands are rainfall, temperature and grazing with the interaction between grazing and growth conditions playing the major role. The species composition of the grasslands, given the same treatments, are fairly similar with a few outlying species at either end of the moisture and temperature scales. Intensive grazing, however, alters this to the extent that the dry areas have a greater difference in species composition compared to the moist areas than when the area is more leniently grazed.

8.3 Change in grasslands

The results from Chapter 6 indicated that there has been substantial change in the composition of the grasslands over the last 50 years. This effect is more pronounced in communal areas where the grazing intensity is high (Forbes & Trollope 1991; McKenzie 1984; Trollope 1985).

The difference in the amount of change between the communal and commercial grazing areas is also marked and this is probably due to the increased amount of knowledge about veld management in the commercial areas. It may also be a result of the ultimate objectives of the communal and commercial farmers being different in that communal farmers strive for quantity of animals and commercial farmers strive for quality of animals (Trollope 1985). Thus animal performance would be better in the commercial areas.

Chapter 5 showed that the main factor which influenced the distribution of species in the grasslands was the type of grazing. This was also the factor which influenced the change in the species composition (Chapter 6). Although the study concentrated on the different types of grazing (*i.e.* communal or commercial) these can be assumed to be of different intensities. Communal grazing lands are generally very overstocked relative to the recommended stocking rates whereas commercial grazing lands are generally more lightly stocked due to different farming objectives and differing levels of farming knowledge (Trollope 1985). This was an important finding because it showed that the composition of the grasslands would be more similar in all the study areas if it were not for the fact that the grazing intensities differed.

There are certain species which occur in the hotter, drier areas and not in the cooler, moister areas and *vice versa* but these are generally in the minority. The dominant species which constitute the humid grasslands of KwaZulu-Natal are the same (*e.g. Themeda triandra, Tristachya leucothrix, Hyparrhenia hirta, Eragrostis* *curvula, Eragrostis plana* and *Sporobolus africanus*).

The overlap, in terms of species composition, between commercially grazed sites was great thus making them all fairly similar. The communal sites on the other hand, tended to be very dissimilar to each other depending on the bioclimatic region. This was borne out by the spread of the communal sites in the ordination diagrams (Chapter 6). The hotter, drier regions under communal tenure tended to have species such as *Tragus berteronianus, Bothriochloa insculpta, Urochloa mosambicensis* and *Aristida congesta* subsp. *barbicollis* whereas the wetter, cooler regions under communal tenure tended to consist of species such as *Paspalum notatum, Paspalum scrobiculatum* and *Paspalum dilatatum*. There were also species which were present in all of the communally grazed sites regardless of the local bioclimate. These included *Sporobolus africanus, Eragrostis curvula* and *Eragrostis plana*. This species composition was expected under heavily grazed conditions (Tainton *et al*. 1978; McKenzie 1984; Tainton 1988; Morris *et al*. 1992).

The commercially farmed areas tended to have high proportions of Decreaser species (e.g. *Themeda triandra, Tristachya leucothrix, Heteropogon contortus*) regardless of bioclimatic conditions. This is probably the result of regular burning and moderate stocking rates. The timing of burning is also important. As previously mentioned the commercial farmers depend on the sustainability of their grass swards for continued production and hence continued income so many of them would burn to maintain their grasslands in a sustainable state.

Apart from the differences in species composition between communal and commercial areas, the difference in basal cover also is a clear indicator of the effects of heavy veld utilization. In communal grazing areas, the plants are so heavily grazed that the plants begin to exhibit prostrate growth habits thus resembling a lawn (pers. obs.). The size of the individual tufts is also significantly smaller. Tainton (1988) suggests that this effect results from the reduced vigour of the plants caused by regular defoliation and thus the reduced ability of the plants to photosynthesize resulting in reduced growth rates and/or tillering.

The species composition of the communal areas has been shown to have changed to a large degree. The increased proportions of the Increaser II species in communal swards results in decreased productivity since these plants tend to be less palatable to animals than Decreaser species and may only provide nutritious grazing in early spring (Tainton *et al.* 1976). If, however, the grazing pressure had to be lessened in these areas, they could become invaded by other undesirable species such as *Aristida junciformis* due to the increased selective grazing which would then occur giving young seedlings of *Aristida junciformis* a chance to establish (Morris *et al.* 1992). The chances that these areas will revert to a *Themeda triandra* dominated grassland are minimal (Tainton 1988). It is possible that the areas which have been heavily grazed have crossed a threshold and tended towards another stable state (Friedel 1991). The soil in these regions is also more susceptible to erosion than in commercial areas now that it has lost a lot of its cover. In commercial areas, there is not only a higher basal cover than in the communal areas but most likely more above ground herbage due to the lower grazing pressure. This herbage helps protect the soil from erosion agents such as wind and rain drop splash. The lower stocking rates in the commercial areas also reduce the destructive effect of excessive trampling by stock.

Although the grazing intensities affect the species distribution in the study grasslands, the bioclimatic factors interact with grazing to affect the amount of change. In the drier areas the difference between commercial and communal sites in terms of their species composition is higher than in the cooler, moister areas. This showed that dry areas are more sensitive to grazing impacts than wet areas. This is probably due to the fact that the amount of fluctuation found in drier areas is greater owing to erratic rainfall conditions.

