PATCH GRAZING IN THE HUMID GRASSLANDS OF KWAZULU-NATAL

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Declaration of originality

I, Bernd Uwe Lütge, declare that the research reported in this thesis comprises my own original work except for the assistance acknowledged, or where due reference is made in the text. This thesis has not been submitted for any degree or examination at any other university.

B. U. Lütge

ABSTRACT

Patch grazing may be an important factor providing the focus from which wide-scale veld degradation has occurred in the humid grasslands of KwaZulu-Natal. A number of discrete studies were therefore initiated to examine the patch grazing patterns and selected factors which may influence patch grazing at two sites in the humid grasslands of KwaZulu-Natal. The sites were located at Ukulinga Research Farm, situated in the Southern Tall Grassveld, and Kokstad Research Station in the Highland Sourveld.

An investigation into the frequency and intensity of gazing patches and non-patches at Ukulinga Research Farm indicated that patch grazing was most evident and most extensive during summer and autumn. As forage in the patches became limiting during winter animals were forced to forage in areas not frequently grazed during the season. The patch grazing pattern was further modified by the time of grazing commencement after a burn in early spring. Early grazing significantly reduced the extent of patch grazing. With early stocking animals were forced to graze less selectively while with increased delay in the commencement of grazing, animals became increasingly patch-selective. Early grazing in conjunction with an autumn rest and heavy grazing during winter could significantly reduce patch grazing.

Urine and dung significantly influenced the patch grazing pattern. The sward surrounding a urine deposit was preferentially grazed by both cattle and sheep for a period of at least six months after deposition. Cattle rejected the sward surrounding cattle and sheep dung immediately after deposition and for a period of up to six months. Sheep also rejected cattle and sheep dung patches immediately after deposition. As dung deposits aged, sheep tended to increase their grazing around both cattle and sheep dung pats, and after six months dung did not seem to influence sheep grazing. Urine may be an important factor influencing patch initiation and consequent patch development.

A study to examine the characteristics of patches and non-patches in the Highland Sourveld revealed that patches were characterised by lower soil moisture, soil depth and hydraulic conductivity, but by a higher soil nutrient status. Patches and non-patches could also be

distinguished in terms of species composition and basal cover. Patches were characterised by Increaser II species, especially *Microchloa caffra* and, non-patches by Increaser I species such as *Trachypogon spicatus*, *Alloteropsis semialata* and *Eulalia villosa*.

Three seasons of patch grazing at Kokstad Research Station negatively influenced the vigour of *Themeda triandra* in patches relative to the non-patches. The vigour of *T. triandra* in patches was consistently low throughout a full season's rest. The vigour of *T. triandra* in non-patches was initially significantly higher than the vigour in the patches and remained so for *c.* 24 weeks. Vigour measurements at the start of the following season showed that photosynthate accumulation had taken place and a full seasons rest proved to be sufficient in restoring the vigour of *T. triandra* in patches to the same level as that in non-patches. A full seasons rest did, however, not prevent animals from regrazing the same previously grazed patches the following season. Growth in patches also started *c.* six weeks later than in non-patches and above-ground herbage production in patches was significantly lower than non-patches for at least 20 weeks after a burn. At the end of a full season's rest above-ground herbage production in patches was still slightly lower than that in non-patches possibly due to a difference in species composition between patches and non-patches.

Some implications of patch grazing are discussed together with an evaluation of some management recommendations for the humid grasslands with the aim of reducing the potential for patch degradation.

TABLE OF CONTENTS

TITLE PAGE i

DECLARATION ii

ABSTRACT iii

TABLE OF CONTENTS v

ACKNOWLEDGEMENTS viii

CHAPTER 1 - INTRODUCTION 1

CHAPTER 2 - FACTORS INFLUENCING PATCH GRAZING BY CATTLE AND SHEEP: A REVIEW OF THE LITERATURE

2.1 INTRODUCTION 4

2.2 PLANT FACTORS INFLUENCING SELECTIVE GRAZING 5

2.3 FACTORS INFLUENCING THE DISTRIBUTION OF PATCH GRAZING 5

2.3.1 The physical environment 6

2.3.2 Disturbance factors 7

2.3.3 The effect of animal distribution on patch grazing 8

2.4 FACTORS INFLUENCING PATCH GRAZING 9

2.4.1 The patch sward 10

2.4.2 The patch environment 10

2.4.3 Animal factors 12

2.4.3.1 The selection patterns of cattle and sheep 12

2.4.3.2 Previous grazing 14

2.5 DISCUSSION 18

CHAPTER 3 - STUDY AREA

3.1 STUDY AREA AND SITE DESCRIPTION 20
3.2 TERMINOLOGY 25

CHAPTER 4 - THE FREQUENCY AND INTENSITY OF GRAZING *THEMEDA TRIANDRA* IN PATCHES AND NON-PATCHES (STUDY I)

4.1 INTRODUCTION 26
4.2 PROCEDURE 27
4.3 RESULTS 29
4.3.1 Initial height 29
4.3.2 Frequency and intensity of grazing 31
4.4 DISCUSSION 36

CHAPTER 5 - THE EFFECT OF URINE AND DUNG ON THE PATCH GRAZING PATTERNS OF CATTLE AND SHEEP (STUDY II)

5.1 INTRODUCTION 39
5.2 PROCEDURE 40
5.3 RESULTS 43
5.3.1 Initial sward height 43
5.3.2 Grazing pattern 44
5.3.2.1 Frequency of grazing 44
5.3.2.2 Intensity of grazing 45
5.3.3 Age of treatment deposition (second order interaction - treatment x animal type x age of deposition) 48
5.3.3.1 Cattle dung 48
5.3.3.2 Sheep dung 48
5.3.3.3 Urine 50
5.3.4 The grazing pattern in the proximity of urine and dung 51
5.3.4.1 Frequency of grazing 51
5.3.4.2 Intensity of grazing 51
5.4 DISCUSSION 54

CHAPTER 6 - CHARACTERISATION OF PATCHES AND NON-PATCHES IN TERMS OF SELECTED SOIL AND SWARD PROPERTIES

6.1 INTRODUCTION 57

6.2 PROCEDURE 58

6.3 RESULTS 60

6.3.1 Soil properties 60

6.3.2 Sward properties 61

6.4 DISCUSSION 65

CHAPTER 7 - THE INFLUENCE OF PATCH GRAZING ON TUFT VIGOUR AND SWARD GROWTH

7.1 INTRODUCTION 68

7.2 PROCEDURE 69

7.3 RESULTS 71

7.4 DISCUSSION 73

CHAPTER 8 - THE INFLUENCE OF A FULL SEASON'S REST ON THE REGRAZING OF PREVIOUSLY-GRAZED PATCHES BY CATTLE AND SHEEP

8.1 INTRODUCTION 76

8.2 PROCEDURE 76

8.3 RESULTS AND DISCUSSION 77

CHAPTER 9 - GENERAL DISCUSSION AND CONCLUSION 79

9.1 FACTORS INFLUENCING PATCH INITIATION AND DEVELOPMENT 79

9.2 CONSEQUENCES OF PATCH GRAZING 80

9.3 EVALUATION OF CURRENT GRAZING RECOMMENDATIONS . . . 83

9.4 FUTURE RESEARCH PRIORITIES 85

REFERENCES 87

APPENDICES 96

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CHAPTER 1

INTRODUCTION

The humid grasslands of KwaZulu-Natal (Bioclimatic Regions 2,3,4,5 and 6 (Phillips 1973)) constitute approximately 48% of the total KwaZulu-Natal region (Phillips 1973). A large portion of these humid grasslands, *c.* 53.5%, is devoted to livestock production on natural veld (Fotheringham 1981). Although these figures may have changed since then, it is evident that a large proportion of the humid grasslands are grazed by cattle and sheep on natural veld. While the humid grasslands are considered to be more stable than arid and semi-arid grasslands (Mentis & Huntley 1982), they are vulnerable to degradation, and the implementation of veld management practices that sustain livestock production, without degrading the veld further, is of great importance.

Selective grazing, especially by sheep (Barnes 1992), is considered to be one of the main reasons for the decline in veld condition (Hatch & Tainton 1990; Barnes & Dempsey 1992). Although selection may occur at a number of levels, Hatch & Tainton (1993) observed that area selection was prevalent in the Southern Tall Grassveld (Acocks 1988).

What is area-selective grazing? Booysen (1967) defined it as, "the habit of the grazing animal to graze certain areas of the veld/pasture in preference to other areas". My interpretation of that definition is that animals select areas (ecotypes), e.g. areas with different veld types and botanical composition, or gentle slopes in preference to steep ones. This is the basis for separating differing areas within rotational grazing systems (Barnes 1992; O'Reagain & Turner 1992).

However, this definition of area-selective grazing does not adequately describe the tendency of animals to graze areas or patches within an apparently uniform sward (Arnold & Dubzinski 1978), and even in the extreme case of a planted pasture containing a single species (Barnes 1992). Other terms such as mosaic grazing (Mott 1985) and patch grazing (Ring *et al.* 1985; Mott 1987; Willms *et al.* 1988) have been used to describe this tendency. Patch grazing consequently implies a relatively discrete spatial pattern in grazing, but does not establish a constraint on patch size, internal homogeneity or discreteness. It also implies a relationship of one patch to another in space and the surrounding unaffected or less affected matrix (non-patch) (Pickett & White 1988).

Patches are selected as a result of their higher quality herbage (Ring *et al.* 1985; Mott 1985, 1987) relative to the surrounding sward. Patch grazing may therefore increase animal performance and allow for greater sward heterogeneity (Arnold 1981). Why then is patch grazing seen as a detrimental consequence of grazing (Tainton 1972; Mott 1985, 1987; Hatch & Tainton 1990; Fuls 1991; Fuls & Bosch 1991; Fuls 1992a,b; Kellner & Bosch 1992; Wandera 1993)?

Tainton (1972) argued that a change in botanical composition in the Southern Tall Grassveld (Acocks 1988), from a *Themeda triandra* dominated state to a *Sporobolus africanus* and *Aristida junciformis* dominated state, may be related to the incidence of patch grazing. Hatch & Tainton (1990) observed, in the same veld type, that patches become increasingly dominated by less palatable species such as *A. congesta* subsp. *barbicollis*, *Eragrostis racemosa* and *Microchloa caffra*. A gradient of patches from newly-initiated to permanently-established patches may be recognized (Hatch & Tainton 1990). Willms *et al.* (1988) suggested that even at moderate stocking rates, sward degradation will still take place because of the animals tendency to patch graze. In addition to botanical changes, soil properties have been found to be different in patches compared to the surrounding sward. Grazing leads to less plant material to protect the soil (Scott 1988) which may increase soil compaction and decrease infiltration. Soil compaction tends to increase (MacDonald 1978; Hatch & Tainton 1990) and infiltration rates and soil moisture tend to decrease (MacDonald 1978) in patches. Deterioration in veld condition has been correlated with decreased infiltration rates (Van den Berg *et al.* 1976). Localized degradation through patch grazing may therefore be the foci from which veld degradation proceeds. This justifies the concern surrounding patch grazing.

Patch grazing has therefore been investigated in the past, but only in terms of patch characteristics, with very little work having been done on the causal mechanisms of patch grazing and the patch grazing patterns of animals. It is therefore imperative to investigate these factors, if one is to try and establish management recommendations with the aim of reducing the tendency for patch/sward degradation. Given the short time period for this study, and the large number of factors that may play a part in patch grazing, a number of discrete studies were established at two sites in the humid grasslands of KwaZulu-Natal, one in the Highland Sourveld (veld type no. 44a, Acocks 1988) and the other in the Southern Tall Grassveld (veld type no. 65, Acocks 1988).

The objectives of this study were to:

1) examine the seasonal patterns in the frequency and intensity of defoliation of patches and non-patches in relation to sward structure (Study I);
2) investigate the effect of urine and dung deposition on patch initiation and development (Study II);
3) characterise patches and non-patches in terms of species composition, basal cover and selected soil properties (Study III);
4) trace the regrowth and vigour patterns of patches and non-patches during a full seasons rest (Study III), and;
5) examine if animals continue to selectively graze previously grazed patches after a full seasons rest (Study III).

This will give a greater understanding of the pattern and process of patch grazing, which may assist in an evaluation of current grazing management recommendations.

CHAPTER 2

FACTORS INFLUENCING PATCH GRAZING BY CATTLE AND SHEEP: A REVIEW OF THE LITERATURE

2.1 INTRODUCTION

Selection is a term used to describe the conscious decision an animal makes with regard to the food it eats (Hatch 1991). Diet selection, and therefore selective grazing, occurs at a number of levels, namely, species selection, area-selection (Theron & Booysen 1968) and the selection for different plant parts (Arnold 1981). This review is concerned with area-selection. With little published literature on area-selection available, this review will also use some principles of species selection available in the literature to try and explain some principles of area-selection.

Animals selectively graze or patch graze in an apparently uniform sward in search of forage with a higher nutrient content to meet minimum energy requirements (Laycock & Price 1970). The degree of selection is also directly related to energy requirements and body size. Small animals (e.g. sheep), have lower absolute, but higher relative, energy requirements than larger animals (e.g. cattle) (Mentis 1988). Smaller animals are therefore more selective than larger animals (Arnold 1964a,b, 1981).

The objective of this review was to investigate the possible causal mechanisms of patch grazing, by cattle and sheep, which may lead to veld degradation.

2.2 PLANT FACTORS INFLUENCING SELECTIVE GRAZING

The individual grass plant is one of the most important factors influencing diet selection. An animal is likely to select a plant best suited to satisfy its nutritional needs. The animal will make a decision based on a number of factors. The palatability of a plant concerns the specific factors of the feed itself, which determines the attractiveness of a plant to the animal (Mentis 1988). Palatable foods are generally associated positively with high levels of crude protein (nitrogen), phosphorus, potassium, ether extract and soluble carbohydrate, and negatively associated with high levels of lignin, toxins, crude fibre and cellulose (Hatch 1991). The acceptability of a food source is defined as the sum of factors that operate to determine whether and to what extent items are taken by animals (Mentis 1988). Acceptability implies a broader connotation than palatability and includes external properties of the plant which may influence selection by animals. Forage availability is that part of the sward that is available to the animal which influences selection (Hatch 1991). With a large amount of forage available (high availability) animals will be highly selective, while decreasing selectivity is associated with decreasing forage availability (Mott 1985). These plant based factors will determine whether a plant is grazed or not. As patch grazing is an area based selection habit, there are numerous factors that determine and modify these plant-based factors and therefore the selection process.

2.3 FACTORS INFLUENCING THE DISTRIBUTION OF PATCH GRAZING

Two main factors seem to influence the distribution of patch grazing, firstly, the physical environment (Arnold 1981) and secondly, disturbance factors (Wandera 1993). These factors result in the animals using the space available to them non-randomly. Non-random grazing occurs in both small and large camp systems (Arnold 1981). Animals may therefore spend more time in certain areas than others, either, because the abovementioned factors make these areas more accessible to the animal (physical environment) and/or, the factors change the plant based factors in such a way as to make them more acceptable to the animals (physical environment and/or disturbance factors). These factors may not necessarily affect patch grazing *per se*, but may affect the size, number and distribution of patches in an area related to the site preferences of animals.

2.3.1 The physical environment

Topography may play an important role in influencing the distribution of patch grazing. Cook (1966) observed on mountain grassland in Utah that slope significantly influenced area-selective grazing. Some of these slope factors influencing grazing were:

(1) percent slope at a site;

(2) percent slope adjacent to water;

(3) percent slope from site to water;

(4) percent maximum slope between site and water, and;

(5) percent slope from site to salt or other supplementation.

Although this study was conducted on high and steep country, these factors may still apply to many areas of our humid grasslands. Cook's (1966) study is important in that it showed that slope may eliminate certain areas from excessive patch grazing whereas other areas may be severely patch grazed. Some areas in this steep country may not be grazed, either, because the difficulty animals may have in reaching these areas, or because of the time animals need to walk to water and supplements. In lower, flatter veld this may not be a problem but slope may still influence the grazing distribution of the animals. Scholes (1993) observed that through nutrient distribution (especially downslope), nutrient oasis' occur which may lead to area-selective grazing. He observed that animals may spend up to six times the amount of time on these nutrient richer areas than would be expected from random grazing. The steeper the slope, the greater the run-off and the lower the infiltration rates are likely to be. The run-off water will start infiltrating somewhere else, or be lost, and those areas with greater infiltration capacity are likely to be visited more frequently than those areas with lower infiltration. Thus slope plays an important role in determining the distribution of patch grazing in an area. Aspect plays a similar role in determining animal concentrations on certain sites and thereby affects patch grazing. North-facing slopes are usually warmer and drier than south-facing slopes in the southern hemisphere. This may affect the moisture regime, and therefore the plant-based factors, and make an area more acceptable to the animals than another.

Soil type also plays an important role in site selection (Scholes 1993). Soil differences are usually caused by variations in the underlying parent material (Scholes 1990). Areas with dolerite or basalt parent materials are likely to contain higher quality herbage than plants growing in soils derived from sandstone or shale (Cuthbert 1961). These nutrient richer areas are likely to be visited more frequently by the animals than areas in nutrient poorer soils (Scholes 1993). In addition, soils from two sites may have the same physical and chemical properties, but may differ in their depth and thus their moisture balance (Cole 1982). This may lead to some areas having a higher moisture status soil than other areas, possibly resulting in the more frequent grazing in the areas of higher soil moisture. Topography plays an important role in determining the spacial distribution of grass species and their characteristics, by modifying the underlying soil in terms of physical and chemical properties and soil moisture, and in so doing, may influence the pattern of patch grazing.

Cook (1966) and Andrew & Lange (1986a,b) found that selection may be influenced by distance to water, irrespective of slope. Water leads to a piosphere effect, where grazing is heaviest around water points and decreases as distance from the water source increases. A similar response may be expected with feed supplementation stations. Degradation of both the vegetation (Andrew & Lange 1986a) and the soil (Andrew & Lange 1986b) was evident closer to water. Plant mortality increased, and grass biomass decreased, significantly closer to the water. This problem is especially true for natural watering points. With artificial watering points and supplementation stations, management can influence the distribution of animals, and thus decrease the potential for sward degradation. This may be achieved by periodically moving watering points and supplementation stations, or by placing them in an area where animals are likely to concentrate for the least amount of time (Mott 1985).

2.3.2 Disturbance factors

Fire will influence the distribution of animals as animals will tend to graze areas that have recently been burnt in preference to unburnt areas (du Plessis 1972; Andrew 1986b). Patch burning (i.e. fires which do not burn a whole area), will cause animals to spend more time on the burnt than the unburnt areas (Andrew 1986b). Burnt areas are therefore likely to be heavily patch grazed in relation to the other areas. This may continue until another area is burnt, because these continually grazed areas contain regrowth which animals prefer (Ring *et al.* 1985). Fire may thus be used as a management option to rotate animals and thereby decrease the potential for patch grazing.

Track development is prevalent in large camp systems (Arnold & Dubzinski 1978; Arnold 1981; Andrew 1986a). A suitable area for patch grazing has a far greater chance of being patch grazed if it is located close to one of these tracks than if it were further away (Arnold 1981). This may be the cause of a concentration of patches along the perimeter of fences, where paths are often evident.

These factors are large-scale area-selection factors and may only serve to concentrate animals on certain sites.

2.3.3 The effect of animal distribution on patch grazing

The effect of animal distribution on patch grazing is best described in terms of stocking rate (pressure). In effect, a preferred area has a higher stocking rate than a non-preferred area. With increasing stocking rate animals are forced to graze increasingly non-selectively, while at low stocking rates, animals are allowed to be highly selective (Wolton 1979). Consequently, as stocking rate increases, patch size increases (J. Martens, pers. comm., Döhne Agricultural Development Institute, P/Bag X15, Stutterheim, 4930) up to a point where at very high stocking rates animals will be forced to graze non-selectively. When animals are allowed to be highly selective, ungrazed areas quickly mature and become unacceptable to the animals (Mott 1985, 1987). Animals are then forced to graze a small portion of the sward repeatedly and severely, i.e. severe patch grazing. At higher stocking rates, areas that would have remained ungrazed at low stocking rates are less likely to become moribund and therefore unacceptable. As stocking rate increases, a greater proportion of the sward will be grazed and less grazing may be focused onto the patches than at lower stocking rates. The non-patches will provide some grazing at high stocking rates, but at low stocking rates the non-patches may become too moribund and will therefore provide little or no grazing. This results in the grazing of a greater proportion of the sward, with less severe patch grazing at higher stocking rates, while at lower stocking rates a number of smaller, but discrete, patches may develop making patch grazing more severe. At lower stocking rates where patch grazing is more severe, patch degradation may be severe. Patch degradation at higher stocking rates may not be as severe as at lower stocking rates, however, overall sward degradation may be higher if the stocking rate is too high.