8.4 Limitations in the use of Acocks's sites for the reassessment of grassland

This study has provided an ideal opportunity to examine the suitability of Acocks's sites for reassessment purposes. Owing to the fact that the sites were first surveyed about 50 years ago, it was considered a good baseline set for the assessment of the veld after 50 years of use and change. There were, however, problems with the original sampling procedure, relocation of sample sites and analyses which will be discussed in this chapter.

The sites were originally drawn on a 1:500 000 scale topocadastral map. The size of the dot for each site was large (*i.e.* 2 - 5mm in diameter) for the scale on the map. To put this in context, a dot 2mm in diameter equates to a site which is 1000 m long. This makes accurate relocation very difficult especially in areas where the vegetation varies over a small area. This is often the case in the humid grasslands of KwaZulu-Natal where the topography is varied thus creating many different microclimates. The descriptions that Acocks wrote down to relocate the sites were often scant and difficult to recognise in the field. The distances from site to site that he recorded for each of the sites were also difficult to follow because a lot of the roads he travelled are now non-existent. Another set of coordinates was obtained from the Botanical Research Institute in Cape Town. The two sets of coordinates were compared and those that coincided were considered to be accurately relocated sites. In this study only 36 out of the total 46 sites could be confidently relocated and this was partly due to the descriptions and coordinates being accurate for those sites.

The original data set was considered to be very consistent (Westfall *et al.* 1996) but the manner in which it was derived gave rise to some questions. Firstly, the plant abundances seemed to be unrealistic in terms of the figures quoted in the text (Acocks 1953). Plant abundances recorded by Acocks (1953) were as high as 15 122 520 plants (mean inter-plant spacing of 25 mm) per hectare although this would obviously be a rare occurrence. The next abundance level down was, however, found to be quite common in the original data sheets and this equated to 1 680 280 plants per hectare, which is derived from a mean inter plant spacing of 76 mm. In the follow-up survey plant abundances of this magnitude were not recorded. Although the original data set was considered to be consistent in the ranking order of the species abundances, it was not considered to be accurate for individual species' abundances. This made it difficult to compare direct measurements for species. Secondly it was common for more than one species to gain the same abundance symbol at any site in the original survey. This made quantitative comparisons very difficult because a quantitative approach seldom yields exactly the same measurements for two different species let alone four or five species.

Acocks's (1953) species lists for each site differed in their level of recording. For some of the sites he recorded full species lists whereas for others he recorded only some of the species. This is evident especially in cases where he surveyed bush clumps in the Tall Grassveld (Acocks 1953) areas of KwaZulu-Natal.

The recording of forbs was also difficult to follow up because of the annual or ephemeral nature of a lot of them. For resurvey purposes the conspicuous common perennial forbs were the only ones easily surveyed.

The exact way in which Acocks surveyed his sites was also obscure. In the text (Acocks 1953) it states that areas of homogenous vegetation were surveyed but the data sheets often reveal different types of vegetation such as forest and grassland for the same site.

Acocks's (1953) data set achieved its objectives and this is borne out by the fact that Acocks (1953) has been, and continues to be, cited in many scientific reports. The question whether it is a good baseline for long term monitoring programs is debateable. The resurveying of Acocks's sites has involved a great deal of fitting "square pegs into round holes" in terms of the data manipulation and analysis and it has been very difficult to achieve any fine level of accuracy. Coarse changes in the vegetation are easily picked up by examining changes in the dominant species between the surveys. This is an important aspect of long term monitoring and, as this survey has indicated, can be achieved. Further than that I see no easy method of using the original data set as a baseline for vegetation monitoring.

8.5 Conclusion

Acocks's (1953) sites were used successfully to assess the extent of compositional change in the KwaZulu-Natal grasslands. It was found that change in composition had occurred in all the sites with the most pronounced change being found in the communally grazed sites. This change may not be considered to be detrimental to some farming objectives but in terms of species composition degradation has occurred.

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Appendix 1

Coordinates of study sites

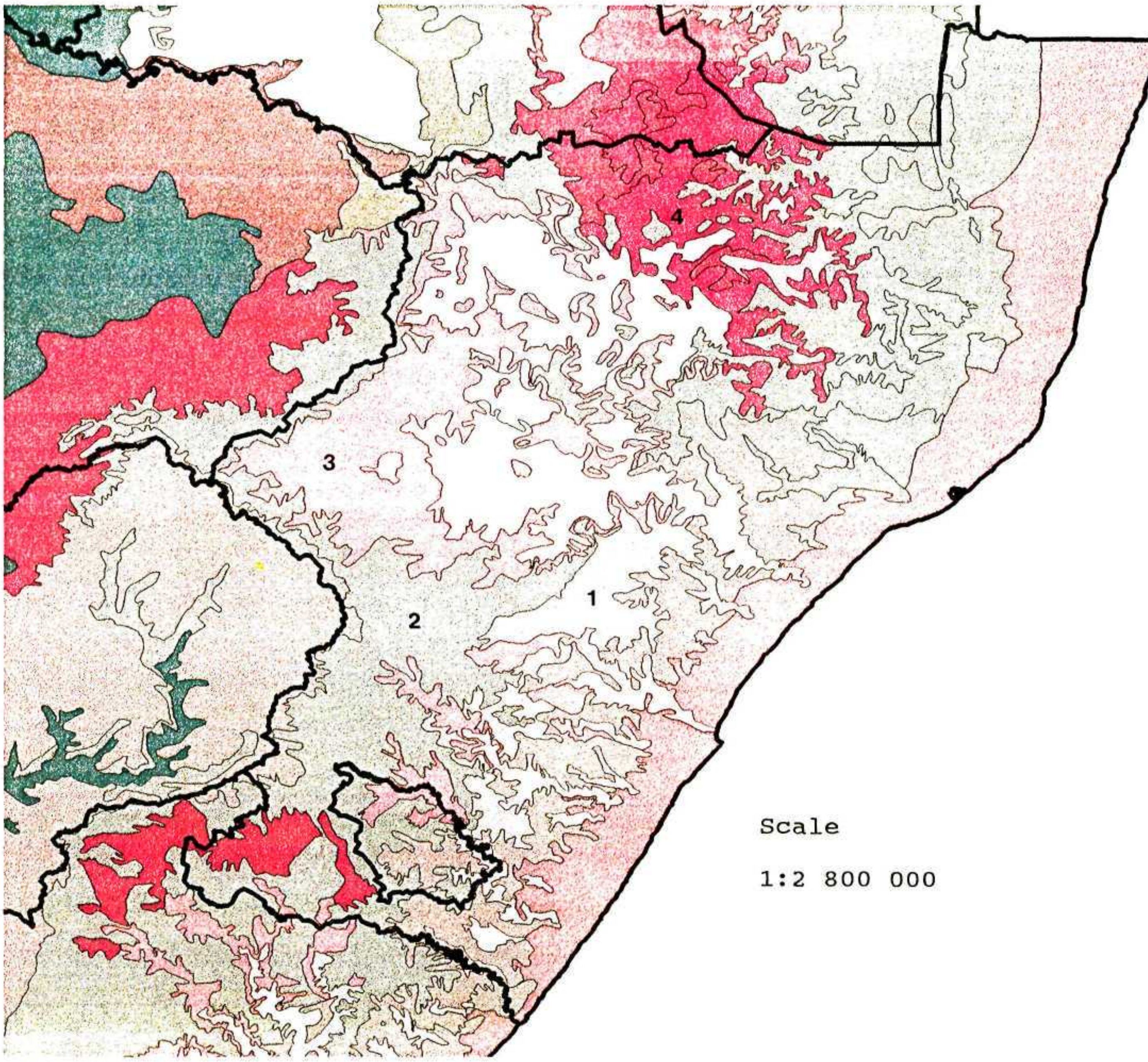
Site number	Latitude	Longitude
325	28 08 44	29 57 25
326	29 05 27	29 47 45
330	29 00 00	29 42 33
332	28 58 55	29 49 26
333	28 51 16	29 47 58
335	29 06 49	29 38 53
336	28 55 22	29 48 04
362	28 33 41	29 03 56
365	29 07 22	29 38 25
370	27 47 03	30 21 31
392	29 17 19	30 03 40
394	29 22 05	30 14 55
397	28 34 30	30 26 39
409	28 22 55	29 56 30
410	28 34 05	29 56 30
412	28 35 27	29 40 49
414	29 03 16	29 45 37
418	28 58 22	30 45 00
468	27 08 03	30 49 09
532	30 34 05	29 54 04
573	28 22 22	29 23 16
718	28 33 49	29 40 21
760	27 39 16	29 52 01
761	29 23 27	29 54 29
802	27 47 35	31 13 38
803	27 34 30	30 54 33
888	27 14 44	31 15 27
889	27 16 46	30 53 56
923	29 11 11	29 47 27
927	28 58 22	30 13 01
928	28 57 00	30 13 47
931	28 15 49	29 46 49
932	28 13 38	29 39 42
997	29 38 27	29 48 46
998	29 39 33	30 05 34
1039	29 27 16	30 06 37
1049	29 04 05	29 48 53
2726	30 15 25	29 57 50
2729	29 26 11	30 25 43
2733	29 27 16	29 44 51
2738	30 31 05	29 24 30
2763	30 15 57	29 29 13
2766	29 44 44	29 49 48
2767	29 40 55	29 31 51
2768	29 33 16	29 36 30
2777	30 21 00	28 48 36

Note:

1) Latitude coordinates are all South
2) Longitude coordinates are all East
3) All coordinates are in Degrees, minutes and seconds format.

Appendix 1 continued

Distribution of Acocks's Veld Types in KwaZulu-Natal



- 1 NGONGONI VELD OF NATAL MIST-BELT
- 2 HIGHLAND SOURVELD AND DOHNE SOURVELD
- 3 SOUTHERN TALL GRASSVELD
- 4 NORTHERN TALL GRASSVELD