Although patch degradation may occur in the non-preferred site, overall degradation of the sward is likely to be greater in areas preferred by the animals through the invasion of species adapted to increased grazing intensity. Animals must therefore not be allowed to concentrate on one area more than another. The recommended practice in the grasslands of southern Africa, whereby camps are selected so as to separate these differing areas (Barnes 1992; O'Reagain & Turner 1992), is essential to decrease the potential for veld degradation due to patch grazing. Patch grazing in these apparently homogeneous areas may, however, still occur.

2.4 FACTORS INFLUENCING PATCH GRAZING

Various factors play a role in influencing the pattern of patch grazing in an apparently homogeneous sward. Some of these are:

1) biotic factors (the patch sward);
2) abiotic factors (the patch environment)(Wandera 1993);
3) disturbance factors (Wandera 1993), and;
4) animal factors.

These factors will interact to modify an apparently uniform sward into a mosaic of potential patches and the remaining non-patches.

2.4.1 The patch sward

Biotic factors play a small role in modifying the sward and therefore patch grazing. Grass species composition may, however, be an important factor influencing patch grazing as species are not randomly distributed within the sward. The non-randomness caused by the plants themselves, e.g. close seeding, lateral tillering and competition, may influence species composition and distribution. This may lead to a concentration of preferred species within a patch. Grazing animals may select for these areas and initiate patches. On the other hand, a concentration of plants, not readily grazed by the animal (e.g. *Alloteropsis semialata* in the Highland Sourveld (Acocks 1988)), may cause the animal to reject those areas. This is one possible explanation, even if all other factors are ignored, how patches may be initiated. Abiotic factors modify the sward even further and thereby the patch grazing patterns.

2.4.2 The patch environment

Plants growing in an area depend on numerous abiotic factors. These abiotic factors may change from patch to patch (Scholes 1990;1993), and the plants growing in them may consequently differ from patch to patch. Even small changes in the micro-environment may lead to large changes in the plant community and may therefore lead to patch grazing.

The micro-topography (the topography within an apparently uniform camp) of an area has a great influence on soil properties. Small changes in the micro-topography can cause significant changes in pH (Verma & Rao 1988), soil nutrients (Scholes 1990; Miles 1987), soil texture and chemical characteristics (Bowman *et al.* 1986; Tongway & Ludwig 1990) and soil hydrological characteristics (Bridge *et al.* 1983). Soil texture and hydrological properties in turn modify the soil moisture regime (Wandera 1993). These modifications to the micro-environment in turn modify the plant community that grows there.

Verma & Rao (1988) found that with increasing soil pH above-ground production declined. This in turn caused species compositions to be different at different soil pH values (Anderson 1965; Verma & Rao 1988). This suggests that plant nutrient status may also vary at the different soil pH values.

Variability in soil nutrients within an area (Miles 1987; Scholes 1990) may lead to herbage of different nutritional value. Soil nutrient status is also likely to affect species composition. A similar response could be expected from areas with different soil texture and chemical composition. Soil texture may also affect the soils moisture regime and thereby affect moisture availability (Wandera 1993), which in turn may affect plant characteristics and species composition.

Soil hydrological properties, such as infiltration rates, will also affect moisture availability and therefore plant and sward characteristics. Other properties, such as soil compaction, may influence soil moisture and hence seedling establishment and species composition. Numerous authors contend that after several seasons of patch grazing the soil in patches becomes degraded (MacDonald 1978; Mott 1985, 1987; Hatch & Tainton 1990; Fuls 1992a). Infiltration rates, nutrient content and moisture content are lower, and compaction higher in patches than in non-patches. Despite soil degradation in patches, patches may continue to be grazed because grazed plants have been found to contain higher crude protein levels than ungrazed plants (Bakker *et al.* 1983). Andrew (1986a) also states that the attractiveness of new regrowth of plants (patches) overrides any usual preference for a particular species (patch).

Soil depth has also been found to play a part in modifying the sward. Scholes (1993) found that shallow or stony areas can constrain nutrient availability, resulting in slower growth rates. Willms *et al.* (1988) found that the soil A horizon was shallower in patches than in non-patches.

The abovementioned abiotic factors may influence the sward growing in a number of ways. The sward may respond by a change in: 1) species composition, 2) sward nutrient levels, 3) physical characteristics of the plants and/or, 4) growth rates, in those areas.

Species composition changes, which may have resulted from the abiotic site factors, may have the effect of concentrating desirable and undesirable grazing species into different patches. Animals are then likely to graze patches containing desirable species in preference to the rest of the sward. Similarly, animals are likely to graze patches containing plants which are nutritionally and physically more attractive than the surrounding sward.

As abiotic factors influence the sward, growth rates in different areas are likely to differ. Some areas will grow quicker than others. Cattle in Australia will patch graze in rapidly growing swards because material accumulates faster than the animal can remove it (Stafford-Smith, pers. comm., CSIRO, P.O. Box 2111, Alice Springs, NT0871, Australia). In these swards it may follow that animals (not only cattle) select patches with slower growth rates, where sward quality is likely to be higher than the surrounding sward, which quickly becomes rank. On the other hand, if animals initially grazed a fast growing patch, it allows the animals to frequent the patches more often because they provide frequent high quality regrowth. Similarly, in slower growing swards, animals may graze patches with faster growth rates than the surrounding sward, because it allows the animals to graze the nutritious regrowth more frequently, e.g. urine patches.

These factors all combine to change the plant-based factors in different patches to form a mosaic of areas that will be preferred and others that will be ignored by animals. A mosaic of heavily grazed patches and leniently/ungrazed areas may consequently develop. Once patch grazing has taken place, especially in fast growing swards, the structure of the sward will rapidly change to areas with taller, stemmier and therefore unacceptable material on the one hand and areas with shorter material that gets frequently grazed on the other (Mott 1985, 1987). Once this sward structure has been created, patch grazing will continue, and will only change if the material in the patches becomes unavailable and the animals are then forced to forage in the other areas, or by management intervention, such as burning (Mott 1985, 1987).

2.4.3 Animal factors

2.4.3.1 The selection patterns of cattle and sheep

When selecting food, the animal uses four basic senses, namely, sight, smell, touch and taste. Sight is primarily used in the orientation of the animal to other animals and the environment (Arnold 1966a,b). Krueger *et al.* (1974) found that sight and touch were also used for specific plant conditions, such as succulence and growth form. Both researchers found that taste was the most influential factor in the selection process, with smell being of little significance. Arnold (1966a,b), however, found that the combined senses of taste, touch and smell were important in the selection process and herbage intake.

Sheep and cattle have different selection habits because of their different energy requirements. Small animals (sheep), relative to large ones (cattle), have lower absolute, but higher relative energy requirements (Mentis 1988). To meet these higher energy requirement, sheep are highly selective in their grazing habit (Mentis 1988). Cattle on the other hand have a large rumen and are able to digest larger quantities of low quality, high cellulose content forage. This was confirmed by Dubzinski & Arnold (1973) and Wilson (1976) who found that cattle diets were usually lower in N content and higher in fibre content than those of sheep. Sheep are able to select so intensively because they have the *time/unit mass of intake* to selectively forage (Mentis 1988), and have small mouths to be able to take small items of food (Hanley & Hanley 1982). Sheep have a cleft upper lip, which permits them to graze virtually to the soil surface (Hafez & Schein 1962; Hafez & Scott 1962). Cattle use their highly mobile tongue as prehensile organ (Hafez & Schein 1962) and the structure of the lower jaw makes it impossible for cattle to graze closer than approximately 1.3 cm from the soil surface (Voison 1959), and they do generally not graze lower than 5 cm, unless forced to do so to obtain forage (Heinemann 1969, cited by Vallentine 1990). This does not, however, mean that cattle do not graze selectively. Laycock & Price (1970) suggest that the composition of the animal's diet is higher in nutritional value than the sward average. Both sheep and cattle tend to eat leaf material in preference to stem material, and green (young) material in preference to dry (old) material. The material eaten is usually higher in N, phosphate and gross energy, but lower in fibre than the forage on offer (Arnold 1981). Other mineral constituents and soluble carbohydrates in the diet vary and do not seem to influence selection (Arnold 1981). Ring *et al.* (1985) also found that animals tend to return to the same patches because of the higher quality regrowth that occurs in these areas. This selection then leads to both, species and patch selection patterns.

These differences in sheep and cattle relate directly to differences in their patch grazing habits. Sheep tend to graze the sward down to a much lower level than cattle. Cattle tend to graze the tops of the plants and prefer the leafy portions between 12 and 15 cm in height (Voison 1959; Hafez & Schein 1962). Because sheep tend to prefer shorter swards or plants, those plants initially grazed will be repeatedly grazed (Arnold 1964a,b; Tainton 1972). Mentis (1988) also states that where only sheep are grazed or where the cattle : sheep ratio is narrow, extreme area- and species selection occurs. Daines (1976) found that cattle in the Döhne Sourveld (Acocks 1988) initially grazed the tops of preferred species (most likely also on an area basis), removing less than 50% of the plant (area). Cattle would then return to the same plants (areas) removing more than 50% of the plant material. Danckwerts *et al.* (1983) also found that preferred species (areas) are returned to before attempting to graze less preferred species (areas).

Because of the close grazing by sheep it follows that the severe defoliation of these patches will negatively influence the vigour and regrowth potential in relation to the ungrazed areas. If these areas are continuously returned to, degradation of these areas is possible (Tainton 1972). Cattle on the other hand do not graze as closely as sheep and the plants have a greater ability to recover. However, if cattle are not managed properly, it will lead to heavy grazing of patches and species, and may lead to degradation. The co-grazing of sheep and cattle has been recommended in certain areas of the humid grasslands, firstly to overcome the problem of degradation by sheep (Barnes 1992), and secondly, to ensure that the generally more profitable sheep enterprise (Malherbe 1971) is not lost. When grazing cattle and sheep together, cattle may open up a larger portion of the sward that will be acceptable to sheep. With a larger portion of the sward open to the sheep, the continued regrazing of a few small patches will be reduced and degradation is likely to be less.

2.4.3.2 Previous grazing

Previous grazing plays an important role in the patch selection process. In the short term patch grazing has the effect of keeping certain areas shorter than others. Animals will select these areas because they contain fresh regrowth which is higher in nutritional value than the old material (Ring *et al.* 1985). With time, the non-patches become more rank and unacceptable, forcing the animal to continually graze the established patches. The differences in sward height of patches and non-patches at the end of a grazing season are likely to persist into the next grazing season (Mott 1985). Grazing of previously grazed patches will continue, and will accentuate from year to year, if burning is not applied after a season (Mott 1985). After several seasons of patch grazing, these patches may become permanent (continue to exist even after burning) and indicate patch degradation.

This continued patch grazing may eventually lead to a change in the species composition in the patches and the non-patches. Such degradation has been reported by numerous authors (Tainton 1972; Mott 1985, 1987; Hatch & Tainton 1990; Fuls 1991; Fuls & Bosch 1991; Fuls 1992a,b; Kellner & Bosch 1992; Wandera 1993). If this is a consequence of patch grazing, then patch grazing may play an important role in the future patch grazing patterns. Andrew (1986a) observed that animals will graze less palatable plants in preference to more palatable ones, if the unpalatable plants are grazed short and the palatable ones left ungrazed. However, once these changes have taken place, and species of lower forage production potential are abundant in patches, animals may start to initiate new patches, or increase the size of existing patches, in order to graze more palatable species. In so doing, animals increase the area for potential patch degradation and thereby accentuate overall sward degradation.

A similar response could possibly be observed when soil conditions, which have been found to degrade in patches (MacDonald 1978; Mott *et al.* 1979; Bridge *et al.* 1983; Hatch & Tainton 1990; Wandera 1993), deteriorate. This deterioration of soil in patches, may lead to a change in species composition and/or a decrease in the nutrient content of the herbage in the patches in relation to the remainder of the sward. It may thus follow that patch grazing will be extended to other areas, or will lead to an increase in the size of patches, and thereby increasing the potential for sward degradation.

Numerous authors (Joblin & Keogh 1979; Jones & Ratcliff 1983; Day and Detling 1990; Jaramillo & Detling 1992b) have related urine and dung deposition to the incidence of patch grazing. Urine contains a large amount of nutrients, particularly nitrogen (N) and potassium (K). When urine is deposited on a small area (2 litres per 0.25 m^2)(Jaramillo & Detling 1992a,b) it has the effect of a high fertilizer application in the vicinity of the urine deposit.

Urine has been found to dramatically increase tiller density (Norman & Green 1958; Jaramillo & Detling 1992a), above ground biomass, tiller height and N concentration in the plant in and around the area wetted by the urine (Mundy 1961; Joblin & Keogh 1979; Jaramillo & Detling 1992a). Jaramillo & Detling (1992a) also found that urine delayed the senescence of leaves in some species, making the herbage acceptable to the animals for a longer period. As animals are known to select for plants or plant parts higher in N concentration than the sward average (Arnold 1981), it could be assumed that the urine patches are likely to be grazed more frequently than unaffected areas. In conjunction with the higher fertility in those areas, plants will be able to recover quicker allowing the animals to graze them more frequently. Norman & Green (1958) observed that areas affected by a urine deposition were largely rejected for a few days (two to four days) before being preferentially grazed. Possible reasons for this rejection, are that the odour of the urine and/or the high concentrations of nutrients released onto the plants are not acceptable to the animals. After two to four days these effects diminish and the urine patches are preferentially grazed (Norman & Green 1958; Day & Detling 1990; Jaramillo & Detling 1992b). The effect N from urine has on the sward lasts about two to four months (Legard *et al.* 1982), while K may have an effect for up to two years (Blagden 1969, cited by Wolton 1979) after deposition. However, patch grazing may continue as previously grazed patches are likely to be preferred to ungrazed or leniently grazed areas (Ring *et al.* 1985)

Dung pats, on the other hand, are rejected almost immediately after deposition (Norman & Green 1958; Marten & Donker 1964), largely due to the odour emitted from the dung (Norman & Green 1958; Marten & Donker 1964). The period of rejection is much longer than the two to four days for urine. Norman & Green (1958) and Marten & Donker (1964) observed that the rejection lasts for at least a season, but may last up to 18 months (Marsch & Cambling 1970). The length of the period of avoidance may be site specific and depend on climatic conditions, coprophagous activity and the consistency of the dung (Wolton 1979). Norman & Green (1958) and Marten & Donker (1964) contend that the rejection for such long periods was not related only to the presence of the dung pat, but to other factors as well. The rejection related directly to the dung pat (e.g. odour) lasts about three to four months (Norman & Green 1958; Marten & Donker 1964). The herbage surrounding the herbage becomes rank and moribund and therefore remains unacceptable to the animals for long periods. Norman & Green (1958) found that herbage around a dung pat was not rejected after three to four months, provided the herbage around the dung pat was clipped after each grazing period. Similar results were obtained by Marten & Donker (1964), who found that heavy overwintering caused animals to graze around the dung pat and therefore eliminated the effect after only a few months. Initial rejection is thus mainly due to the odour emitted from the dung (Arnold 1981), and later it is rejected because the material becomes rank and moribund. Spraying with sugar water or molasses, Marten & Donker (1964) effectively negated the effect of the dung and animals grazed the areas from an early stage. The dung itself may therefore only play a role in the rejection for a short period. This may have been true for the conditions under which the abovementioned research was conducted, because certain dung pats in the Southern Tall Grassveld (Acocks 1988) were still being rejected, some approximately three seasons old, despite three annual burns (own observation). This may suggest that, apart from the smell of the dung and the moribund material surrounding a dung pat, animals develope a learned aversion for dung pats.

The reaction of grazing sheep and cattle to the presence of dung from the same or the other species has a profound effect on the grazing pattern of the animals. In a study to investigate this, Forbes & Hodgson (1985) found that cattle were more sensitive to their own dung than that of sheep, whereas sheep were unaffected by the type of dung. This may simply be due to the cattle dung pat being far greater than that of sheep and hence the total area fouled by cattle is much larger than that of sheep. Sheep are able to graze closer to a dung pat than are cattle. Because sheep graze closer than cattle, and cattle foul a far greater area, Forbes & Hodgson (1985) suggest that mixed grazing would allow a far greater portion of the sward to be grazed than cattle alone and therefore reduce patch grazing.

Urine may promote the initial grazing of patches. Once patch grazing has taken place animals will continue to regraze the same patches because animals prefer to graze the more nutritious regrowth which occurs in patches (Ring *et al.* 1985). Urine patches would probably also contain a higher nutritious sward than other patches unaffected by urine. This would increase the potential for grazing urine patches more than patches unaffected by urine. Dung patches are not grazed and the sward surrounding the dung pat is allowed to become moribund. The increasingly moribund material would become increasingly unacceptable to the animals. These ungrazed dung patches decrease the animals potential grazing area and in so doing may increase the grazing pressure on patches, especially urine patches. Urine and dung deposition of both cattle and sheep may therefore be a catalyst in the patch grazing process.

2.5 DISCUSSION

Patch grazing is a very complex issue with numerous factors affecting the patch grazing process. Animals will continue to regraze previously grazed patches as they contain fresh nutritious regrowth (Ring *et al.* 1985). Whether the initial patches are grazed due to random grazing or not, animals will continue to graze these initiated patches (Ring *et al.* 1985). This would be especially true for sheep who require short nutritious herbage (Barnes 1992). The animal would therefore seem to be the most important factor when considering patch grazing. Having said that, the animal is significantly influenced by the sward. Animals preferentially graze plants (patches) higher in nutrient content, unless the plants are toxic in any way, than the sward average (Arnold 1964a, 1981). The higher nutrient content of the herbage in patches may come about as a result of numerous factors with the most important being, higher nutrient status soil, species composition which is inherently higher in nutrient content and/or urine deposition. Urine deposition is the only factor which has been identified to directly influence patch grazing and may be one of the most important factors in the patch initiation process. No research relating urine and dung to patch grazing has, however, been conducted in South Africa. In addition the reaction of cattle and sheep to the presence of dung from either species needs more research (Forbes & Hodgson 1985). The variations in the herbage of the sward may therefore play an important part in the initiation of patches and patch grazing then continues as a result of the shorter, leafy material contained in grazed patches.

Mott (1985) observed that the differential in sward height created by patch grazing may continue into the next grazing season. Grazing of previously grazed patches over consecutive season may therefore continue until the area is burnt (Mott 1985). I believe this may be true only if fires were used frequently (annually or biennially), because the degradation associated with patch grazing (Hatch & Tainton 1990; Fuls 1991; Fuls & Bosch 1991; Fuls 1992a,b;

Kellner & Bosch 1992; Wandera 1993) would not take place if fires were to stop the regrazing of previously grazed patches. As the humid grasslands are usually burnt less frequently than biennially, burning may not necessarily prevent the same patches being grazed again. The potassium (K) in urine may have an effect on the sward, and therefore influence patch grazing, for up to two years (Blagden 1969, cited by Wolton 1979) and even a full season's rest may not prevent the regrazing of previously grazed patches.

If patches were to continue to be grazed even after a burn, patch grazing may have negative consequences for plant vigour. Peddie (1994) observed that heavily grazed plants have significantly lower vigour than leniently/ungrazed plants. The reduction in vigour of plants in patches may therefore result in the replacement of those species by species which are adapted to heavy defoliation (e.g. Increaser II species).

Although patch grazing is a common occurrence (Barnes 1992) and is associated with veld degradation (Tainton 1972), no research has been conducted on the seasonal patterns of patch grazing. The patch grazing pattern is important as it will provide a better understanding on how patch grazing changes, or does not change, over the grazing season. Understanding the patterns of patch grazing will allow for a critical analysis of current grazing recommendations with the aim of reducing the effect of patch grazing.

CHAPTER 3

STUDY AREA

3.1 STUDY AREA AND SITE DESCRIPTION

The investigation comprised three separate studies and was conducted at two sites. Studies I and II were conducted on the University of Natal research farm, Ukulinga, which is situated near Pietermaritzburg (29° 40' E, 30° 24' S; 775 m a.s.l.) in the Southern Tall Grassveld of Natal (Acocks 1988) (Figure 3.1). The mean annual rainfall is 718 mm (73 years data) with rain falling mainly during summer (October to March) (Figure 3.2). Winters are mild (mean minimum 9.2 °C), while summers are warm (mean maximum 25.3 °C).[1] Study sites I and II were situated adjacent to each other on a flat dolorite hilltop. The veld was considered to be in very good condition for livestock production, and was dominated by *Themeda triandra* (Table 3.1).

Study III, comprising a number of sub-studies, was conducted at the Kokstad Research Station (29° 25' E; 30° 31' S; 1340 m a.s.l), in the Highland Sourveld (Acocks 1988) (Figure 3.1). The mean annual rainfall is 790 mm (60 years data) with rain falling mainly from October to March (Figure 3.3). Winters are cold with frequent frosts (mean minimum 2.1°C), while summers are warm (mean maximum 24.5°C).[2] Study site III was located within an existing trial situated on an undulating easterly to southerly aspect. The veld was also considered to be in good condition, with high proportions of *T. triandra* and *Tristachya leucothrix* (Table 3.1).

Study I was conducted within an existing trial which was designed to investigate the effect of grazing on patch developement. The original trial was established in 1990 on an area which had not been grazed for, at least, the past 40 years (Tainton pers. comm., Dept.

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[1] Climatic data for Ukulinga was supplied by the Computing Centre for Water Research, University of Natal, P/Bag X01, Scottsville, 3209

[2] Climatic data for Kokstad Research Station was supplied by the staff at Kokstad Research Station. Dept. Agric. Developement, P/Bag X9059, Kokstad, 4700.

Grassland Science, University of Natal, P/Bag X01, Scottsville, 3209). Data for the present study (Study I) were collected over a two year period, starting in June 1992 and ending in May 1994. Only cattle (Bonsmara-cross steers) were used in this study. Rainfall during the 1992/93 season was considerably lower (505.2 mm) than the long-term mean and data were not collected between October 1992 and April 1993 due to forage limitations. Rainfall in the 1993/94 season was above-average (760.3 mm) (Figure 3.2).

Study II was conducted adjacent to Study I, on an area that had received a single mowing defoliation annually (no grazing and very infrequent burning) for, at least, the past 45 years (Tainton pers. comm.). The study period lasted from October 1993 to June 1994, with above-average rainfall during most months (Figure 3.2). Both cattle and sheep were used in Study II. Bonsmara-cross steers and two-tooth Merino ewes were used.

The different parts of Study III were conducted within an existing trial which was designed to determine the effect of different cattle:sheep ratios on animal performance and on the vegetation (Hardy 1994) (Appendix 3.1). The existing trial commenced in the 1989/90 grazing season with the trial area having been rested for the previous three years. Fourteen month old Hereford steers and heifers (at the start of the season), and two-tooth Merino wethers were used in the trial. Cattle:sheep ratios were balanced in terms of animal units and stocked at 1.4 ha AU^{-1}. Each ratio treatment was managed as an individual four camp rotational grazing system, with one camp rested for the entire season. A 42-day grazing cycle was applied to the remaining three camps of each ratio treatment, with a 14 day period of stay in and a 28 day period of absence from each camp.

The data for this study were collected during the 1993/94 season in two camps of the 1:1 cattle:sheep ratio treatment. Data were obtained from the camp being rested and the camp that had received a full seasons rest in the previous (1992/93) season. Rainfall during the 1993/94 season was slightly higher (875.5 mm) than the long-term mean. Above-average rains fell from October to March, with slightly below-average rainfall during the other months (Figure 3.3).

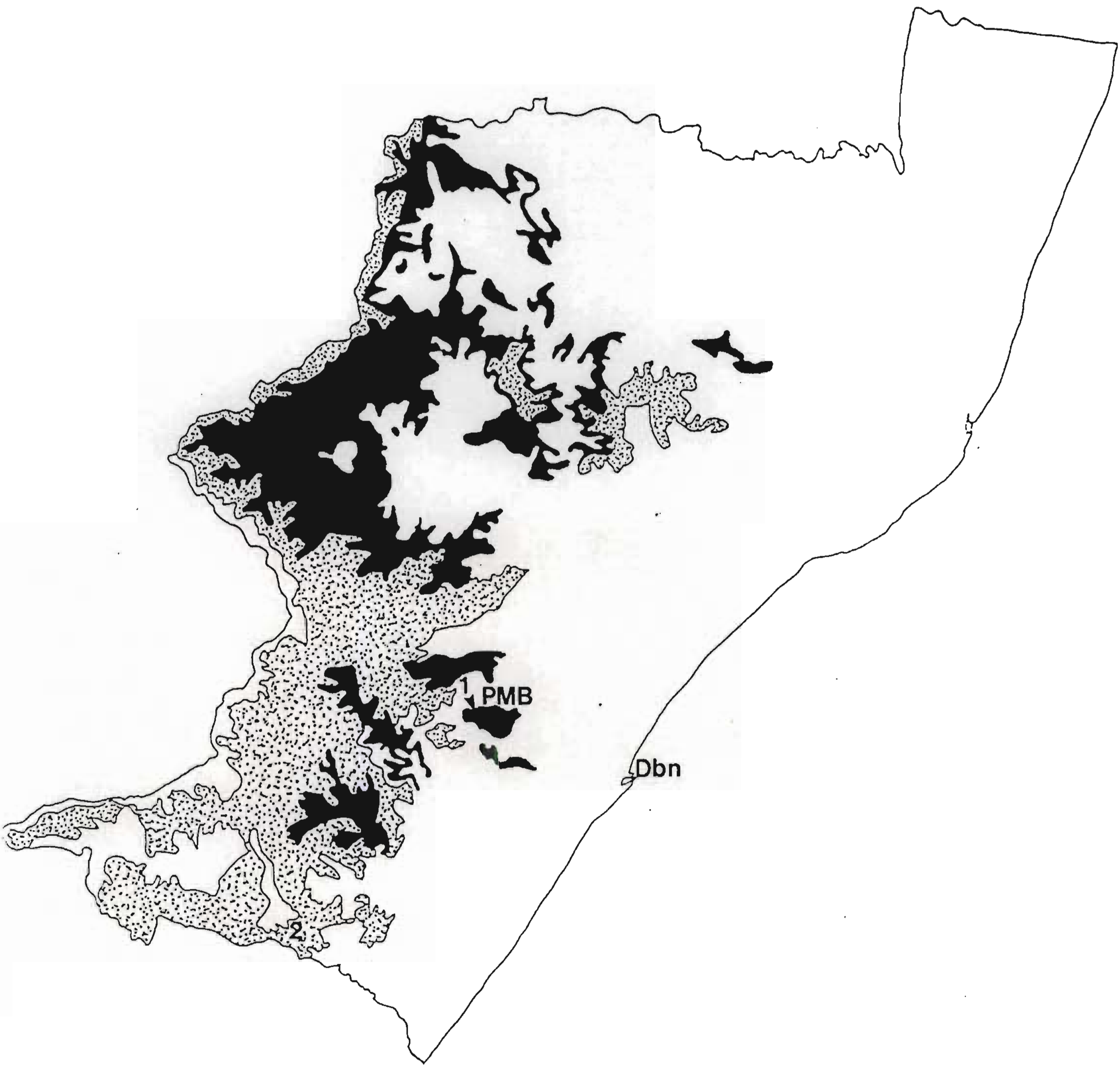

Figure 3.1 Location of the experimental sites at Ukulinga (1) in the Southern Tall Grassveld (solid) (Acocks 1988) and Kokstad Research Station (2) in the Highland Sourveld (dotted) (Acocks 1988).

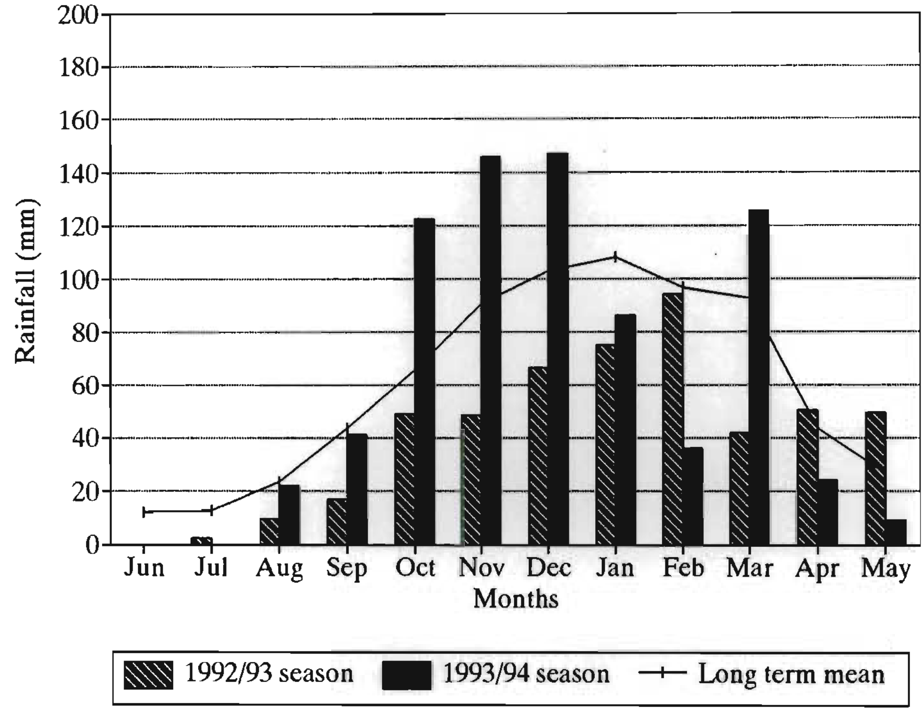

Figure 3.2 Mean monthly long-term (73 years data) rainfall (mm) and the monthly rainfall (mm) during the study period (June 1992 to May 1994) at Ukulinga Research Farm.

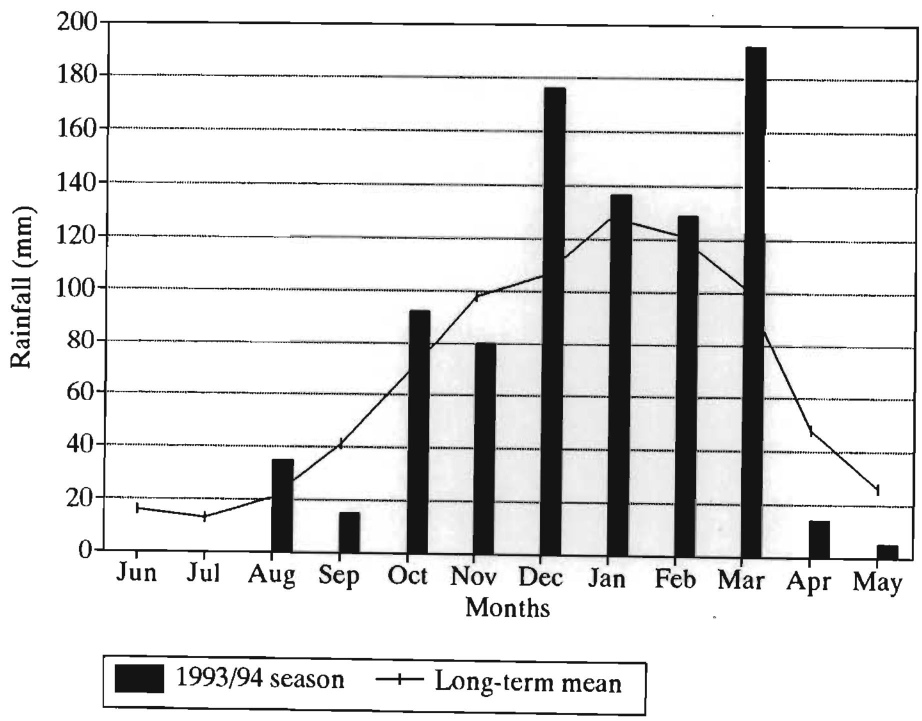

Figure 3.3 Mean monthly long-term (60 years data) rainfall (mm) and the monthly rainfall (mm) during the study period (1993/94 season) at Kokstad Research Station.

Table 3.1 Percentage species composition on the experimental sites at Ukulinga Research Farm and Kokstad Research Station.

SPECIES	Ukulinga	Kokstad
DECREASER		
Brachiaria serrata	0.3	0.2
Diheteropogon amplectens	-	-
Heterogogon contortus	0.9	0.8
Helictotrichon turgidulum	-	0.2
Themeda triandra	36.4	23.5
INCREASER I		
Alloteropsis semialata	-	2.9
Eulalia villosa	-	0.2
Harpochloa falx	-	10.8
Setaria nigrirostris	3.2	1.8
Trachypogon spicatus	-	5.0
Tristachya leucothrix	2.1	21.3
Cymbopogon excavatus	3.5	-
INCREASER II		
Eragrostis capensis	-	0.2
Eragrostis curvula	3.2	0.1
Eragrostis plana	-	1.3
Eragrostis racemosa	0.6	0.1
Koeleria capensis	6.7	9.3
Microchloa cafra	-	7.5
Hyparrhenia hirta	0.4	-
Sporobolus africanus	0.0	1.5
Forbs	15.6	1.5
Sedges	26.9	1.3
Other	0.0	0.8
INCREASER III		
Elionurus muticus	-	10.4
Diheteropogon filifolius	-	-
Aristida junciformis	0.2	-
TOTAL	100	100

3.2 TERMINOLOGY

A description of terms used throughout this document is given.

Patch grazing: The tendency of animals to select certain areas in an apparently uniform sward in preference to others and concentrate on these for the rest of the season.

Patch: A patch is a discrete area within an apparently uniform sward **grazed** to a maximum mean height of 40 mm (Hatch & Tainton 1990), measured during the dormant season, after a full seasons grazing.

Non-patch: A non-patch comprises the remainder of the sward, not classified as a patch. However, for the purpose of selecting non-patch sampling areas, a non-patch consisted of an area with a mean minimum height of 100 mm, measured during the dormant season, after a full seasons grazing.

Urine and/or dung patch: The sward surrounding (*c.* 1 m^2) a urine and/or dung deposit.

Intensity of grazing: The amount of forage removed in a single grazing, expressed as a reduction in plant height (mm), therefore giving a measure of the severity of grazing (Hatch 1991).

Frequency of grazing: Refers to the frequency of grazing in an area with no consideration given to the intensity of grazing. It was defined as the number of marked tufts (or sub-quadrats) grazed per patch or non-patch (quadrat) within a given sampling period.

Initial height: The height of a tuft or the sward prior to grazing commencement.

Leaf table height: The height below which 80% of the leaves were subjectively judged to occur (O'Reagain & Mentis 1989).

Extended leaf table/tuft height: The average height of a tuft, when extended upright.

CHAPTER 4

THE FREQUENCY AND INTENSITY OF GRAZING *THEMEDA TRIANDRA* IN PATCHES AND NON-PATCHES (STUDY I)

4.1 INTRODUCTION

Patch grazing may be described as the frequent and intense regrazing of localised areas within an apparently uniform sward (Spedding 1971; Ring *et al.* 1985; Mott 1985, 1987; Hatch & Tainton 1990). This is due to animals grazing plants with a higher nutritive value within the patches relative to the surrounding sward (Ring *et al.* 1985). Frequent and severe defoliation of individual plants within the patches may consequently lead to sward (Tainton 1972; Mott 1987; Willms *et al.* 1988) and soil (MacDonald 1978; Hatch & Tainton 1990) degradation. Any resulting sward or soil degradation, may decrease potential grazing capacity and hence negatively influence farm profitability.

With the frequent and severe defoliation of plants in patches throughout the season, forage in these patches is likely to become limiting. As forage becomes limiting, grazing pattern may change. Animals are known to change their selection habits as the season progresses (Gammon & Roberts 1978; Hatch & Tainton 1993), but no work has been conducted on the seasonal patterns of patch grazing. In addition, management decisions such as time of stocking after a burn may also influence patch selection patterns through the season. A knowledge of the seasonal patterns of patch selection would thus assist in developing management options for controlling patch grazing.

It was hypothesised that when grazing commences early after a burn, forage will be limiting and animals will be forced to graze non-selectively. With increasing delay in grazing, the sward matures, forage will no longer be limiting, and animals will become more selective. The objective of this study was to examine seasonal grazing patterns in patches and non-patches as a function of time of stocking veld after a burn in early spring.

4.2 PROCEDURE

A detailed study area and site description of Study I is given in Chapter 3. To test the stated hypothesis, three treatments were applied, namely:

1) an early graze - two weeks after early spring burning;

2) an intermediate graze - four weeks after early spring burning, and;

3) a late graze - eight weeks after a burn in early spring.

These treatments were hypothesised to create different sward structures and forage availabilities, with increased potential for patch grazing with increasing delay in the commencement of grazing. Replications of treatments was not possible due to area limitations. The trial layout is given in Appendix 4.1.

The trial was designed to simulate the recommended grazing management in the Southern Tall Grassveld (Acocks 1988). i.e. a four-camp rotational grazing system at a stocking rate of 2.5 ha AU^{-1} (Anon 1981). The area of the camp allocated to each treatment was only 0.33 ha. Thus, to simulate a realistic grazing system, the equivalent of a 14 day period of occupation and a 28 day period of absence, at a stocking rate of *c.* 2.5 ha AU^{-1}, was obtained by grazing each treatment with two Bonsmara-cross steers for a period of five days and then resting the treatment for 37 days, before the next five day grazing period.

In June 1992, prior to the start of this investigation, five patches were randomly selected according to the criterion of Hatch & Tainton (1990), who defined a patch as an area with a **maximum mean grazed** height of 40 mm. Within each patch, ten *Themeda triandra* tufts were permanently marked on a north -south transect. *Themeda triandra* was selected as it comprised the greatest proportion of the sward and was identified by Hatch (1991) as a key forage species for the Southern Tall Grassveld (Acocks 1988). A paired sampling procedure was used, and adjacent to each patch a second north-south transect of ten *T. triandra* tufts was located to represent the non-patches. The non-patch sampling areas were all located in veld with a mean height greater than 100 mm.

On each of the five days (effectively 14 grazing days ha^{-1}) that the animals grazed a treatment, the frequency and intensity of grazing was measured. The frequency of grazing involved the counting of the number of marked tufts which were grazed on each day per patch/non-patch. To detect if a tuft was grazed from one day to the next, all grazed leaf tips were marked with Tipp-ex (typists correcting fluid). This was done following the procedure of Danckwerts (1984) and Hatch (1991). Marking the grazed leaf tips was possible only when leaves were actively growing. When leaf growth slowed towards winter, all leaves had to be marked. The frequency of grazing was thus calculated as the cummulative number of marked tufts grazed per patch/non-patch, at each sampling occasion. Extended tuft height was also measured prior to the start of each grazing period (initial height) and on each of the days the animals occupied the treatment. The initial height will give a good indication of how close the animals graze the patches and the non-patches. The intensity of grazing was calculated as the average reduction in extended tuft height over successive days. Extended tuft height was used as leaf table height varied from day to day.

During the two year study period 10 grazing periods in each treatment were examined. These 10 grazing periods were allocated into four seasons:

1) spring - September to October (1)[1];
2) summer - November to March (3);
3) autumn - April and May (4), and;
4) winter - June to August (2).

As treatments were not replicated an analysis of variance approach to data analysis (Steel & Torrie 1980) could not be adopted. There were also only two factors, patches and non-patches, and those being paired, paired t-tests (Steel & Torrie 1980) were used to compare initial tuft heights, frequency of grazing and intensity of grazing of patches and non-patches. The paired t-tests were done in three steps. The first analysis compared initial tuft heights, the frequency of grazing and the intensity of grazing patches and non-patches, across all treatment combinations (main effect). Two analyses (1st order interactions) were then conducted to investigate if initial tuft height, the frequency of grazing and the intensity of grazing differed between patches and non-patches, between:

[1] The number of grazing periods in a particular season during which data were collected.

1) treatments, across all seasons, and;

2) seasons, across all treatments.

A third analysis then looked at the second order interaction involving both treatments and season.

A step-wise multiple regression analysis (Rawlings 1988) was also used to establish a relationship between the frequency and intensity of grazing and the number of grazing days. The dependent variables were the frequency and the intensity of grazing. The independent variables were patch or non-patch, treatment, season and grazing days. This relationship was, however, used only to graphically depict the cumulative frequency and intensity of grazing in patches and non-patches during a period of occupation.

4.3 RESULTS

4.3.1 Initial height

Initial tuft heights (mm) were consistently lower in patches than in non-patches, for all seasons and treatments ($P \leq 0.01$) (main effect), in all treatments averaged over the two grazing seasons ($P \leq 0.01$), and during spring ($P \leq 0.05$), summer, autumn and winter, across all treatments ($P \leq 0.01$) (Table 4.1).[2]

[2] Mean initial height of patches in this study were consistently greater than the 40 mm maximum height of patches defined by Hatch & Tainton (1990). Between periods of occupation, plants were able to recover and were therefore likely to be taller than 40 mm by the start of the next grazing period. These areas were also not grazed for a period of six months during the 1992/93 season, allowing plants an undisturbed period of growth. When patches were initially selected during the dormant season of 1991, the overall heights of patches were all below 40 mm.

Table 4.1 The mean initial heights of tufts (mm) in patches and non-patches across all treatments (main effect), within treatments, and over the grazing season (1st order interaction)

Interaction	Treatment	n	Patch	Non-patch	Difference	SED	t-value
Main effect		150	143.3	173.4	30.1	4.01	7.550 **
1st	1	50	133.3	150.8	17.5	4.51	3.863 **
order	2	50	129.5	177.7	48.2	6.34	7.587 **
(Treatments)	3	50	167.1	192.4	25.3	8.71	2.906 **
1st	spring	15	111.1	119.5	8.4	3.65	2.281 *
order	summer	45	178.5	203.9	25.4	5.46	4.653 **
(Season)	autumn	60	153.1	172.9	19.8	5.19	3.813 **
	winter	30	87.0	156.6	69.6	12.74	5.461 **

* = $P \leq 0.05$ ** = $P \leq 0.01$ SED = Standard error of the difference

Patches contained significantly shorter tufts than the non-patches, in all treatments, during winter (Table 4.2). The general trend in initial height was an increase from Treatment 1 to Treatment 3. The differences in the heights of patches and non-patches were, however, greatest in Treatment 2, except during winter where the differences were greatest in Treatment 3 (Table 4.2).