Appendix 2

Original and follow-up surveys' species abundance data

Site	0330	0332	0333	0336	0362	0365	0370	0394	0397	0409	0410	0412
Species	abund	abund	abund	abund	abund	abund	abund	abund	abund	abund	abund	abund
Aap										lab		
Aba				lc			lf		c	lab	lc	lc
Abi												
Aco												
Aju								f				
Ase					f-	o		f				
Bbl												
Bin	ab										IC	
Bse	f					f	o	c	f	f	f	F
Cda	ab						lab		c	lab	lab	o
Cex		ff	o				o		f		lf	
Cga												
Cva							f					
Cvi											lc	
Dam												
Der											o	o
Dfi								c				
Dmo												
Dsa												
Dte												
Dtr									ab	ab		
Eca			f	c				f				f
Ech	c			C			o		f/ab			c
Ecu			o		IC							lf
Egu				o								
Ein												
Emu	f	ff	ff	f						c	f	c
Ene										ff		
Epl		f		lc		c			f	o	f	o
Era	o			c		ab	c	f	c	c		c
Esu			r									f
Evi												
Hco	c		o	C+		ab		f	c	ab	ab	ab
Hdr												
Hfa					f	o						
Hhi	f	c	IAb	lc		lab	C		vab	lc	IC	IF
Hru												
Hta												
Htu			f									
Icy												
Lsi								f				
Mca	c		c			c		f	ab	c		
Mce					C	c		c	f	lf		
Mne												
Mre	f											
Paq												
Pcl												
Pdi												
Pec												
Pna												
Pno												
Ppa												
Psc									o			
Pur												
Ral												
Saf									f	lff		
Sce				c								
Sfi												
Sni				lc								
Spy												
Ssp				lc								
Sst				c								c
Tbe												
Tle		Ab	c	c	ab	ab			f	ab		ab
Tra												
Tsp		c			Ab	c		C		f		
Ttr	c	Ab	Ab	C+	Ab	c	Ab	Ab	o	ab	Ab	ab
Umo												
Upa												

Site	O418	O468	O532	O573	O718	O761	O802	O888	O923	O927	O928	O931
Species	abund	abund	abund	abund	abund	abund	abund	abund	abund	abund	abund	abund
Aap			C									o
Aba												
Abi												
Aco												
Aju	o/lf			r								
Ase			F	C		f			C			
Bbl												
Bin												
Bse	f		F		f	ff	f					o
Cda												r
Cex							o					f
Cga												
Cva												
Cvi										ab		
Dam	f			F	f		C			o		
Der												
Dfi						f			o			
Dmo										f		
Dsa										C	f	
Dte												
Dtr						o	f		lc			ab
Eca	ff		f	f					f	Ab	f	o
Ech										lAb		
Ecu		F			o		o					
Egu												
Ein												
Emu					f		r				f+	
Ene												
Epl								f	lC	o	c	o
Era	c	f	c	ab	f	f	c		ff	ab		o
Esu												
Evi												
Hco	c		C	C	lAb	C	o		VAb	VAb	c	C
Hdr												ff
Hfa						o			o		f	
Hhi		C			Ab	F	C			f	vAb	lAb
Hru												
Hta												
Htu												
Icy												
Lsi						f	f					
Mca			f			c	f		c	ab	c	
Mce				F		ff	f					
Mne												
Mre												
Paq												
Pcl												
Pdi												
Pec				o					f			
Pna						F	f					
Pno												
Ppa												
Psc												
Pur												
Ral				F								
Saf	ff		ff							lab	Ab	lf
Sce												
Sfi												
Sni	lc	C					lab			o	o	f
Spy												
Ssp					f					VVAb		
Sst												
Tbe												
Tle	ab	F	C	Ab		C	Ab	ab	Ab	Ab		
Tra												
Tsp	C	C		C			f		F			Ab
Ttr	c	C	Ab	C	Ab	C	f		Vab	Ab	Ab	VAb
Umo												
Upa												

Site	O932	O998	O1039	O2726	O2733	O2738	O2763	O2766	O2767	O2768	O2777
Species	abund	abund	abund	abund	abund	abund	abund	abund	abund	abund	abund
Aap						IvAb	IAb				
Aba											
Abi											IIc
Aco											Ic
Aju	ff		C	o					o	r	
Ase	C	c	F		c/lab	f+	C+		Ab-	Ab-	
Bbl				o/If							
Bin											
Bse	o		C			o/If				o/f	
Cda		Iab				Ivab					Ivvab
Cex				IC							f+
Cga				IVAb							
Cva											
Cvi											
Dam	f					Ab-	f			C+	
Der											
Dfi	Ab				c+				C+	ab-	
Dmo	o										
Dsa					f-			If	Iab	Ic	
Dte											Ic
Dtr	r				If						
Eca			f	f	f	f	f/Ic		c	f	
Ech		Iab				Iab					
Ecu			ff/IC	IC+	c	Iab	IC	f	IC	If	IIf
Egu											
Ein											
Emu						c			f		
Ene											
Epl	o	VAb		Iab	c	IAb	IvAb	ff	IvAb	IIc	f
Era	ab	f	C		c/lab	c	ff		f/lab-		
Esu											
Evi						F					
Hco		ab	C		f/IAb	Ab	Ivab		IAb	Iab	
Hdr											
Hfa									f		
Hhi	IC		If	Ab			IvAb	ab	IAb	IC	Ab-
Hru											
Hta											
Htu											
Icy											
Lsi			F		f				c	f	
Mca		VVAb		IIc		c	f/lab				f
Mce	Ab		C		f				ab-		
Mne											
Mre											
Paq											
Pcl											
Pdi			IC								r
Pec	C	c			f						
Pna	f				C						
Pno											
Ppa											
Psc	o	Iab		o				o		r	
Pur				Ic							
Ral											
Saf	If	Ab				Ic		c/lab	Ic	Ic	f
Sce									c-		
Sfi											
Sni						ff	Iab				
Spy				Iab							
Ssp			o					f			
Sst											
Tbe											
Tle		ab			Ab-	Ab	Ab		vAb	Iab	Ab
Tra											
Tsp	VAb		f		f/Ic	f+	c		c+		
Ttr	Ab	ab	Ab		c/IAb	Ab	vAb		vAb	c	f
Umo											
Upa											Ic