Table 4.2 The mean initial heights (mm) of patches and non-patches (2nd order interaction)

Season	Treat ments	n	Patch	Non-patch	Differences	SED	t-value
spring	1	5	66.4	68.8	2.4	6.56	0.366 ns
	2	5	102.8	117.8	15.0	3.35	4.482 *
	3	5	164.2	171.8	7.6	8.11	0.936 ns
summer	1	15	162.4	182.5	20.4	7.59	2.688 *
	2	15	147.7	196.9	49.2	10.09	4.884 **
	3	15	225.9	232.4	6.5	7.33	0.657 ns
autumn	1	20	155.4	162.7	7.3	6.28	1.154 ns
	2	20	149.2	194.5	45.3	10.37	4.362 **
	3	20	154.7	161.5	6.8	7.25	0.945 ns
winter	1	10	79.5	120.3	40.9	12.07	3.384 **
	2	10	76.4	145.1	68.7	17.05	4.029 **
	3	10	105.2	204.4	99.2	30.71	3.229 *

ns = $P > 0.05$ * = $P \leq 0.05$ ** = $P \leq 0.01$ SED = Standard error of the difference

4.3.2 Frequency and intensity of grazing

The cumulative frequency and intensity of grazing increased almost linearly over the 14 grazing days in all seasons and treatments (Figures 4.1 & 4.2). Differences in the frequency and intensity of grazing between patches and non-patches decreased as the grazing season progressed. The general trend, however, was a decrease in patch grazing as the season progressed towards winter. Both patches and non-patches were grazed more frequently and more intensively in Treatment 1 than in Treatments 2 and 3, while Treatment 3 was more frequently grazed than Treatment 2. The intensities of grazing Treatments 2 and 3 were very similar (Figures 4.1 & 4.2).

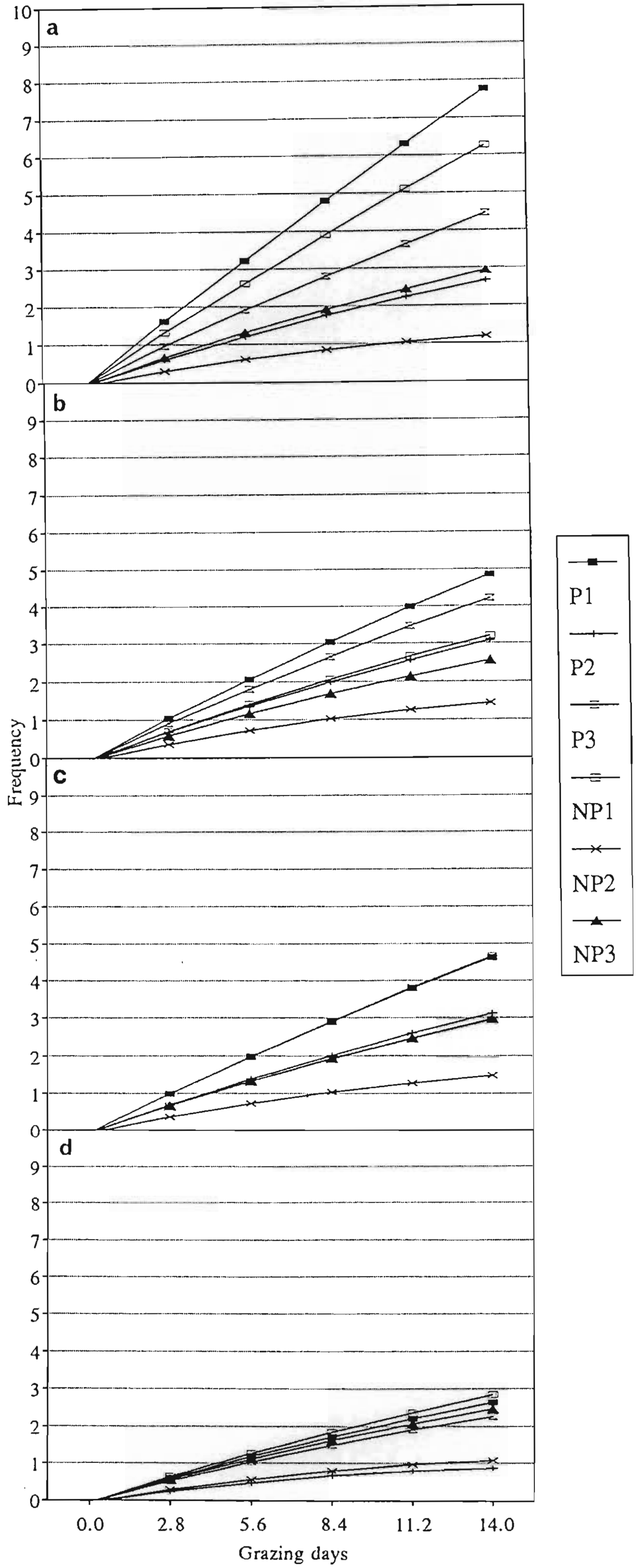

Figure 4.1 The predicted cumulative frequency of grazing patches and non-patches in all treatments during (a) spring, (b) summer, (c) autumn and (d) winter. $R_a^2 = 0.750$.

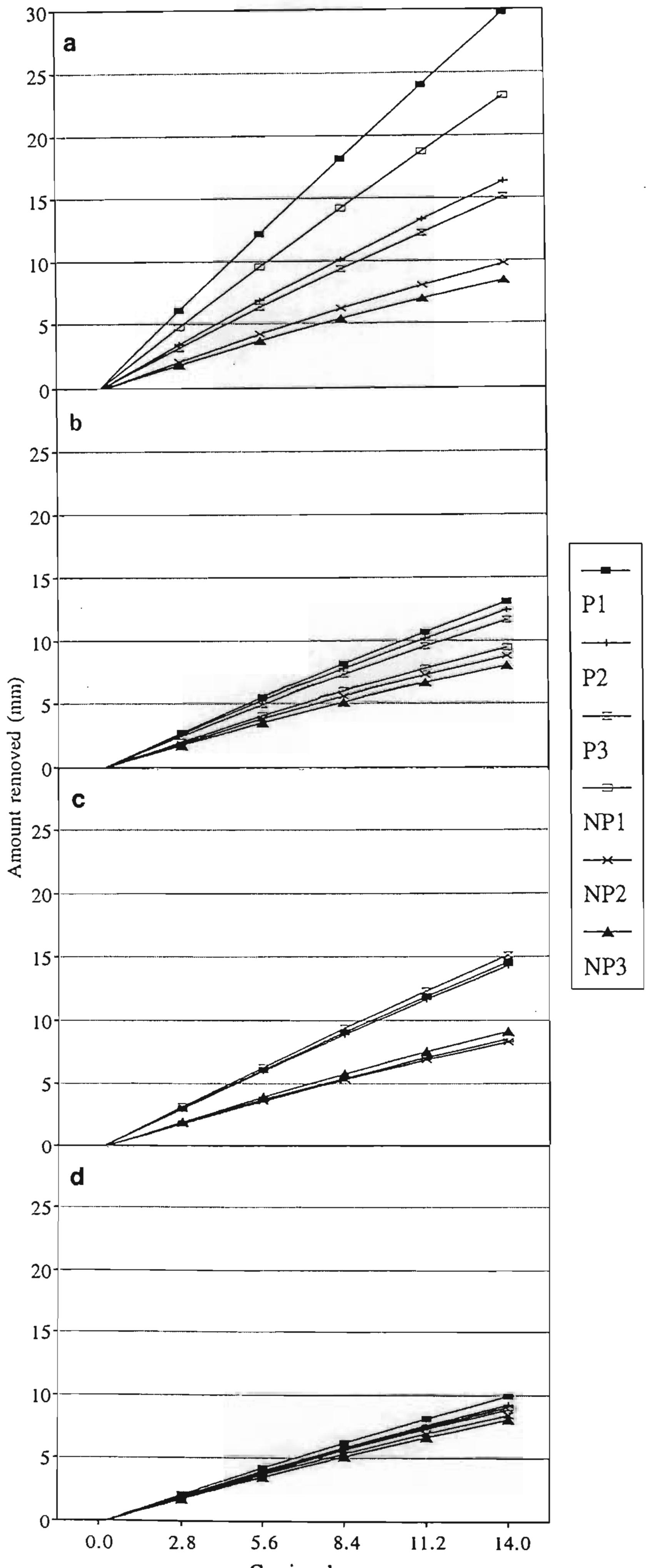

Figure 4.2 The predicted cumulative intensity of grazing patches and non-patches in all treatments during (a) spring, (b) summer, (c) autumn and (d) winter. R_a^2 = 0.674.

Patches were grazed more frequently than non-patches (main effect) ($P \leq 0.01$) (Table 4.3). Patches were also more frequently grazed than non-patches in all treatments, averaged across all seasons ($P \leq 0.01$) (Table 4.3). The comparison of the frequency of grazing between patches and non-patches at the various times of the year, across all treatments, showed that patches were more frequently grazed in spring ($P \leq 0.05$), summer and autumn ($P \leq 0.01$). No significant differences in the frequency of grazing patches and non-patches were observed during winter ($P > 0.05$) (Table 4.3). The frequency of grazing patches increased from spring through to autumn and then decreased in winter. The frequency of grazing non-patches stayed fairly constant throughout the year.

Table 4.3 The mean frequency of grazing patches and non-patches across all treatments (main effect), within treatments, and over the grazing season (1st order interaction)

Interaction	Treatment	n	Patch	Non-patch	Differences	SED	t-values
Main effect		150	6.2	4.0	2.2	0.31	6.958 **
1st	1	50	6.8	5.3	1.5	0.54	2.755 **
order	2	50	5.4	2.7	2.7	0.53	5.011 **
(Treatments)	3	50	6.3	4.0	2.3	0.55	4.325 **
1st	spring	15	5.9	4.3	1.6	0.71	2.331 *
order	summer	45	6.1	3.4	2.7	0.55	4.870 **
(Season)	autumn	60	7.5	4.5	3.0	0.54	5.502 **
	winter	30	3.8	3.8	0.0	0.54	0.123 ns

ns = $P > 0.05$ * = $P \leq 0.05$ ** = $P \leq 0.01$ SED = Standard error of the difference

The intensity of grazing patches was also significantly higher than non-patches (main effect) ($P \leq 0.01$) (Table 4.4). The intensity of grazing between the two areas was only significantly different in Treatment 2 ($P \leq 0.05$), with no significant differences in Treatments 1 and 3 ($P > 0.05$), when compared across all seasons (Table 4.4). The differences in the intensity of grazing indicated that patches were grazed more severely than the non-patches during summer ($P \leq 0.05$) and autumn ($P \leq 0.01$), with no significant differences during spring ($P > 0.05$). During winter, however, the non-patches were grazed more intensively than the patches ($P \leq 0.05$) (Table 4.4). As was observed for the frequency of grazing, the intensity of grazing patches increased steadily through to autumn before declining during winter. However, the intensity of grazing non-patches, in contrast to the frequency of grazing non-patches, increased steadily throughout the year (Table 4.4).

Table 4.4 The mean intensity (mm) of grazing patches and non-patches across all treatments (main effect), within treatments, and over the grazing season (1st order interaction)

Interaction	Treatment	n	Patch	Non-patch	Differences	SED	t-values
Main effect		150	28.5	22.5	6.0	2.16	2.774 **
1st	1	50	28.1	25.5	2.6	2.47	1.055 ns
order	2	50	22.6	14.7	7.9	3.40	2.339 *
(Treatments)	3	50	35.0	27.5	7.5	4.97	1.498 ns
1st	spring	15	22.2	15.1	7.1	3.94	1.795 ns
order	summer	45	29.4	20.9	8.5	3.39	2.511 *
(Season)	autumn	60	36.9	23.7	13.2	3.13	4.218 **
	winter	30	13.6	26.3	-12.7	5.88	-2.157 *

ns = $P>0.05$ * = $P\leq 0.05$ ** = $P\leq 0.01$ SED = Standard error of the difference

The frequency and intensity of grazing of patches did not differ significantly from non-patches during winter, in all three treatments ($P>0.05$) (Table 4.5). The frequency of grazing was higher in the non-patches than in the patches in Treatment 3 during this period, while the intensity of grazing was higher in the non-patches in all treatments, during winter (Table 4.5). The differences in the frequency and intensity of grazing patches and non-patches were generally smallest in Treatment 1 during all seasons, with the only significant difference in the frequency of grazing ($P\leq 0.05$) occurring during summer. The differences in the intensity of grazing patches and non-patches in Treatment 1 were non-significant ($P>0.05$) during all seasons (Table 4.5). Generally the frequency and intensity of grazing both patches and non-patches was lower in Treatment 2 than Treatments 1 and 3. The general trend in the differences between the frequency and intensity of grazing patches and non-patches increased from Treatment 1 through to Treatment 3 in most seasons, except winter. During winter the differences in the frequency and intensity of grazing were also greatest in Treatment 3, but the non-patches were grazed more frequently and intensively than the patches (Table 4.5). Summer and autumn could be seen as the seasons in which most patch grazing occurs, as it was during this period that the differences in the frequency and intensity of grazing patches and non-patches were generally greatest (Table 4.5).

Table 4.5 The frequency and intensity (mm) of grazing patches and non-patches (2nd order interaction)

	Season	Treatment	n	Patch	Non-patch	Difference	SED	t-value
Frequency	spring	1	5	8.0	6.8	1.2	1.69	0.712 ns
		2	5	4.6	3.4	1.2	1.24	0.967 ns
		3	5	5.2	2.6	2.6	0.81	3.200 *
	summer	1	15	7.7	5.5	2.2	1.04	2.119 *
		2	15	3.9	1.2	2.7	0.99	2.684 *
		3	15	6.6	3.4	3.2	0.87	3.334 **
	autumn	1	20	7.1	5.3	1.8	0.99	1.765 ns
		2	20	7.5	3.6	3.9	0.96	4.008 **
		3	20	7.9	4.6	3.3	0.84	3.985 **
	winter	1	10	4.2	4.1	0.1	0.67	0.148 ns
		2	10	3.9	2.8	1.1	0.74	1.492 ns
		3	10	3.4	4.4	-1.0	1.26	-0.796 ns
Intensity	spring	1	5	20.5	15.7	4.8	6.68	0.719 ns
		2	5	19.3	15.1	4.2	6.74	0.623 ns
		3	5	26.8	14.6	12.2	7.93	1.539 ns
	summer	1	15	33.9	33.0	0.9	6.00	0.144 ns
		2	15	14.1	5.1	9.0	4.64	1.938 ns
		3	15	40.3	24.6	15.7	6.55	2.244 *
	autumn	1	20	32.1	27.2	4.9	3.91	1.252 ns
		2	20	35.0	20.6	14.4	6.71	2.138 *
		3	20	43.8	23.5	20.3	4.95	4.112 **
	winter	1	10	15.1	15.6	-0.5	2.23	-0.201 ns
		2	10	12.3	16.8	-4.5	6.11	-0.736 ns
		3	10	13.4	46.5	-33.5	14.88	-2.224 ns

ns = $P \geq 0.05$ * = $P \leq 0.05$ ** = $P \leq 0.01$ SED = Standard error of the difference

4.4 DISCUSSION

Initial heights revealed that, by the end of the season, patches were grazed far more closely than the non-patches, even though the non-patches were grazed more intensively than the patches during winter. Closely grazed swards (or areas within a sward), i.e. overgrazing, have been found to negatively influence the species composition by allowing undesirable grazing species to invade (Tainton 1972, 1988b; Barnes 1992).

Although a high degree of patch grazing was evident during the spring period (Figures 4.1 & 4.2), the differences between the frequency and intensity of grazing patches and non-patches were not significant. This could be due to only one data set being collected during spring, resulting in higher data variability. Patch grazing was, however, high during the summer and autumn period while the extent of patch grazing declining to a minimum in winter, where in some treatments the grazing was more severe in the non-patches than in the patches. This corroborates the findings of Hatch & Tainton (1993), who observed that animals selected for *Hyparrhenia hirta* during the spring period and then patch grazed during the late summer/autumn period, when the sward is characterised by high herbage availability. During winter they argued that patch selection declined, and animals were forced to graze plants that were previously left ungrazed. During winter the differences in initial heights of patches and non-patches were at a maximum. Non-patches were also more severely grazed than patches during winter, indicating that a lack of forage in the patches may be the reason for the decline in patch grazing during winter.

The differences in the frequency and intensity of grazing in patches and non-patches were smallest in Treatment 1. This indicates that early grazing after a burn allowed less patch grazing than delayed grazing. With early stocking, forage was limiting and the animals tended to graze non-selectively, thereby reducing the effect of patch grazing. However, early stocking may be disadvantageous, in that the sward is grazed after plants have used their stored reserves to start growth and before sufficient leaf material has accumulated for the plant to replace reserves (Tainton 1988b). When these plants are grazed early, potential photosynthetic material is removed, forcing the plants to use more stored reserves, further into the season, thereby decreasing the plants ability to grow later in the season (Tainton 1988b). Barnes & Dempsey (1992) reported that early grazing may also affect seeding because plants, in local veld, flower and set seed in the first half of the growing season. For these reasons, grazing recommendations have been to start grazing only when the sward is 100 to 150 mm high (Tainton 1987). Barnes (1992) and Barnes & Dempsey (1992), however, indicate that these recommendations need drastic revision. In the south-eastern Transvaal sourveld, Barnes & Dempsey (1992) found that grazing sheep early after a burn increased sheep performance drastically without negatively affecting species composition or sward vigour, when compared to later stocking after burning. However, they suggest that a 'therapeutic treatment' be applied the following season. Here they suggest commencing grazing later in the season and not grazing for the entire season, which may include an autumn rest to allow plants to store reserves (Tainton 1971, 1988c), but preferably by resting the veld for an entire season.

A delay in grazing after burning, of even two weeks after the early grazing treatment, increased the incidence of patch grazing. It was hypothesised, that as grazing after burning is deferred, so patch grazing would increase. The differences in the frequency and intensity of grazing between patches and non-patches were generally smallest in Treatment 1 and greatest in Treatment 3, even though all treatments were burnt annually for the four years since the start of the initial trial. Annual burning was applied because the late grazing commencement had accumulated large amounts of moribund and stemmy material by the end of the season. Burning could have reduced the effect of patch grazing. It was also apparent that the patches in Treatment 3 were smaller than in the other two treatments. It would thus seem that the results corroborate the stated hypothesis.

Early grazing after a burn would seem to be the best management option to reduce the effect of patch grazing. In addition, early grazing increases sheep performance dramatically, without affecting the sward, provided sufficient resting is applied (Barnes 1992; Barnes & Dempsey 1992). It could be assumed that early grazing would also increase cattle performance. The priority camp system of Venter & Drewes (1969), commonly used in the humid grasslands of KwaZulu-Natal, may be used in conjunction with an early graze in the priority camp. The priority camp could be grazed early after a burn, but in subsequent seasons, grazing should be delayed to allow plants to accumulate leaf material before being grazed. During winter non-patches were grazed more frequently and intensively than patches. Heavy overwintering could therefore possibly reduce the effect patch grazing may have in the following season, by reducing the differences in height of plants in patches and non-patches the following season. If patch grazing is very severe and sward degradation is evident, it may be possible to reduce the effect of patch grazing, by reducing the four camp system to a three camp system. This would allow animals more access to fresh growth (every third year) and is likely to give patches less chance of becoming established and continue to exist after a full seasons rest.

CHAPTER 5

THE EFFECT OF URINE AND DUNG ON THE PATCH GRAZING PATTERNS OF CATTLE AND SHEEP (STUDY II).

5.1 INTRODUCTION

Most of the nutrients ingested by grazing animals are returned to the sward via urine and dung (During 1972, cited by Legard *et al.* 1982). The area affected by a urine or dung deposit is small. Cattle urine affects an area of 0.25 m^2 (Jaramillo & Detling 1992a,b) to 0.45 m^2 (Peterson *et al.* 1956; Richards & Wolton 1976) in size. Cattle dung affects a smaller area, 0.05 to 0.07 m^2 (Wolton 1979). The effect of sheep fouling would be even smaller. Although only small areas are affected by a single urine or dung deposition, the total area fouled in a camp during a grazing season may be large.

Numerous authors have related urine and dung deposition to the incidence of patch grazing (e.g. Joblin & Keogh 1979; Jones & Ratcliff 1983; Day & Detling 1990; Jaramillo & Detling 1992b). Urine patches are generally preferentially grazed while dung patches are generally not grazed by the animals. This is true for both cattle and sheep grazing. However, the reaction of cattle and sheep to the presence of dung from the same or the other species has not been thoroughly investigated (Forbes & Hodgson 1985).

Urine patches are preferentially grazed almost immediately after deposition and continue to be grazed for a period of two to four months after deposition (Legard *et al.* 1982). Dung patches are usually ignored for a period of three to four months (Norman & Green 1958; Marten and Donker 1964) to 13 to 18 months (Marsch & Cambling 1970). A concern with most of these studies was, that animals repeatedly grazed the same areas (rotational grazing systems), and past grazing may have influenced sward height and therefore the grazing pattern. The effect of urine and dung on the grazing pattern in and around the deposit could therefore be masked by previous grazing.

This study was initiated to investigate the effect of urine and dung on the grazing pattern of cattle and sheep and their reaction to the presence of dung from the same or the other animal. The effect of time since urine and dung deposition, excluding the effect of previous grazing, had on the grazing pattern of cattle and sheep was also investigated.

5.2 PROCEDURE

A detailed study area and site description of Study II is presented in Chapter 3.

Hatch & Tainton (1990) observed that previous grazing may strongly influence subsequent patch grazing. An investigation of the effect of urine and dung on grazing pattern would therefore require that no previous grazing should have taken place. The sward should be uniform in both structure and composition. Hence the selection of the present study site.

Four treatments were used to investigate the grazing pattern of cattle and sheep grazing in and around urine and dung depositions. The treatments were:

1) urine;
2) cattle dung;
3) sheep dung and;
4) a control (or no treatment).

An artificial urine solution was made up using the formula of Day & Detling (1990). The chemical composition of the solution is summarized in Appendix 5.1. The solution was successfully used in grazing experiments by Day & Detling (1990) although, it did not have the typical urine smell, which may have influenced grazing behaviour. Fresh cattle dung was collected at the local abattoir. Sheep dung was collected from the holding pens at Ukulinga.

The study conprised six camps (40 m x 40 m), which facilitated an examination of the selection patterns of both sheep and cattle, and the influence the age of urine and dung had on these patterns. The camps were divided into three pairs, with one camp in each pair grazed by cattle and the other by sheep to examine the differences in the cattle and sheep grazing patterns (Appendix 4.1). These paired camps were then grazed at intervals of *c.* three months to investigate the effect of age of urine and dung on the grazing pattern of cattle and sheep. The cattle camps were grazed by two Bonsmara-cross steers and the sheep camps by 40 two-toothed Merino ewes for a period of two days. In a visual assessment of the amount of forage removed in a preliminary study, this proved to be the most effective stocking pressure. The grazing schedule is summarized in Table 5.1.

Table 5.1 Grazing schedule of urine and dung study

Camp	Animal type	Grazing dates
1	Cattle	8 and 9 November 1993
2	Sheep	8 and 9 November 1993
3	Cattle	18 and 19 February 1994
4	Sheep	18 and 19 February 1994
5	Cattle	24 and 25 May 1994
6	Sheep	24 and 25 May 1994

Each camp was divided into 16 10 m x 10 m areas to provide a 4 x 4 Latin square design (Steel & Torrie 1980). This allowed for four replictes of each of the four treatments to be used in a cafeteria layout, giving the animals a choice of all treatments. Within each of these areas, five 1 m by 1 m quadrats were marked to serve as the sampling unit, with all five quadrats in each area, containing the same treatment (Appendix 5.2). Each treatment therefore had 20 sampling areas (1 m^2 quadrats) in each camp. Two litres of urine (Norman & Green 1958, Day & Detling 1990) was poured into a circular 0.25 m^2 quadrat (Jaramillo & Detling 1992a,b) into the centre of each 1 m^2 urine quadrat. A circular 0.1 m^2 quadrat was used to deposit 2 kg (Waite *et al.* 1951) of cattle dung into the centre of each cattle dung quadrat. A quarter of a kilogram of sheep dung was placed into the centre of each 1 m^2 sheep dung quadrat by hand. Nothing was applied to the control quadrats. The treatments were applied to all six camps two days prior to grazing the first set of camps (Camps 1 and 2).

Sward growth in the area surrounding a urine or dung deposit may be affected by the release of nutrients, resulting in higher above ground herbage production than the areas not affected by either deposit (Norman & Green 1958; Mundy 1961; Marsh & Cambling 1970; Wolton 1979; Legard *et al.* 1982; Jaramillo & Detling 1992a). This may influence the grazing pattern of the animals. Marten & Donker (1964) used a mower to remove any trace of previous grazing. In this study, mowing was used to remove any effects the treatments may have had on sward height. With the aim of a sward height of *c.* 150 mm when grazing commenced, all camps, excepting for camps one and two, were mown to *c.* 100 mm in height, three weeks prior to grazing in the respective camps. Camps one and two were not mown because they were to be grazed two days after the treatments were applied and it was assumed that the treatments would not have influenced sward height prior to grazing.

For the purpose of data collection, each 1 m x 1 m quadrat was divided into 25 equal sub-quadrats. Leaf table height was measured in each sub-quadrat prior to grazing (initial height). After each grazing period all 25 sub-quadrats were checked if they were grazed or not (frequency of grazing), and the leaf table height remeasured (intensity of grazing).

An Analysis of Variance (Latin square blocking structure) (Steel & Torrie 1980) using GENSTAT (Genstat 5 Committee 1987) was used to analyse the data. Least significant differences (LSD) were used to examine differences between treatment means.

The effect of the treatments (urine, cattle dung and sheep dung) on the frequency and intensity of grazing were compared against the control. The results obtained from the control quadrats were subtracted from the treatment quadrat results, i.e. the control was always zero. If the frequency and the intensity of grazing was higher than zero in any treatment, then that treatment was classified as being a preferred area. If the frequency and intensity of grazing was less than zero, then the control was preferred (treatment appeared to be rejected) by the animals. This procedure allowed the results to be described in terms of a preference rating. The preference rating was used to index selection. Grazing frequency was expressed as the number of sub-quadrats grazed per 1 m^2 area. Grazing intensity was expressed as the average reduction in leaf table height over the whole 1 m^2 area.

The grazing pattern within the 1 m^2 area surrounding the applied treatments was also investigated. Only the grazing pattern of cattle and sheep, averaged across all three deposition ages, were examined, since the differences between the different deposition ages were small. Topographical diagrams using the programm SURFER ver. 4 (Golden Software 1989), were used to depict the grazing patterns.

5.3 RESULTS

5.3.1 Initial sward height

Initial heights in the cattle and sheep camps were not significantly different ($P > 0.05$) (Figure 5.1a). Sward heights at the start of each grazing period were different, with the initial heights being significantly higher ($P \leq 0.05$) during the second grazing period (Time 2) than the first (Time 1) and third (Time 3) grazing periods. The initial heights at Time 1 were slightly higher than at Time 3 ($P \leq 0.05$) (Figure 5.1b). The higher sward height at Time 2 is probably due to insufficient herbage being removed during the mowing of the Time 2 camps, and that subsequent growth was faster than expected. Initial sward heights at the different treatments were not significantly different ($P > 0.05$) (Figure 5.1c).

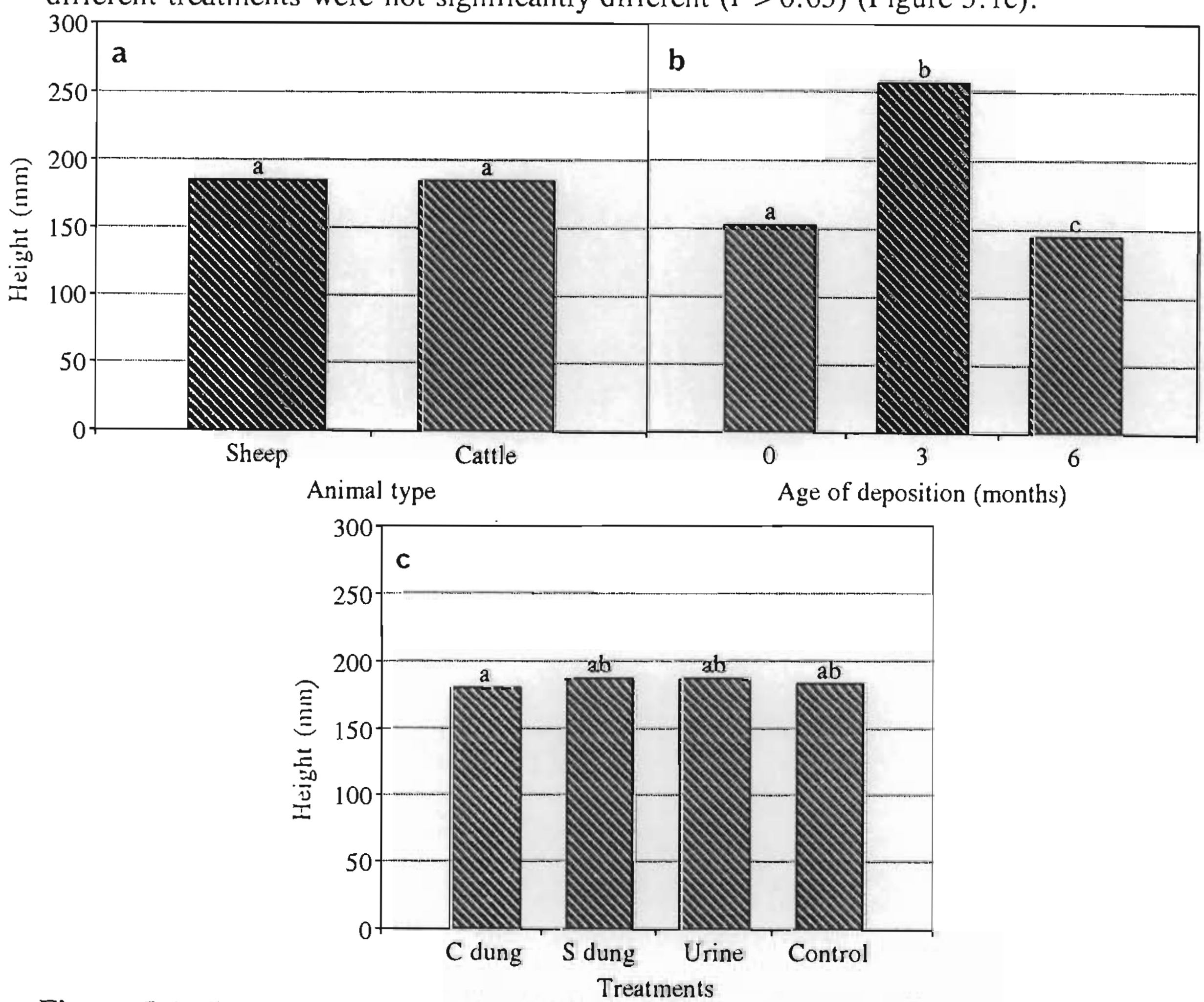

Figure 5.1 Initial sward heights of (a) all treatments across all camps and across all deposition ages in the cattle and sheep camps, (b) all treatments across the combined cattle and sheep camps at the different deposition ages, and (c) the combined cattle and sheep camps across all deposition ages, at the different treatments applied. Letters not in common indicate significant differences ($P \leq 0.05$)

5.3.2 Grazing pattern

The highest order interaction (treatment x animal type x age of deposition) in the analysis of variance was highly significant ($P \leq 0.001$) for both the frequency and intensity of grazing. For clarity, the main effect of treatment will be described before describing any interactions. The second order interactions are presented in Appendices 5.3 and 5.4.

5.3.2.1 Frequency of grazing

Both cattle and sheep reacted to the presence of urine and dung. The control areas were preferred to the cattle and sheep dung patches, while the areas surrounding urine deposits were preferentially grazed by both animals ($P \leq 0.01$) (main effect - treatment) (Figure 5.2a). The differences in the preference rating between the treatments (selection pattern) by sheep was not as great as for cattle, i.e. cattle were far more sensitive (Figure 5.2b). Sheep grazed the urine patches less frequently than cattle did, and cattle dung patches were grazed far more frequently by sheep than by cattle. Sheep dung had no effect on sheep grazing but cattle preferred the control areas to the sheep dung patches (1st order interaction - treatment x animal type) (Figure 5.2b). Cattle were therefore far more reactive to the presence of dung from either species than were sheep.

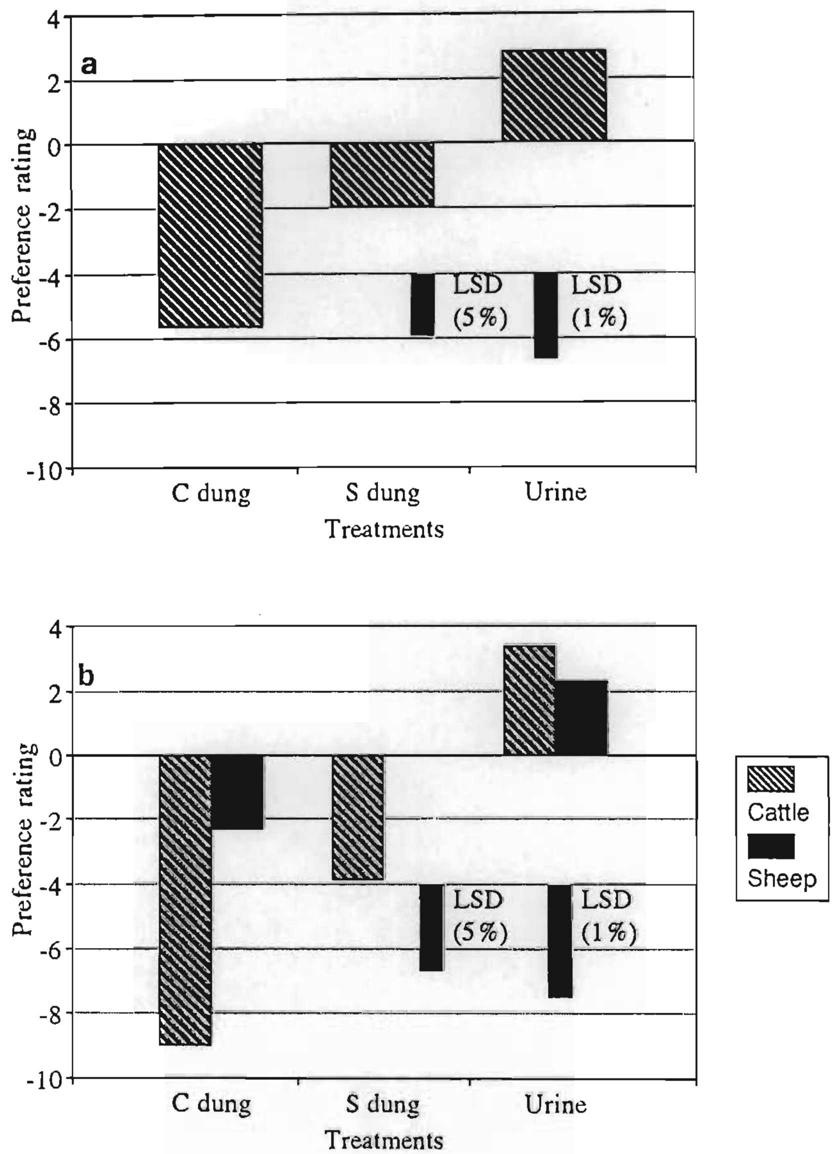

Figure 5.2 The difference in the frequency of grazing (preference rating) of (a) cattle and sheep combined (main effect), and (b) of cattle and sheep separately (1st order interaction - animal type x treatments), at the different treatments across all seasons.

5.3.2.2 Intensity of grazing

A similar response to the frequency of grazing was observed in the intensity of grazing of both animals. Grazing was significantly different at the different treatments. Grazing of urine patches was significantly more intense than the grazing of cattle and sheep dung patches ($P \leq 0.01$), and sheep dung had a significantly higher intensity of grazing than cattle dung ($P \leq 0.01$) (main effect - treatment) (Figure 5.3a).

The control areas were preferred to the cattle dung patches by both cattle and sheep but the preference rating of sheep was higher than that for cattle. Urine treated areas were preferred by both cattle and sheep but the cattle preference rating was higher than that for sheep. Sheep dung patches were generally not grazed by cattle and only slightly preferred by sheep. Sheep dung therefore had the least effect on grazing, especially sheep grazing (1st order interaction -treatment x animal type) (Figure 5.3b).

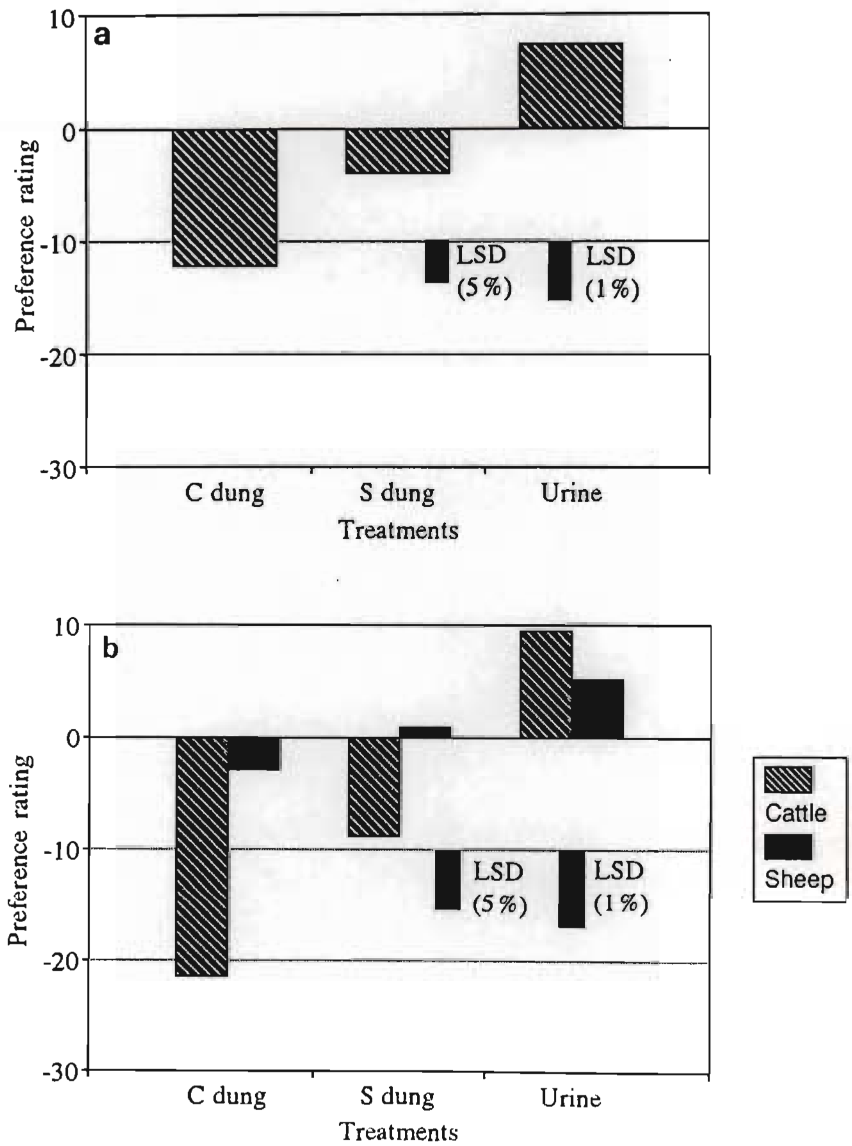

Figure 5.3 The difference in the intensity of grazing (preference rating) of (a) cattle and sheep combined (main effect), and (b) of cattle and sheep separately (1st order interaction - animal type x treatments), at the different treatments across all seasons.