Site	F325		F326		F330		F332		F333		F335	
Species	freq	dens	freq	dens	freq	dens	freq	dens	freq	dens	freq	dens
Aap	3	150							1	18	2	37
Aba												
Abi												
Aco												
Aju	2	150	1	150	16	36						
Ase	1	150									22	31
Bbl												
Bin												
Bse			2	11	2	150	11	150	18	48	1	8
Cda												
Cex							6	150	9	62		
Cga												
Cva							8	150				
Cvi												
Dam	5	42									6	74
Der												
Dfi	2	150									18	34
Dmo												
Dsa												
Dte												
Dtr					11	32						
Eca	2	150			4	14	7	43			5	150
Ech												
Ecu	2	25	9	28			1	10	12	36		
Egu												
Ein												
Emu	21	18			12	20	25	35	1	15		
Ene												
Epl	1	31	17	45	2	150	3	150				
Era	21	20	8	16	29	16	2	150				
Esu									11	31		
Evi											2	150
Hco	17	20	3	13	21	26	5	40	10	20	8	58
Hdr			13	22								
Hfa											3	150
Hhi			7	27	13	29	13	54	10	40		
Hru												
Hta											1	150
Htu												
Icy												
Lsi												
Mca	3	150			20	28	7	53	1	150	2	15
Mce	18	38									5	42
Mne												
Mre												
Paq											2	150
Pcl			2	9								
Pdi			1	12								
Pec	1	150	1	32							5	45
Pna												
Pno			28	12								
Ppa												
Psc												
Pur												
Ral												
Saf			27	18	6	150	1	150				
Sce									4	150		
Sfi												
Sni							21	28				
Spy												
Ssp					3	72	1	24				
Sst									2	17		
Tbe												
Tle	28	21	7	15	29	7	29	14	12	24	30	14
Tra					1	5						
Tsp	7	30									5	16
Ttr	27	23			5	16	16	48	28	22	28	13
Umo												
Upa												

Site	F336		F362		F365		F370		F392		F394	
Species	freq	dens	freq	dens	freq	dens	freq	dens	freq	dens	freq	dens
Aap			2	150	7	14			6	53	1	150
Aba	2	150					18	24				
Abi												
Aco												
Aju									8	150	17	30
Ase			15	47	18	54			12	57	5	150
Bbl												
Bin	2	150										
Bse							1	150	10	53	17	76
Cda							4	16				
Cex	2	150					12	41				
Cga												
Cva												
Cvi												
Dam			3	52			1	150				
Der												
Dfi									1	34	13	60
Dmo												
Dsa												
Dte					2	150			9	54		
Dtr			8	26							10	29
Eca	5	23	3	43	15	14			1	47	10	60
Ech							2	24				
Ecu	12	41	4	40	1	53	17	35	18	34	1	5
Egu	4	45										
Ein												
Emu												
Ene												
Epl	4	150			24	29			6	65		
Era			8	29			12	19			25	32
Esu	23	32										
Evi												
Hco	7	150	22	27	1	150	14	28	12	34	24	38
Hdr												
Hfa			5	32	18	26			2	31	4	150
Hhi	2	72					11	29				
Hru												
Hta												
Htu					1	92						
Icy												
Lsi											16	48
Mca	25	37			3	150	5	150	6	52	12	53
Mce			27	27							23	34
Mne												
Mre												
Paq					3	150						
Pcl												
Pdi												
Pec					11	25					3	43
Pna			20	29							6	29
Pno												
Ppa												
Psc												
Pur												
Ral			2	13								
Saf					6	11			8	36		
Sce												
Sfi												
Sni	1	150	2	150								
Spy												
Ssp	4	20							1	150		
Sst	25	14										
Tbe							2	150				
Tle	1	3	21	23	24	20			24	22	8	150
Tra												
Tsp			6	45								
Ttr	27	16	25	18	27	15	28	14	29	22	28	15
Umo							2	36				
Upa												

Site	F397		F409		F410		F412		F414		F418	
Species	freq	dens	freq	dens	freq	dens	freq	dens	freq	dens	freq	dens
Aap	1	150										
Aba	19	39	3	25	21	23	12	39	5	34		
Abi												
Aco					5	29	1	18				
Aju									4	40	30	16
Ase												
Bbl												
Bin	2	11			26	21	19	16				
Bse			3	150	2	25					9	41
Cda	3	150	1	150	4	150	13	22				
Cex	19	33	2	150	6	36	4	150				
Cga												
Cva	1	150										
Cvi					4	150						
Dam											4	150
Der					1	150	2	36				
Dfi												
Dmo												
Dsa	3	150			3	17						
Dte												
Dtr			5	150					3	10		
Eca			2	15			1	20			13	72
Ech												
Ecu	12	19			2	73	7	52	12	37	21	25
Egu									2	100		
Ein												
Emu			9	39								
Ene			6	31								
Epl	7	150	2	35	3	22	2	150	11	34	4	150
Era	15	22	22	12	1	23	1	38	4	15	9	51
Esu							5	28				
Evi												
Hco	9	24	13	33	2	150	11	19	22	16	30	12
Hdr	1	150	3	25	1	70			20	25		
Hfa												
Hhi	26	17	27	25	2	21	13	26	7	27		
Hru							3	47				
Hta												
Htu												
Icy												
Lsi												
Mca	8	40	2	33			3	8	16	11	9	15
Mce												
Mne												
Mre	1	150										
Paq												
Pcl												
Pdi	2	150										
Pec												
Pna												
Pno			1	6					7	22		
Ppa												
Psc	2	13							13	23		
Pur												
Ral												
Saf	20	39	2	150	7	17	4	150	27	19	4	36
Sce												
Sfi												
Sni											4	12
Spy												
Ssp												
Sst							8	26				
Tbe					6	31						
Tle			16	31					1	12	13	76
Tra												
Tsp			1	150								
Ttr	2	150	15	45	1	7	4	18			4	150
Umo					3	26						
Upa												

Site	F468		F532		F573		F718		F760		F761	
Species	freq	dens	freq	dens	freq	dens	freq	dens	freq	dens	freq	dens
Aap												
Aba									5	28		
Abi												
Aco	3	12										
Aju					7	85						
Ase					2	150					20	36
Bbl												
Bin												
Bse	1	150					15	61			8	150
Cda							9	74	11	8		
Cex									5	58		
Cga			4	25								
Cva												
Cvi												
Dam					2	44			1	150	1	150
Der									1	150		
Dfi											1	150
Dmo												
Dsa									1	150		
Dte												
Dtr					4	7					10	15
Eca					6	67	13	38				
Ech	1	31										
Ecu	15	30	3	22	13	33	19	40	18	22	5	28
Egu	6	150										
Ein									5	150		
Emu							23	37			7	18
Ene												
Epl	9	54	26	13	9	47	2	150	15	30	11	60
Era	20	15			29	20	17	47	9	20	14	41
Esu												
Evi												
Hco	13	40			30	13	9	36	5	52	30	16
Hdr												
Hfa											1	150
Hhi	23	29	5	150			12	76	22	36		
Hru												
Hta												
Htu												
Icy												
Lsi												
Mca					1	150	4	150				
Mce	6	62			29	13					4	150
Mne												
Mre												
Paq												
Pcl												
Pdi									5	14		
Pec					2	150					1	150
Pna											3	25
Pno												
Ppa												
Psc	3	150	4	55					2	150		
Pur			26	27								
Ral												
Saf	12	41	30	14					12	37	1	55
Sce												
Sfi												
Sni									4	33		
Spy									1	17		
Ssp												
Sst							8	25				
Tbe												
Tle	6	150			28	17	24	14			23	28
Tra												
Tsp	15	34			2	32					7	30
Ttr	15	39			18	37	6	43	8	27	9	29
Umo									3	150		
Upa												

Site	F802		F803		F888		F889		F923		F927	
Species	freq	dens	freq	dens	freq	dens	freq	dens	freq	dens	freq	dens
Aap												
Aba			2	26								
Abi												
Aco	1	42			5	11						
Aju											3	73
Ase									4	65		
Bbl												
Bin					13	23						
Bse					2	150					9	65
Cda												
Cex	16	38	23	36	5	150	19	44				
Cga												
Cva												
Cvi												
Dam	1	150	1	150	1	150	4	150			13	53
Der												
Dfi									11	65		
Dmo												
Dsa			2	150			1	150				
Dte												
Dtr									5	17		
Eca	2	16	1	26					13	19	15	52
Ech			1	10								
Ecu	17	34	19	17	13	24	30	15	18	40	12	29
Egu												
Ein												
Emu	1	150			1	11			21	34		
Ene												
Epl			8	34			13	30	17	49	18	26
Era	4	60					7	56	21	32	1	12
Esu					1	48						
Evi												
Hco	1	73			4	33	5	13	12	37	8	48
Hdr	2	150										
Hfa									8	54	2	43
Hhi	23	14	30	27	25	22	24	26			19	40
Hru	7	35	1	46								
Hta											4	80
Htu									2	150	1	43
Icy			16	22								
Lsi												
Mca									13	26	1	150
Mce	6	35									2	150
Mne	5	25										
Mre	14	25										
Paq												
Pcl												
Pdi							10	37				
Pec												
Pna												
Pno												
Ppa	1	150										
Psc	4	150	5	150	1	150	14	49	1	1	4	150
Pur												
Ral												
Saf	16	41	30	20			22	33	3	150	20	31
Sce												
Sfi					27	25						
Sni											9	150
Spy	1	65										
Ssp												
Sst												
Tbe												
Tle	1	9			5	40	2	28	28	15	21	23
Tra	1	150										
Tsp									1	150	6	41
Ttr	2	150							19	17	26	26
Umo					18	25						
Upa	2	150			1	150						