The treatments had less of an effect on sheep than they did on cattle grazing. This may in part be attributed to the fact that cattle removed a significantly greater quantity of herbage from all quadrats than did sheep ($P \leq 0.05$) (Figure 5.4a). This may simply be attributed to the fact that cattle, having wider mouth parts, take in more material with each bite as the frequency of grazing showed no significant differences between cattle and sheep grazing ($P \geq 0.05$) (Figure 5.4b)

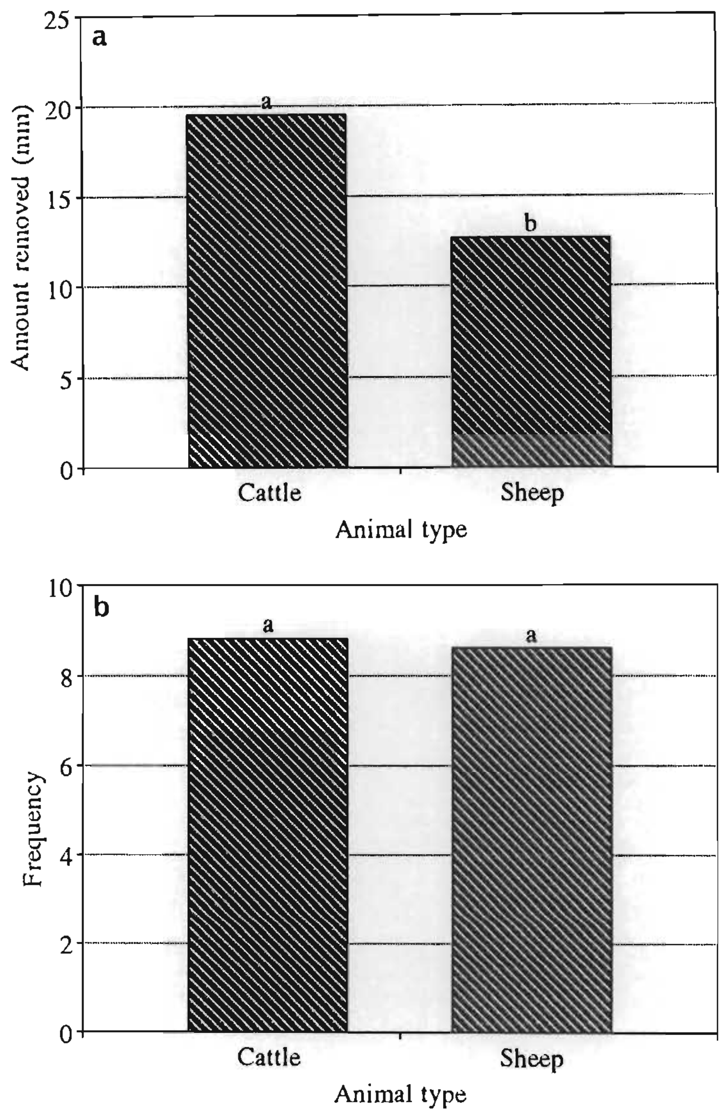

Figure 5.4 The intensity (a) and the frequency (b) of grazing cattle and sheep, across all treatment combinations (main effect). Letters not in common indicate significant differences ($P \leq 0.05$)

5.3.3 Age of treatment deposition (second order interaction - treatment x animal type x age of deposition)

5.3.3.1 Cattle dung

The frequency of grazing around a cattle dung pat suggested that cattle do not readily graze the area for a period of at least six months, and sheep for at least three months. The pattern of selection, however, changed as the dung pat ages (Figure 5.5). Patches containing fresh cattle dung were grazed the least, but as the dung pats age the areas surrounding the dung pats become more acceptable, and the frequency of grazing increased. For cattle this trend is very pronounced, where the preference rating of the frequency of grazing increased from -18.7 to -4.7 to -3.6 over the six month period. Sheep displayed a similar trend, but the preference rating did not change as much as that of cattle. A slight decrease in the preference rating from -3.2 to -3.9 between Time 1 to Time 2 and then an increase to 0.2 at Time 3 indicated that the effect of cattle dung on sheep grazing had almost disappeared after six months (Figure 5.5).

The trend in the intensity of grazing was almost identical to the frequency of grazing around a cattle dung pat (Figure 5.6). The preference rating of the intensity of cattle grazing increased from -5.0 to -0.9 to -0.6 over the six month period. Sheep grazing decreased from a preference rating of -0.30 to -0.56 between Time 1 and Time 2 and then increased to -0.03 at Time 3 (Figure 5.6).

5.3.3.2 Sheep dung

The frequency of grazing showed that, during the first period of grazing, sheep preferentially grazed around their own dung but cattle did not. As the age of the sheep dung increased, cattle increased their frequency of grazing around the dung from a preference rating of -6.0 to -1.4 between Time 1 and Time 2, and then the frequency decreased before Time 3 to -4.3. Sheep preferentially grazed around their own dung during Time 1 (3.3), but then the preference rating of the frequency of grazing decreased to -3.1 by Time 2 before increasing to -0.3 by Time 3 (Figure 5.5).

The intensity of grazing showed a very similar trend to that of the frequency of grazing, with cattle grazing more intensively during Time 2 (-0.3) than Time 1 (-1.8) and Time 3 (-0.6). The intensity of grazing also showed that sheep preferentially grazed the area surrounding their own dung at Time 1 (0.9), the preference rating then decreased to -0.4 by Time 2 before increasing again to -0.2 by Time 3 (Figure 5.6).

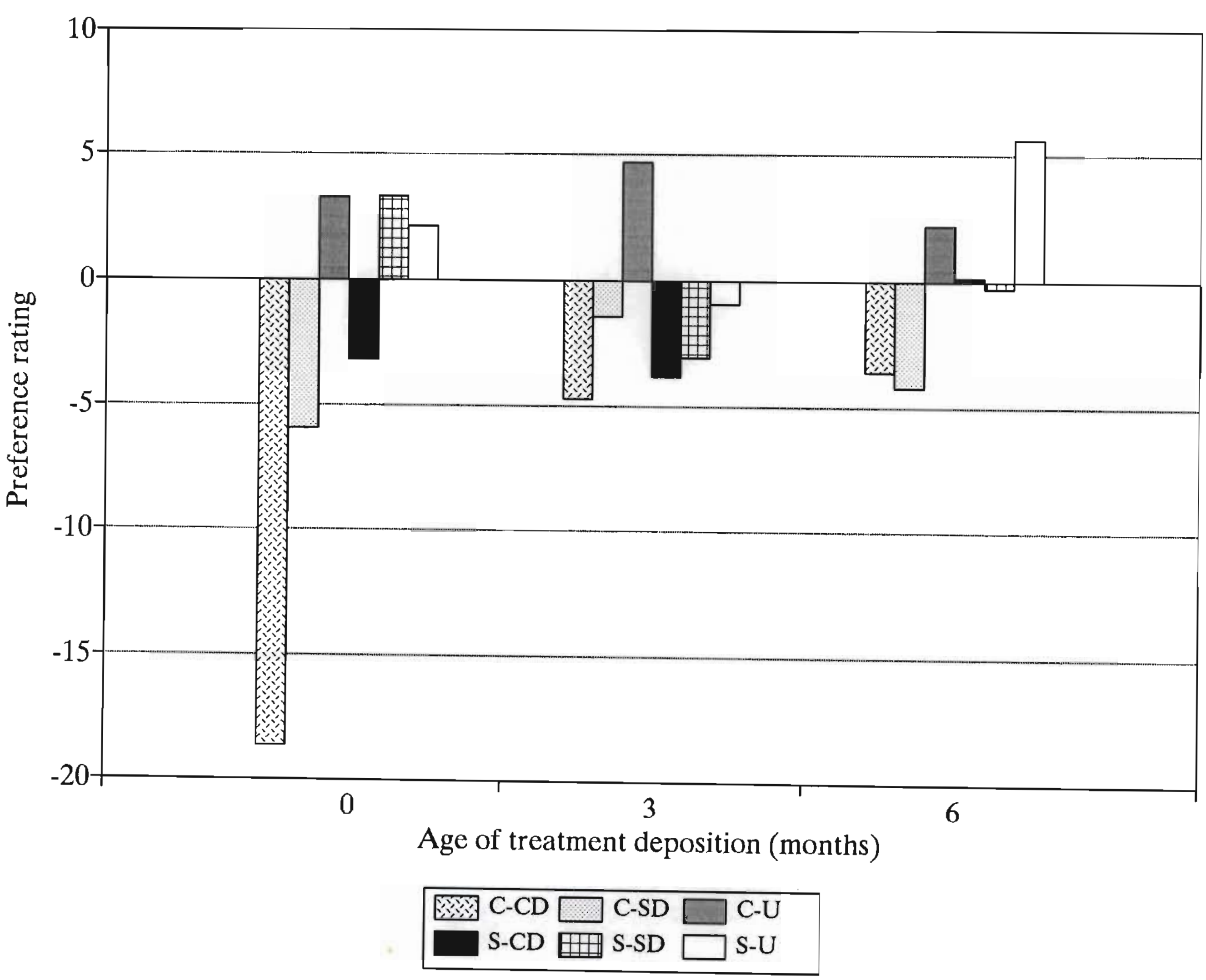

Figure 5.5 The differences in the frequency of grazing cattle (C) and sheep (S) in the vicinity (1 m²) of cattle dung (CD), sheep dung (SD) and urine (U), expressed as a preference rating.

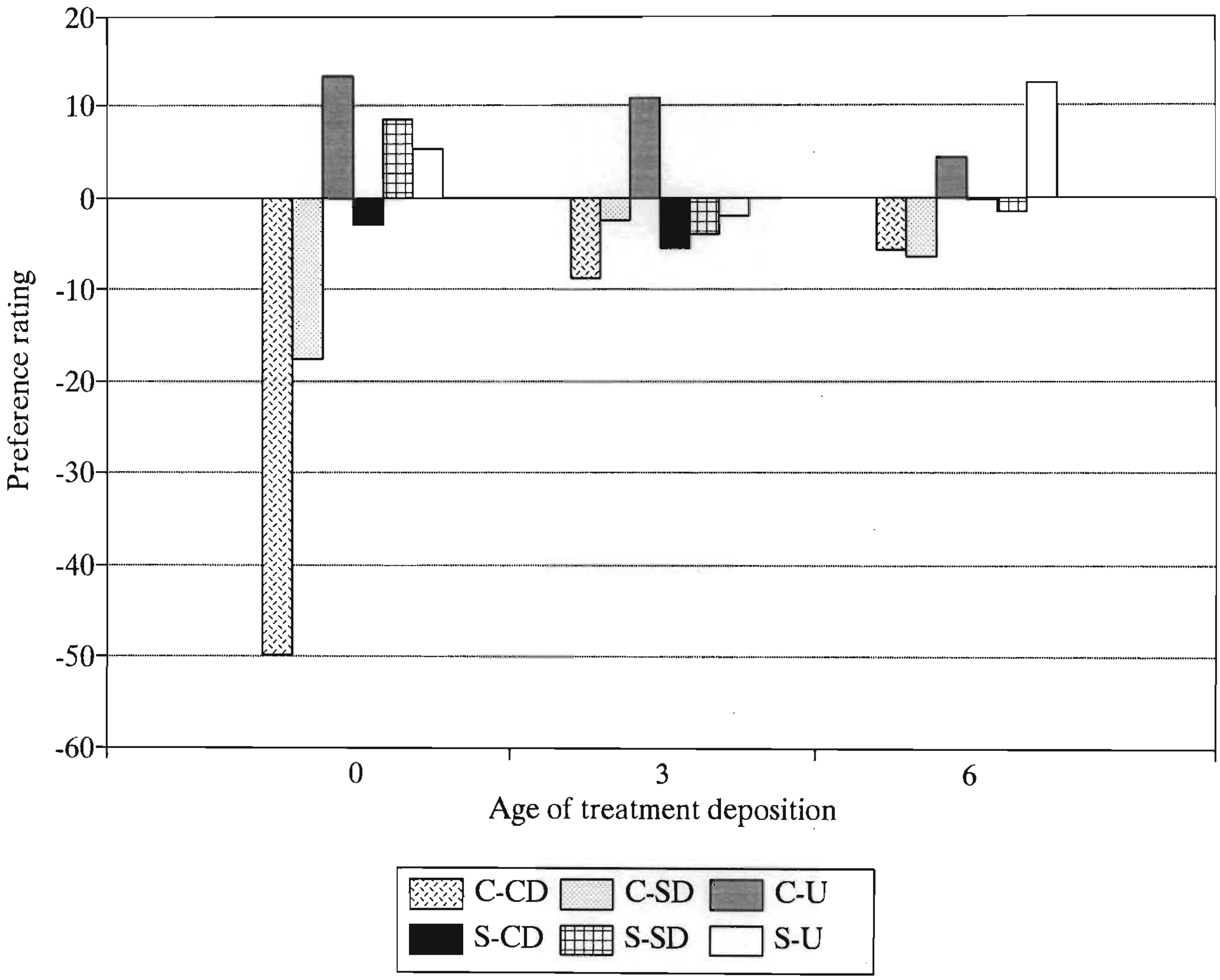

Figure 5.6 The differences in the intensity of grazing cattle (C) and sheep (S) in the vicinity (1 m^2) of cattle dung (CD), sheep dung (SD) and urine (U), expressed as a preference rating.

5.3.3.3 Urine

Cattle and sheep preferentially grazed areas surrounding the urine deposition. The preference rating of the frequency of grazing by cattle around a urine deposit increased from 3.3 at Time 1 to 4.7 by Time 2 and then decreased to 2.2 by Time 3. Sheep also preferentially grazed the urine patch at Time 1 (2.2) then preferred the control areas to the urine patch at Time 2 (-0.9) before preferentially grazing the urine patches again by Time 3 (5.7) (Figure 5.5).

The preference rating of intensity of grazing by cattle around a urine patch decreased slightly from 1.3 at Time 1 to 1.1 at Time 2 to 0.4 at Time 3. Similarly, to the frequency of grazing, sheep preferentially grazed the urine patches at Time 1 (0.5) then changed their preference to the control at Time 2 (-0.2) before preferentially grazing the urine patch again at Time 3 (1.2) (Figure 5.6).

5.3.4 The grazing pattern in the proximity of urine and dung

5.3.4.1 Frequency of grazing

The pattern of grazing around the treatment depositions was very distinct. Grazing was clearly focused around the centre of the 1 m^2 area where the urine was placed. As the distance from the centre increased, so grazing frequency decreased (Figure 5.7a). Cattle dung had the exact opposite effect. The little grazing that did take place, was concentrated on the perimeter of the quadrat, with very little grazing in the centre of the quadrat (Figure 5.7b). Sheep dung had a similar effect to the cattle dung except, that the difference in the grazing around the outside and the centre of the quadrat, was not as great. Only a slight depression could be observed towards the centre of the 1 m^2 area (Figure 5.7c). The control had virtually no effect on the grazing pattern and the frequency of grazing was fairly uniform across the whole quadrat (Figure 5.7d).

5.3.4.2 Intensity of grazing

The intensity of grazing was very similar to the frequency of grazing, except that the pattern of grazing was not as distinct as the frequency of grazing. The urine patches showed that most of the material was removed from the centre of the 1 m^2 area (Figure 5.8a). Animals tended not to graze the centre of a cattle dung patch. Most of the material was removed along the perimeter of the quadrat (Figure 5.8b). The area surrounding the sheep dung was more intensely grazed on one side of the quadrat than the other side. No distinct pattern around the centre of the quadrat can be observed (Figure 5.8c). The grazing within the control quadrat showed no distinct pattern in the intensity of grazing (Figure 5.8d).

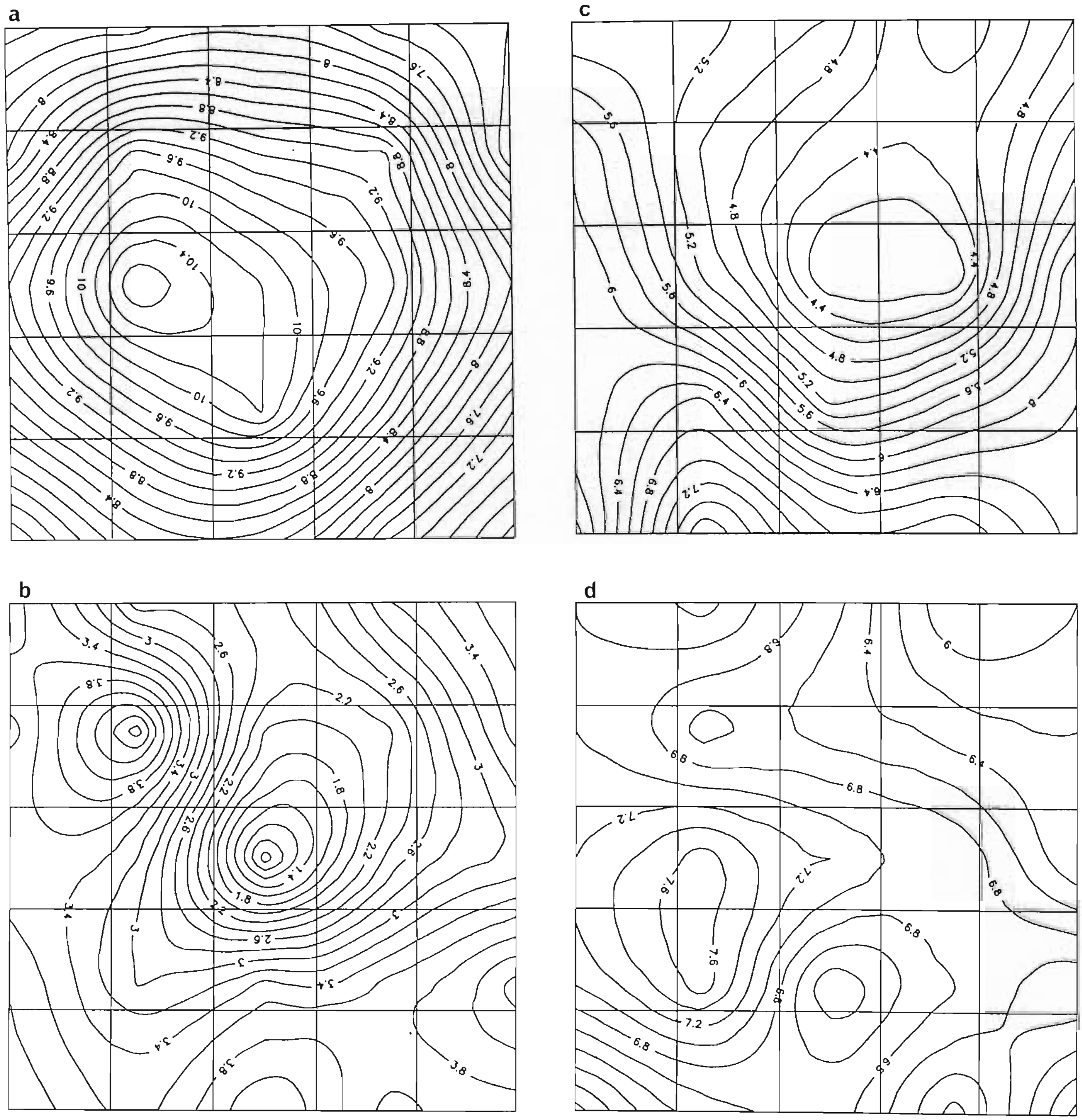

Figure 5.7 A topographical representation of the frequency of grazing within a 1 m² area around (a) urine, (b) cattle dung, (c) sheep dung and (d) the control patches. The treatment was placed into the centre sub-quadrat in each 1 m² area.

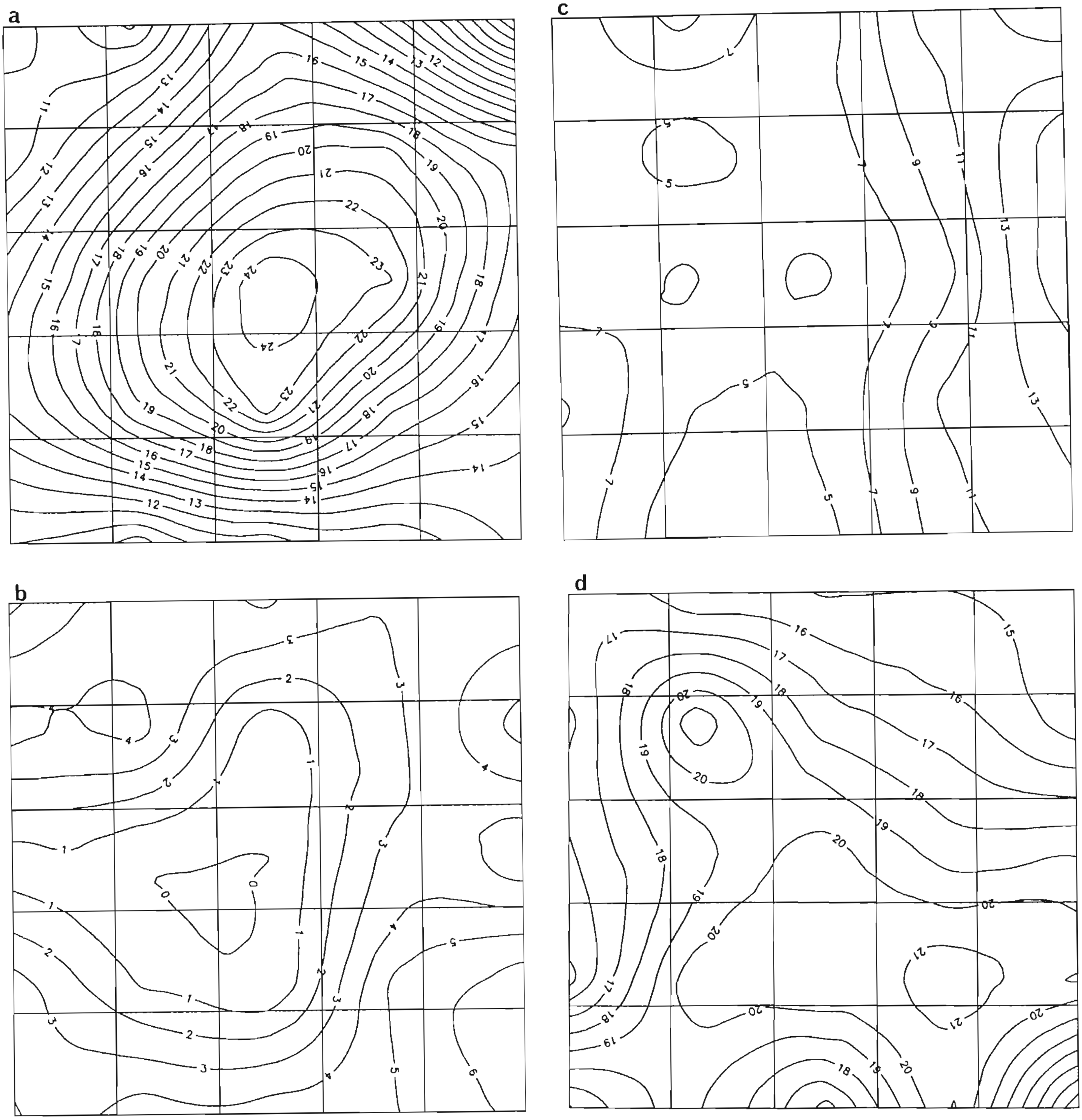

Figure 5.8 A topographical representation of the intensity of grazing within a 1 m^2 area around (a) urine, (b) cattle dung, (c) sheep dung and (d) the control patches. The treatment was placed into the centre sub-quadrat in each 1 m^2 area.