Site	F928		F931		F932		F997		F998		F1039	
Species	freq	dens	freq	dens	freq	dens	freq	dens	freq	dens	freq	dens
Aap	3	39	10	35	1	150	1	39	16	22		
Aba												
Abi												
Aco												
Aju	3	67			1	33					29	14
Ase	5	88			13	97						
Bbl												
Bin												
Bse	3	150	1	150	1	25					15	25
Cda			5	37					1	10		
Cex			15	57								
Cga												
Cva												
Cvi												
Dam	14	20			1	150					19	33
Der												
Dfi					9	90						
Dmo					2	150						
Dsa							11	69				
Dte												
Dtr			23	16	8	37						
Eca	4	150	2	150	1	19			1	6	12	24
Ech												
Ecu	6	24	14	34	12	30	25	10	13	36	5	39
Egu												
Ein												
Emu	2	38										
Ene												
Epl	20	28	14	80	8	74	23	31	29	12		
Era	3	35	14	39	13	53					26	17
Esu												
Evi												
Hco	8	32	20	17	6	11	2	150			14	25
Hdr			11	48	23	24						
Hfa	5	15									3	150
Hhi	16	32	4	150							9	36
Hru												
Hta												
Htu	3	29										
Icy												
Lsi												
Mca	2	19	1	16			7	8			21	20
Mce					22	36						
Mne												
Mre												
Paq	5	17					2	150				
Pcl												
Pdi							3	27	2	150	1	150
Pec											1	150
Pna			8	38	6	150						
Pno							1	43	20	6	7	25
Ppa												
Psc					2	150	6	25			8	71
Pur												
Ral												
Saf	14	31	21	23	4	150	28	20	3	42	4	38
Sce												
Sfi												
Sni	4	49	1	150								
Spy												
Ssp	1	7									2	150
Sst												
Tbe												
Tle	14	24			2	150	8	13				
Tra												
Tsp	2	52			11	47					2	150
Ttr	27	16	9	35	25	49			1	18	3	150
Umo												
Upa												

Site	F1049		F2726		F2729		F2733		F2738		F2763	
Species	freq	dens	freq	dens	freq	dens	freq	dens	freq	dens	freq	dens
Aap											26	17
Aba					6	32						
Abi												
Aco												
Aju			1	32	9	53						
Ase							18	46	11	60	4	56
Bbl			3	15								
Bin												
Bse									2	150		
Cda					7	8						
Cex	16	45			17	24						
Cga			7	42	10	18						
Cva	6	150										
Cvi												
Dam												
Der												
Dfi							9	67				
Dmo												
Dsa			1	150			3	150				
Dte												
Dtr							1	25				
Eca			3	8	4	50	5	86				
Ech												
Ecu	2	150	1	150	24	22	5	23	25	40	12	29
Egu												
Ein												
Emu	1	17										
Ene												
Epl	3	73	8	19	8	31	12	47	13	53	23	30
Era			9	17			7	43	2	39	7	27
Esu												
Evi												
Hco			9	58			25	12	1	150	9	26
Hdr	22	28										
Hfa												
Hhi	24	24	17	37	14	25					5	19
Hru												
Hta												
Htu												
Icy												
Lsi												
Mca	1	71	1	16							2	150
Mce							1	150				
Mne					1	150						
Mre												
Paq												
Pcl												
Pdi					3	3						
Pec							2	45				
Pna												
Pno					11	8						
Ppa												
Psc	7	44	2	150							1	150
Pur			1	150								
Ral												
Saf	10	64			17	14			11	53	21	62
Sce												
Sfi												
Sni									5	20	14	35
Spy			30	13								
Ssp	3	8			6	24						
Sst												
Tbe												
Tle							30	16	29	15	22	18
Tra					1	77						
Tsp												
Ttr	9	18	22	14			29	15	28	15	8	25
Umo												
Upa												

Site	F2766		F2767		F2768		F2777	
Species	freq	dens	freq	dens	freq	dens	freq	dens
Aap								
Aba	4	16						
Abi							2	150
Aco					4	42	2	150
Aju	3	55	8	41	1	42		
Ase			7	150				
Bbl								
Bin								
Bse					1	20		
Cda					1	7	9	12
Cex							1	150
Cga								
Cva								
Cvi								
Dam								
Der							5	13
Dfi			15	34				
Dmo								
Dsa	4	150	4	70	3	20		
Dte							2	150
Dtr								
Eca			1	150				
Ech								
Ecu	2	150	7	72	20	13	18	17
Egu								
Ein								
Emu								
Ene								
Epl	4	150	6	21	11	33	13	64
Era			16	46	17	20		
Esu								
Evi								
Hco			29	12	9	14		
Hdr	7	32					1	28
Hfa								
Hhi	30	16	1	18	24	24	24	46
Hru								
Hta								
Htu								
Icy								
Lsi								
Mca					10	36		
Mce	1	22	9	60				
Mne								
Mre								
Paq								
Pcl								
Pdi							1	30
Pec								
Pna								
Pno	1	6						
Ppa								
Psc	1	150			5	50		
Pur								
Ral								
Saf	16	31			23	22	12	43
Sce								
Sfi								
Sni					3	16		
Spy								
Ssp								
Sst								
Tbe								
Tle			28	18				
Tra								
Tsp								
Ttr			2	150	1	22		
Umo								
Upa							4	150

Species acronyms

Aap - *Andropogon appendiculatus*
Aba - *Aristida congesta* subsp. *barbicollis*
Abi - *Aristida bipartita*
Aco - *Aristida congesta* subsp. *congesta*
Aju - *Aristida junciformis*
Ase - *Alloteropsis semialata*
Bbl - *Bothriochloa bladii*
Bin - *Bothriocloa insculpta*
Bse - *Brachiaria serrata*
Cda - *Cynodon dactylon*
Cex - *Cymbopogon excavatus*
Cga - *Chloris gayana*
Cva - *Cymbopogon validus*
Cvi - *Chloris virgata*
Dam - *Diheteropogon amplectens*
Der - *Digitaria eriantha*
Dfi - *Diheteropogon filifolius*
Dmo - *Digitaria monodactyla*
Dsa - *Digitaria sanguinalis*
Dte - *Digitaria ternata*
Dtr - *Digitaria tricholaenoides*
Eca - *Eragrostis capensis*
Ech - *Eragrostis chloromelas*
Ecu - *Eragrostis curvula*
Egu - *Eragrostis gummiflua*
Ein - *Eleusine indica*
Emu - *Elionurus muticus*
Epl - *Eragrostis plana*
Era - *Eragrostis racemosa*
Esu - *Eragrostis superba*
Evi - *Eulalia villosa*
Hco - *Heteropogon contortus*
Hdr - *Hyparrhenia dregeana*
Hfa - *Harpochloa falx*
Hhi - *Hyparrhenia hirta*
Hru - *Hyparrhenia rufa*
Hta - *Hyparrhenia tamba*
Htu - *Helictotrichon turgidium*
Icy - *Imperata cylindrica*
Lsi - *Loudetia simplex*
Mca - *Microchloa caffra*
Mce - *Monocymbium ceresiiforme*
Mne - *Melinis nerviglumis*
Mre - *Melinis repens*
Paq - *Panicum aquinerve*
Pcl - *Pennisetum clandestinum*
Pdi - *Paspalum dilatatum*
Pec - *Panicum ecklonii*
Pna - *Panicum natalensis*
Pno - *Paspalum notatum*
Ppa - *Perotis patens*
Psc - *Paspalum scrobiculatum*
Pur - *Paspalum urvillei*
Ral - *Rendlia altera*
Saf - *Sporobolus africanus*
Sce - *Sporobolus centrifugus*

Sfi - *Sporobolus fimbriatus*
Sni - *Setaria nigrirostris*
Spy - *Sporobolus pyramidalis*
Ssp - *Setaria sphacelata*
Tbe - *Tragus berteronianus*
Tle - *Tristachya leucothrix*
Tra - *Tragus racemosus*
Tsp - *Trachypogon spicatus*
Ttr - *Themeda triandra*
Umo - *Urochloa mosambicensis*
Upa - *Urochloa panicoides*

Key to species by sites matrix:

O330 - Original site number 330
F330 - Follow-up site number 330
freq - Number of quadrats in which species was found
dens - Median inter-plant spacing between plants of the same species
abund - Acocks's original abundance symbols. Explanations and interpretations of these symbols may be found in the text (Acocks 1953).

Appendix 2 continued

Environmental data of survey sites

Site number	Land-use	Alt(m)	MAR(mm)	MAT(°C)	Veld Type
325	CC	1543	897	14.9	STGV
326	CG	1511	828	15.5	HSV
330	CG	1197	876	16.5	STGV
332	CC	1181	700	16.5	STGV
333	CC	1102	671	17.5	STGV
335	CG	1559	836	14.9	HSV
336	CC	1102	691	17.4	STGV
362	CC	2094	908	14.7	HSV
365	CG	1637	827	14.9	HSV
370	CC	1275	667	17.0	STGV
392	CC	1520	837	14.2	HSV
394	CC	1130	1009	16.6	NMNV
397	CG	1102	667	17.3	STGV
409	CG	1228	856	17.3	STGV
410	CG	1102	708	17.5	HSV
412	CG	1102	718	17.7	STGV
414	CG	1401	861	15.6	STGV
418	CC	1236	713	16.0	NMNV
468	CC	1219	922	17.5	NTGV
532	CG	850	811	17.2	HSV
573	CC	1732	1008	14.1	HSV
718	CC	1071	768	17.9	STGV
760	CC	1354	777	16.5	STGV
761	CC	1614	898	14.7	HSV
802	CG	1102	792	17.1	NTGV
803	CC	980	820	18.5	NTGV
888	CC	869	745	19.0	NTGV
889	CC	1039	877	18.2	NTGV
923	CC	1622	1001	14.1	HSV
927	CC	1520	700	15.2	STGV
928	CC	1400	678	15.5	STGV
931	CG	1322	824	16.2	STGV
932	CC	1637	990	15.5	HSV
997	CG	1455	998	15.9	HSV
998	CG	1400	894	15.7	HSV
1039	CC	1220	1132	16.4	HSV
1049	CC	1338	798	16.6	STGV
2726	CC	1338	814	17.8	STGV
2729	CC	650	901	18.9	STGV
2733	CC	1826	1087	15.3	HSV
2738	CG	1559	884	15.8	HSV
2763	CC	1640	850	14.4	HSV
2766	CC	1039	945	16.8	STGV
2767	CC	1580	906	14.5	HSV
2768	CG	1373	937	16.1	HSV
2777	CC	1630	830	14.7	HSV

Key overleaf.

Key:
Alt: altitude
MAT: mean annual temperature
MAR: mean annual rainfall
CC: commercial grazing
CG: communal grazing
HSV: Highland Sourveld
NMNG: Natal Mistbelt Ngongoni Veld
NTGV: Northern Tall Grassveld
STGV: Southern Tall Grassveld