5.4 DISCUSSION

These results of this study concur with the results of Norman & Green (1958), Day & Detling (1990) and Jaramillo & Detling (1992b), who observed that urine patches were preferentially grazed to the surrounding sward. Norman & Green (1958) and Marten & Donker (1964) also found that dung patches were rejected. Few studies, however, have investigated both cattle and sheep grazing around urine, cattle and sheep dung deposition together in one trial.

It was evident that sheep were less affected by any of the treatments than were cattle. Forbes & Hodgson (1985) observed that cattle were more sensitive to their own dung than that of sheep, while sheep were not affected by dung type. This study, however, showed that both cattle and sheep were more sensitive to cattle dung than to sheep dung, but sheep seem unaffected by their own dung. This could be expected, simply because the cattle dung pat is much larger, and may therefore be more repulsive.

The investigation into the effect age of deposition had on the patch grazing patterns, indicated that both cattle and sheep dung were rejected from the outset, and that the rejection were strongest when the dung was fresh. This was especially true for cattle dung patches being grazed by cattle, which had a highly negative preference rating when the dung was fresh. Cattle dung which was three months old was grazed significantly more than when it was fresh. It was, however, still rejected after six months. Sheep grazing around cattle dung was less affected by the age of deposition. The preference rating was much higher than that for cattle even from an early stage and did not change much between Time 1 and Time 2. The frequency and intensity of grazing around cattle dung patches by sheep indicated that sheep seemed unaffected by cattle dung after six months. The results reported by Norman & Green (1958) and Marten & Donker (1964) indicated that cattle dung is rejected only for three to four months if the areas surrounding the dung patches did not become moribund and unacceptable. In this trial, the areas were not allowed to become moribund and the data suggest that cattle dung patches were rejected for longer than the three to four months suggested by Norman & Green (1958) and Marten & Donker (1964).

The grazing around the sheep dung was slightly different. Cattle rejected sheep dung early on, but sheep preferentially grazed around their own dung. Sheep then preferentially grazed the sward surrounding the sheep dung patches after three months, and after six months, sheep dung seemed to have no effect on sheep grazing. This may possibly be attributed to the sheep dung not having much of an effect on sheep grazing and that the observed variations were due to random variations in the grazing pattern of sheep. During the second grazing period the grazing pattern may also have been distorted because of the taller sward. This was also evident in the grazing pattern of cattle in sheep dung patches. During the second grazing period, cattle grazed sheep dung patches more than during the third grazing period. The results do, however, indicate that cattle continued to reject sheep dung patches after six months, while sheep were no longer affected.

Another anomaly appeared in the grazing of sheep in urine patches, where urine was rejected during the second grazing period. Urine patches, however, appeared to be preferentially grazed by both cattle and sheep, throughout the six month period.

It is thus important to note that cattle appear to be more sensitive to both sheep and cattle dung than are sheep. It is also important to note that the rejection of dung by cattle lasts up to six months, even though the sward was not allowed to become moribund around the dung deposits. Sheep, on the other hand, appeared unaffected by either dung after six months. This may possibly be attributed to the fact that sheep are able to select more intensively due to their smaller mouths (Hanley & Hanley 1982). Sheep are able to select plants or plant parts closer to a dung pat, without coming into contact, or without being affected, by the dung. Cattle and sheep grazing together may consequently increase the proportion of the sward grazed as sheep are able to graze areas that cattle will not (Forbes & Hodgson 1985).

The grazing in the proximity of a urine deposit indicated that the area where the urine was placed is the focus of the grazing. This may therefore lead to the development of patches. The centre of a urine patch is likely to be grazed more frequently than the surrounding sward and when animals return to these urine patches they may increase the size of the patch, which may eventually lead to the patch being permanently grazed, even if the effect of the urine has disappeared.

Urine may thus be an important factor in patch initiation. The areas surrounding urine are preferentially grazed from an early stage, and with continuous regrazing of these areas, animals will return to these initially grazed areas in preference to the surrounding sward, due to the higher quality regrowth (Ring *et al.* 1985). Potassium in the urine may have an effect on the soil and therefore plant quality for a period of two years (Blagden 1969, cited by Wolton 1979). Animals may therefore continue to graze these urine patches, even after a burn and/or a season long rest, and lead to the development of permanent patches.

CHAPTER 6

CHARACTERISATION OF PATCHES AND NON-PATCHES IN TERMS OF SELECTED SOIL AND SWARD PROPERTIES

6.1 INTRODUCTION

Patch selection may be desirable in that it promotes sward (Arnold 1981; Kotliar & Wiens 1990) and soil (Williams *et al.* 1993) heterogeneity. Patch grazing also allows the animals to graze a higher quality herbage than the sward average (Ring *et al.* 1985; Mott 1985, 1987), which may increase animal performance. Although patch grazing may have its short-term advantages, the general view on patch grazing is that it is detrimental to both the sward (Tainton 1972; Mott 1985, 1987; Hatch & Tainton 1990; Fuls 1991, 1992a,b; Kellner & Bosch 1992) and the soil (MacDonald 1978; Mott *et al.* 1979; Bridge *et al.* 1983). This may detrimentally influence the long-term animal production potential of an area of veld.

Tainton (1972) argued that patch grazing may be the foci from which veld degradation occurs. He observed a change in species composition in the Southern Tall Grassveld (Acocks 1988) from a *Themeda triandra* - dominated to a *Sporobolus africanus* and *Aristida junciformis* dominated state. In the same veld type, Hatch and Tainton (1990) observed that patches become increasingly dominated by *A. congesta* subsp. *barbicollis, Eragrostis racemosa* and *Microchloa caffra*. Research in the semi-arid grasslands of South Africa showed that patch grazing leads to a decrease of high ecological status species and an increase of low ecological status species in the patches (Fuls & Bosch 1991; Fuls 1992a,b; Kellner & Bosch 1992). Eventually xeric karroid shrub invasion occurred in the severely overgrazed patches (Fuls 1992a). These authors also observed a significant decrease in basal cover within patches. Similar, veld degradation processes were observed in the *Heteropogon* grasslands of central Queensland where *Aristida* and *Chrysopogon* patches developed within the *Heteropogon contortus* dominated areas (Wandera 1993). In the Rough Fescue Grasslands of Canada, Willms *et al.* (1988) found that patches contained grazing resistant cereal grasses, while the non-patches were dominated by climax grasses.

Soil degradation has also been correlated with patch grazing. MacDonald (1978) observed that soil compaction increased and soil moisture and infiltration tended to decrease in patches of the Redsoil veld in Zimbabwe. Hatch & Tainton (1990) observed similar results in the Southern Tall Grassveld. Mott *et al.* (1979) and Bridge *et al.* (1983), in the Northern Territory of Australia, concluded that patches contained significantly smaller macropores than the non-patches, resulting in decreased infiltration and soil moisture, and increased run-off, in the patches. Patch grazing therefore seems to be a major factor in the process of veld degradation, in various veld types and countries.

The objective of this study was to characterise patches and non-patches which had developed due to grazing by cattle and sheep in Highland Sourveld (Acocks 1988), in terms of selected soil and sward properties.

6.2 PROCEDURE

The study was conducted at the Kokstad Research Station. A detailed review of the study area is given in Chapter 3. This study was separated into two main sections. The first examined selected soil, and the second examined selected sward, properties in patches and non-patches. During June 1993, 30 paired 1 m^2 areas were randomly selected and marked to serve as the sampling areas of patches and non-patches for all the soil property measurements. Because the soil measurements required removing some of the plants, an additional 40 1 m^2 paired patches and non-patches were randomly selected and permanently marked for the sward measurements. The soil measurements were collected during October 1993 and the sward measurements during December 1993.

Soil moisture was determined in all 30 patch and non-patch sample areas. Soil moisture content was determined by oven drying soil samples at 60°C for 48 hours and calculating the moisture percentage by mass difference (Hatch & Tainton 1990). An auger was used to measure soil depth in all 60 soil sampling areas. Soil depth was measured as the depth augered until solid material was struck, up to a depth of 0.6 m. From the 30 patch and 30 non-patch sampling areas, 20 samples (at a depth of 0 to 10 cm) from both areas were randomly selected for the soil nutrient analyses, which were conducted by the Soil Science

Section at Cedara. The nutrients examined were phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg). Organic matter (% organic carbon) and pH (KCl) were also analysed. The *in situ* soil hydraulic conductivity was measured using a disc permeameter (Perroux & White 1988). The disc permeameter was used to distinguish hydraulic conductivity due to pore diameters of <1.15 mm and <0.8 mm by using supply potentials (ψ_0) of -25 and -35 mm respectively, calculated using the equation given by Marshall & Holmes (1988) (Appendix 6.1). A preliminary study determined that a -25 mm supply potential was the minimum tension from which reliable measurements could be taken. Of the 30 patch and 30 non-patch sampling areas, fifteen were used for the measurements of hydraulic conductivity at the -25 mm supply potential and 15 at -35 mm supply potential.

Paired t-tests (Steel & Torrie 1980) were used to analyse the differences between patches and non-patches in all the above measurements.

Species presence/absence was used to determine absolute species frequency using a 1 m x 1 m quadrat divided into 25 equal sub-quadrats in each of the 40 paired 1 m^2 areas. Basal cover was measured in all 40 patch and 40 non-patch sampling areas using three equally spaced line transects, and was calculated as the length (cm) of rooted material intercepted per 1 m length measured. Rooted live and rooted dead material was measured.

The species composition data were then ordinated using Detrended Correspondence Analysis (DCA) (Hill 1979) to assist in the interpretation of the differences in species composition between patches and non-patches. Paired t-tests (Steel & Torrie 1980) were used to examine differences in the absolute frequency of individual species and differences in basal cover between patches and non-patches.

6.3 RESULTS

6.3.1 Soil properties

Soil moisture percentage was significantly lower ($P \leq 0.01$) in patches than in non-patches (Table 6.1). Patches were also characterized by shallower soils than the non-patches ($P \leq 0.05$) (Table 6.1). Soil nutrients (P, K, Ca and Mg) were lower in non-patches than in patches, however, only P and K were significantly lower ($P \leq 0.05$) (Table 6.3). Organic matter and soil pH were not significantly different between patches and non-patches ($P > 0.05$) (Table 6.1).

Table 6.1 Comparison between patches and non-patches in terms of soil moisture percentage, soil depth (mm), selected soil nutrients (parts per million), % organic carbon and pH (KCl)

	Patch (mean)	Non-patch (mean)	Difference (mean)	SED	t-value
% soil moisture	15.2	16.6	1.4	0.004	3.697 **
Soil depth (mm)	277.0	362.0	85.0	31.50	2.702 *
Phosphorus P (ppm)	1.7	0.5	1.2	0.50	2.397 *
Potassium K (ppm)	345.9	302.0	43.9	17.67	2.482 *
Calcium Ca (ppm)	731.9	686.8	45.1	43.45	1.038 ns
Magnesium Mg (ppm)	317.3	278.1	39.2	19.51	2.009 ns
% Organic carbon	2.0	2.2	-0.2	0.10	-1.814 ns
pH (KCl)	4.8	4.8	-0.0	0.04	-0.700 ns

ns = $P > 0.05$ * = $P \leq 0.05$ ** = $P \leq 0.01$ SED = Standard error of the difference

The hydraulic conductivity due to pores < 1.15 mm in diameter was significantly higher in non-patches than in patches ($P \leq 0.01$) (Table 6.2). The difference in hydraulic conductivity between patches and non-patches due to pores < 0.8 mm in diameter were also significantly different ($P \leq 0.05$), but the difference was much smaller than at the larger pore diameter. The overall hydraulic conductivity at the -35 mm tension was much lower than at the -25 mm tension (Table 6.2).

Table 6.2 Comparison of hydraulic conductivity between patches and non-patches at supply potentials (ψ_o) -25 and -35 mm

	Applied tension (ψ_o)	Pore diameter (mm)	Patch	Non-patch	Difference	SED	t-value
Hydraulic	-25 mm	<1.15	17.3	50.3	-33.0	6.37	-5.175 **
conductivity	-35 mm	<0.80	4.3	6.4	-2.1	0.83	-2.528 *

* = $P \leq 0.05$ ** = $P \leq 0.01$ SED = Standard error of the difference

6.3.2 Sward properties

The DCA axes 1 and 2 accounted for the majority of the variation in the data set (Table 6.3). The first axis was interpreted as representing a gradient of grazing pressure, i.e. a gradient of species from non-patches to patches, due to increased grazing pressure in the patches (Chapter 4).

Table 6.3 Eigenvalues, gradient lengths and the accumulated percentage variance for the different axes obtained from the DCA ordination

	Eigenvalues	Gradient length	Accumulated percentage variance
Axis 1	0.093	1.392	18.2
Axis 2	0.066	1.114	30.0
Axis 3	0.042	1.088	39.1
Axis 4	0.024	0.820	43.7

Figure 6.1 displays the sample sites (40 patches and 40 non-patches) on DCA axes 1 and 2, and indicates a clear division between patches (P) and non-patches (V).

The species ordination (Figure 6.2) suggests that species can be grouped according to their distribution within samples into three broad groupings, namely, Decreaser, Increaser I and Increaser II species after the notation of Tainton (1988a).

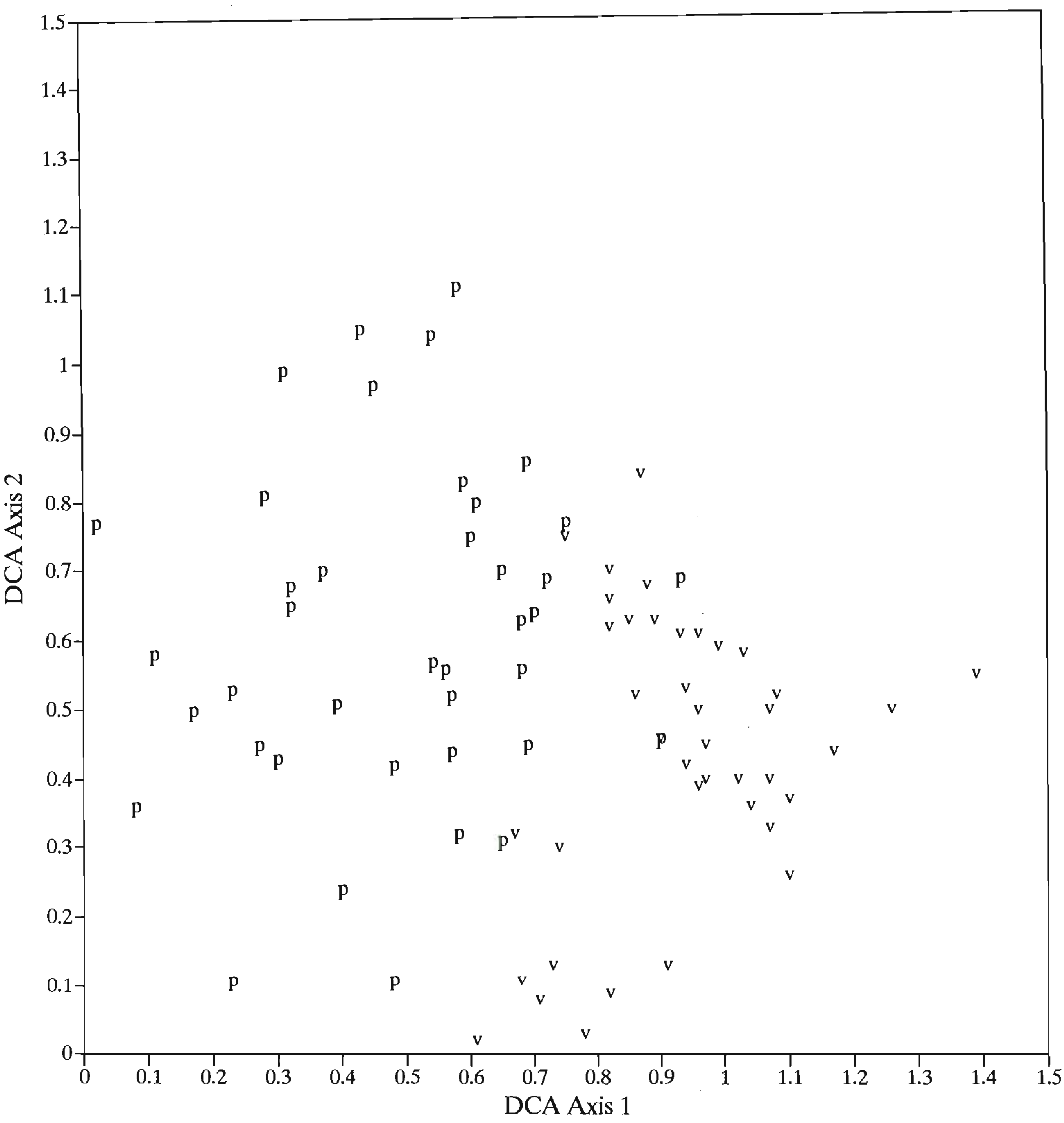

Figure 6.1 Ordination of sample sites along DCA axes 1 and 2 indicating samples located in patches (P) and non-patches (V).

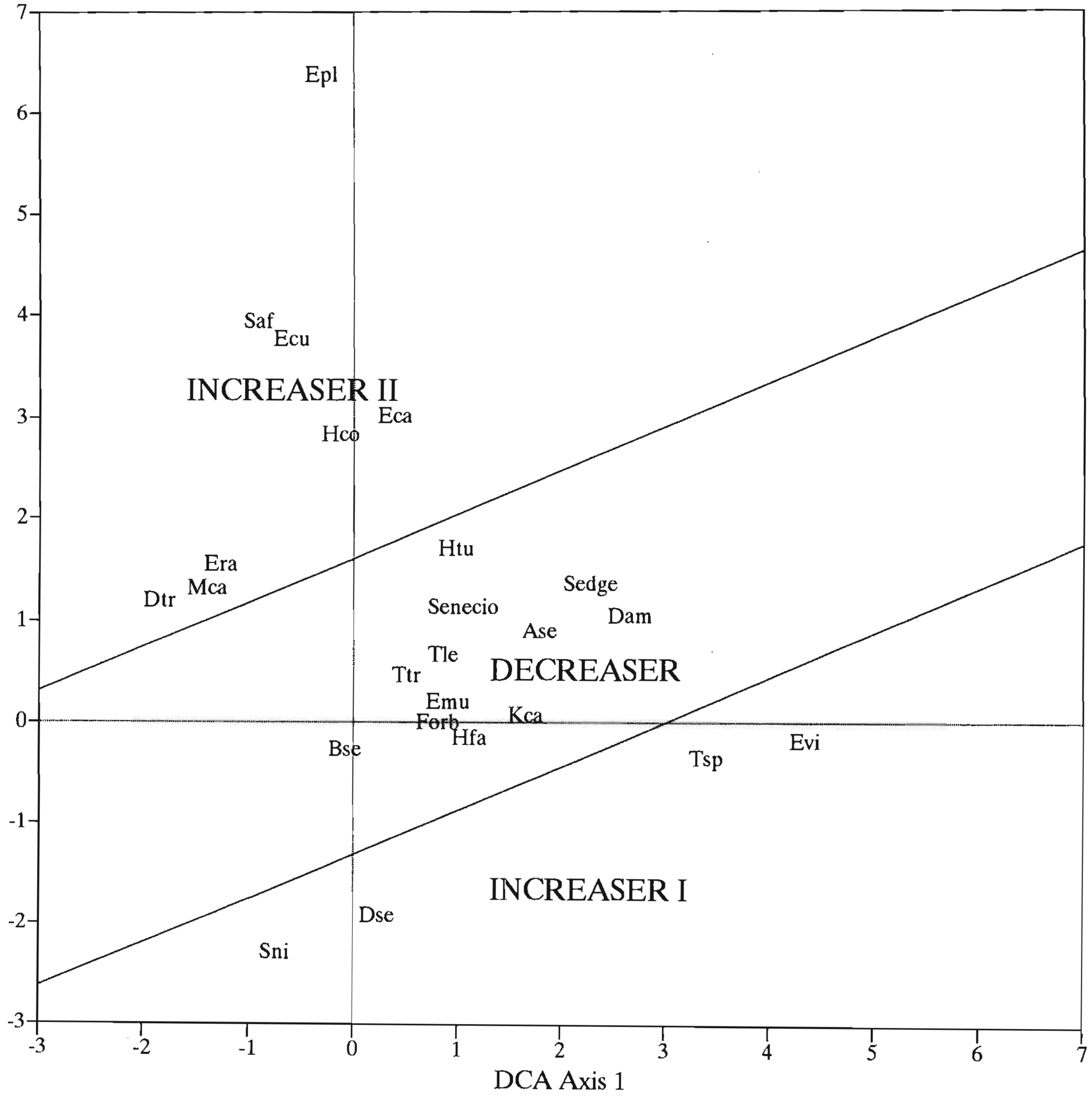

Figure 6.2 Ordination of species along DCA axes 1 and 2 indicating broad groupings of Decreaser, Increaser I and Increaser II species. Species acronyms are given in Appendix 6.2.

On the basis of significant differences in the percentage frequency of individual species between patches and non-patches (Figure 6.3), patches were characterized by *Microchloa caffra* (Increaser II), *Heteropogon contortus* (Decreaser) ($P \leq 0.01$) and to a lesser extent by a high percentage of *Eragrostis curvula, Sporobolus africanus* (Increaser II) and *Digiteria tricholaenoides* (Increaser I) ($P \leq 0.05$) (Figure 6.3). The non-patches were characterized by a high proportion of *Trachypogon spicatus, Alloteropsis semialata, Eulalia villosa* and sedge ($P \leq 0.01$) and forb species (all Increaser I species) and *Diheteropogon amplectens* (Decreaser) ($P \leq 0.05$) (Figure 6.3). Patches could therefore be characterized by Increaser II species and non-patches by Increaser I species (Figure 6.3).

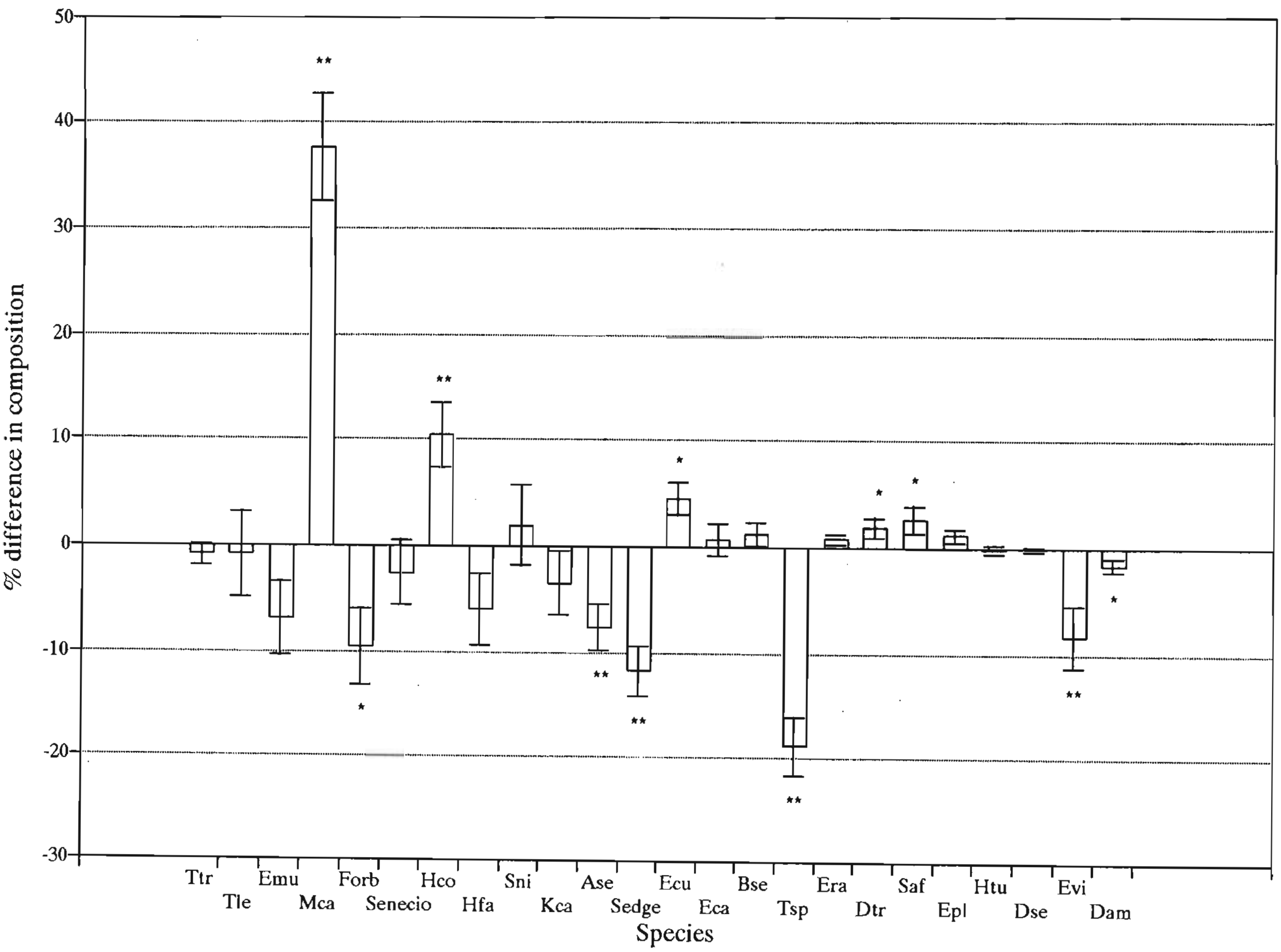

Figure 6.3 Difference in the percentage frequency of species, with SE, indicating species prominent in patches (% > 0) and those prominent in non-patches (% < 0). Species are arranged in decreasing order of abundance. Species acronyms are given in Appendix 6.2. * = $P \leq 0.05$ ** = $P \leq 0.01$ all others not significantly different $P > 0.05$.

Total basal cover (dead and live) was significantly higher in patches than in the non-patches ($P \leq 0.01$) (Table 6.4). Rooted dead material was also significantly higher in patches than non-patches ($P \leq 0.01$) (Table 6.4). Rooted live material was, however, not significantly different between the two areas ($P > 0.05$) (Table 6.4).

Table 6.4 Comparison of total basal cover, live basal cover and dead basal cover of patches and non-patches

Basal cover	Patch	Non-patch	Difference	SED	t-value
Live	20.05	18.52	1.53	1.25	1.228 ns
Dead	7.83	3.94	3.89	0.91	4.290 **
Total	27.88	22.46	5.42	1.31	4.127 **

ns = $P > 0.05$ ** = $P \leq 0.01$ SED = Standard error of the difference

6.4 DISCUSSION

Patches and non-patches could be distinguished in terms of soil moisture, soil depth, certain soil nutrients, hydraulic conductivity, species composition and basal cover. It is, however, not possible to establish if these difference were a cause or effect of patch grazing. Patches had significantly shallower soil, lower hydraulic conductivity and lower soil moisture than non-patches and could, at least in part, explain the higher proportion of *Microchloa caffra* in the patches. *Microchloa caffra* is adapted to shallow soils and extreme water shortages (Tainton *et al.* 1985). The lower hydraulic conductivity in patches may also indicate differences in the proportion of large pores (macropores), which in turn may negatively affect water uptake, run-off rates and subsequent soil water potential (Wandera 1993). This may further increase the potential colonization of patches by *M. caffra*. This does, however, not exclude the possibility that the generally poorer soil conditions, except for soil depth, are the result of patch grazing.

The higher soil nutrient status of the soil observed in patches contrasts with the findings of Hatch & Tainton (1990). They observed a higher, but not significant, nutrient content in the non-patches in the Southern Tall Grassveld of Natal (Acocks 1988). Wandera (1993) recorded similar results to those of Hatch & Tainton (1990), in the *Heteropogon* grasslands of central Queensland. These initial differences may have come about due to the treatments applied prior the start of this trial. Prior to the start of the trial in 1989/90, the camps were rested and burnt occasionally for a period of three years, but grazing did take place prior to that (Hardy 1994). The higher nutrient status of the soils in patches may indicate remnants of urine and dung deposits (Chapter 5) prior to the start of the trial, and these previously fouled areas may now be the focus of the animals' grazing. If these patches are grazed for an even longer period of time it may be expected that these differences in soil nutrient status may decline, as less nutrient cycling will take place, due to less plant material in the patches than in the non-patches. Continued grazing may even lead to patches with a lower soil nutrient status than non-patches, as Hatch & Tainton (1990) observed.

It would therefore seem that differing areas may have been present prior to the start of the trial, and that patch grazing is a consequence of at least some of the above differences between patches and non-patches.

The species composition data indicates that non-patches were characterized by Increaser I species, which increase with lenient or no grazing (Tainton 1988a). Patches on the other hand were characterized by species in the Increaser II category, which tend to increase under heavy or over grazed conditions (Tainton 1988a). Similar results were reported by Hatch & Tainton (1990). This categorization of patches and non-patches, and the fact that patches are grazed more frequently and intensively than non-patches (Chapter 4) indicates that grazing pressure may have played a direct role in the differences in species composition. The fact that *M. caffra* is prominent in the patches may be a consequence of the heavier grazing pressure (Chapter 4), and the shallow and moisture stressed soils in the patches. On the other hand, because the non-patches are grazed infrequently and at lower intensities (Chapter 4), Increaser I species were able to increase in these areas. Hatch & Tainton (1990) observed a gradient of patches from newly initiated to permanent patches. Even if patches existed before the start of trial (4 years), it is likely that the species composition in patches, may have changed, due to the continued heavy grazing in these areas (Chapter 4).

The basal cover results also indicate a certain degree of degradation. Total basal cover was significantly higher in the patches than the non-patches, and may be attributed to the patches containing more smaller species, while the non-patches contained fewer larger species. It was evident that *Heteropogon contortus* was very much larger in the patches than the non-patches, and being more abundant in patches, could therefore also contribute to the higher basal cover in the patches. Patches had significantly higher dead basal cover, indicating a higher tuft mortality. Peddie (1994) found a higher tuft mortality in intensively grazed plants. The higher tuft mortality may lead to veld degradation, as it allows other species, especially Increaser II species (Figure 6.3) to invade into these areas.

While differences between patches and non-patches could not explain the cause or effect relationship of patch grazing, the results indicate that patches in the Highland Sourveld (Acocks 1988) show similar degraded characteristics, as other studies in other vegetation types have shown (McDonald 1978; Bakker *et al.* 1983; Bridge *et al.* 1983; Mott *et al.* 1979; Mott 1985, 1987; Hatch & Tainton 1990; Fuls 1991; Fuls & Bosch 1991; Fuls 1992a,b; Kellner & Bosch 1992; Wandera 1993).

CHAPTER 7

THE INFLUENCE OF PATCH GRAZING ON TUFT VIGOUR AND SWARD GROWTH

7.1 INTRODUCTION

Patch grazing is the frequent and intense grazing of localised patches within the sward (Spedding 1971; Stobbs 1973; Bakker *et al.* 1983; Mott 1985, 1987). The frequent and severe defoliation of plants within patches during the growing season results in a decline in vigour relative to plants that are leniently defoliated or left ungrazed (Crider 1955 cited by Tainton 1988b; Tainton 1958). This may therefore lead to the reduction in vigour of plants located in patches (Tainton 1971). Regrazing of patches over a number of years (Chapters 4 and 8) may lead to the death of desirable grazing species which are then replaced by less desirable species (Tainton 1972).

Grazing management recommendations for sourveld have been designed to include periodic resting to maintain high plant vigour (Tainton 1971). Tainton (1971) recommends a long rest period to reduce the difference in vigour between selected plants (patches) and non-selected plants (non-patches). This is one of the reasons for implementing a season long rest in a rotational grazing system. Importantly, is the currently implemented system of one season's rest, every fourth year, sufficient to reduce the differences in vigour between patches and non-patches?

The objectives of this study were to determine: 1) the effect of three years of grazing on the vigour of *Themeda triandra*, 2) whether a full season's rest is sufficient to restore plant vigour (*T. triandra*) which may have declined due to patch grazing, and 3) the effect patch grazing may have had on above-ground herbage production.

7.2 PROCEDURE

The study was conducted during the 1993/94 season at Kokstad Research Station as outlined in Chapter 3, in a camp due for a full season's rest in the 1993/94 growing season.

During June 1993, following a full grazing cycle of three years, a single randomly selected *Themeda triandra* tuft was marked in each of 100 different randomly selected patches and adjacent non-patches to measure the differences in vigour of *T. triandra* in the two areas. *Themeda triandra* was used as it forms the major component of the sward and is a principal food source in the area. As patch grazing is an area-based selection process, an additional 40 patches and 40 non-patches were randomly selected and marked to measure the differences in above-ground herbage production (growth) of patches and non-patches.

The camp was burnt after the first spring rains (28 August 1993) to remove accumulated moribund material. The camp was then excluded from grazing for the entire 1993/94 season.

Tuft vigour was estimated by collecting etiolated growth immediately after the burn, and repeating the procedure at three-weekly intervals on a new set of tufts, throughout the 1993/94 season.

At each three weekly interval, six randomly selected tufts (Daphne 1992) from patches and adjacent non-patches were clipped to crown height (*c.* 2 cm). The basal area of each tuft was traced onto overhead transparencies. The tuft's basal area was then estimated using a digital planimeter (Peddie 1994). The equivalent of 10 mm of water was applied to each tuft (Peddie 1994). This was to ensure that the plants were not limited in their growth by moisture. Light proof boxes (Edwards 1965) were then placed over the tufts and left for three weeks, after which etiolated growth was harvested. Etiolated growth was calculated as dry matter (DM) per unit basal cover (mg DM cm^{-2}) (Muzzel & Booysen 1967). Each tuft was sampled only once during the season. An additional set of etiolated growth measurements was taken at the start of the 1994/95 season (1 September 1994), following the full season's rest.

Etiolated growth is not a measure of any stored reserves *per se*, but the ability of a tuft to grow (Peddie 1994). The initial measures of etiolated growth are an index of growth potential at the start of the season, with subsequent measures being a combination of residual energy stored over previous seasons and the energy stored from current photosynthesis up to the date of sampling (Richards & Caldwall 1985; Danckwerts & Gordon 1987).

Sward growth was sampled in patches and non-patches every three weeks throughout the season, starting nine weeks after the burn. Growth measurements commenced nine weeks after the burn because the patches contained virtually no above-ground herbage during the first six to eight weeks after the burn.

A 1 m^2 quadrat was located on each of the 40 patches and adjacent non-patches. Each 1 m^2 quadrat was divided into four 0.5 m x 0.5 m sub-quadrats, leaving a total of 160 areas in patches and 160 in non-patches to be sampled throughout the season. At each sampling date, the herbage in 10 randomly selected 0.25 m^2 sub-quadrats in patches and paired non-patches was clipped to crown level (*c.* 2 cm) and the growth collected for drying. Growth was calculated as above-ground dry matter (DM) per unit area (g DM m^2). Each sub-quadrat was sampled only once during the 1993/94 season.

Frequent intervals of data collection allow for curve fitting methods to be used to describe results (Hunt 1978). This functional approach lends itself to the easy interpretation of lengthy series of plant growth data (Parson & Hunt 1981). Using HPcurves (Hunt & Parsons 1994), a best-fit splined function was fitted to the natural logarithm (ln) of the data with 95% confidence intervals. The methodology and reasoning behind the approach are described by Hunt (1979).

7.3 RESULTS

The best-fit function for etiolated growth was linear (Figure 7.1). Etiolated growth measurements indicated that three years of grazing negatively influenced the vigour of *T. triandra* in patches. Etiolated growth of *T. triandra* in patches was much lower than *T. triandra* in non-patches at the start of the season (Figure 7.1). The vigour of *T. triandra* in non-patches decreased rapidly through the season, while the vigour of *T. triandra* in patches remained consistently low throughout the season (Figure 7.1). The trend in vigour of *T. triandra* in patches remained higher than the trend in vigour in the non-patches for a period of *c.* 24 weeks after the burn. From then, through to the end of the season (June 1994), no discernable differences in the trends in vigour of *T. triandra* in patches and non-patches were observed.

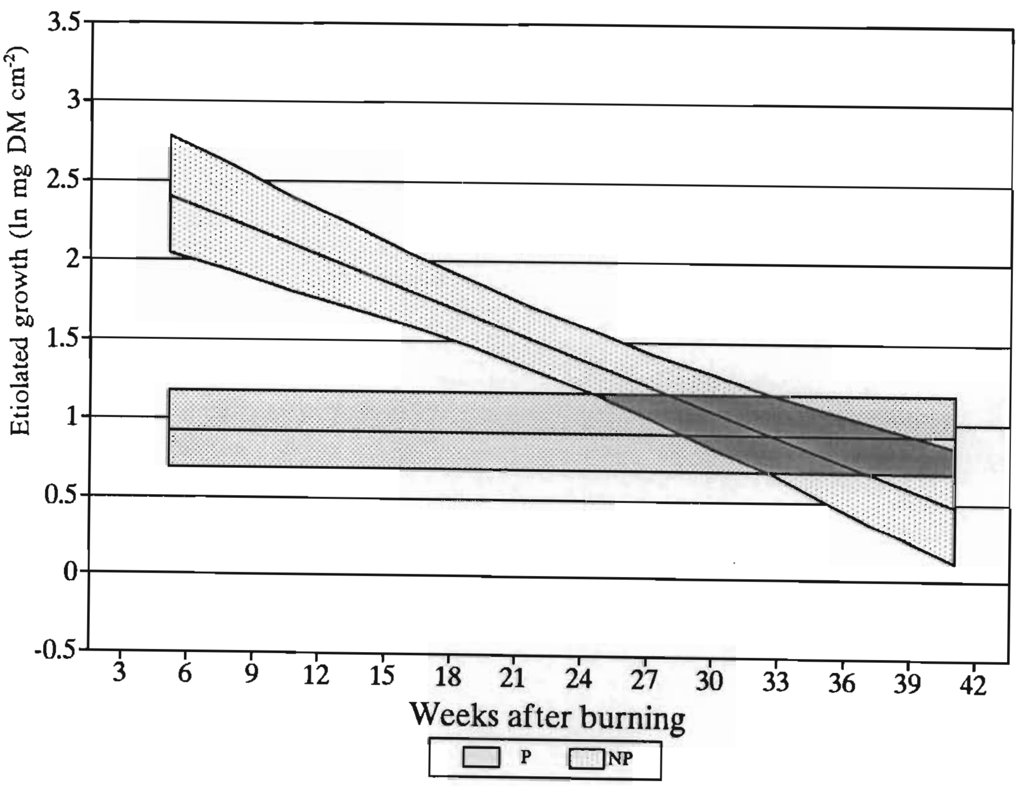

Figure 7.1 A linear function describing the trend in the vigour (natural log of etiolated growth), with 95% confidence limits (shaded areas), of *Themeda triandra* in patches (P) and non-patches (NP) through the season. The darkly shaded area indicates overlapping of confidence limits.

The one set of etiolated growth measurements taken at the start of the 1994/95 season showed no significant differences ($P>0.05$) in etiolated growth between patches and non-patches (Table 7.1). Patches, however, had slightly more etiolated growth than the non-patches.

Table 7.1 Etiolated growth means (mg cm^{-2}) of *Themeda triandra* in patches and non-patches, with significance level, measured at the start of the 1994/95 growing season (01/09/94)

	Etiolated growth (mg cm^{-2})
Patch	10.44
Non-patch	7.95
Difference	2.49
SED	2.40
t-value	1.04 ns

ns = non significant ($P>0.05$) SED = Standard error of the difference

The best-fit growth function was a second order polynomial. Growth of patches and non-patches increased through the season up to *c.* 27 to 30 weeks after the burn, after which plant growth reached a plateau (Figure 7.2). The trend in growth in patches was lower than the trend in the non-patches up to *c.* 21 weeks after the burn after which no discernable differences in the trends between patches and non-patches could be observed (Figure 7.2). The growth of patches was, however, always lower than that of the non-patches (Figure 7.2).

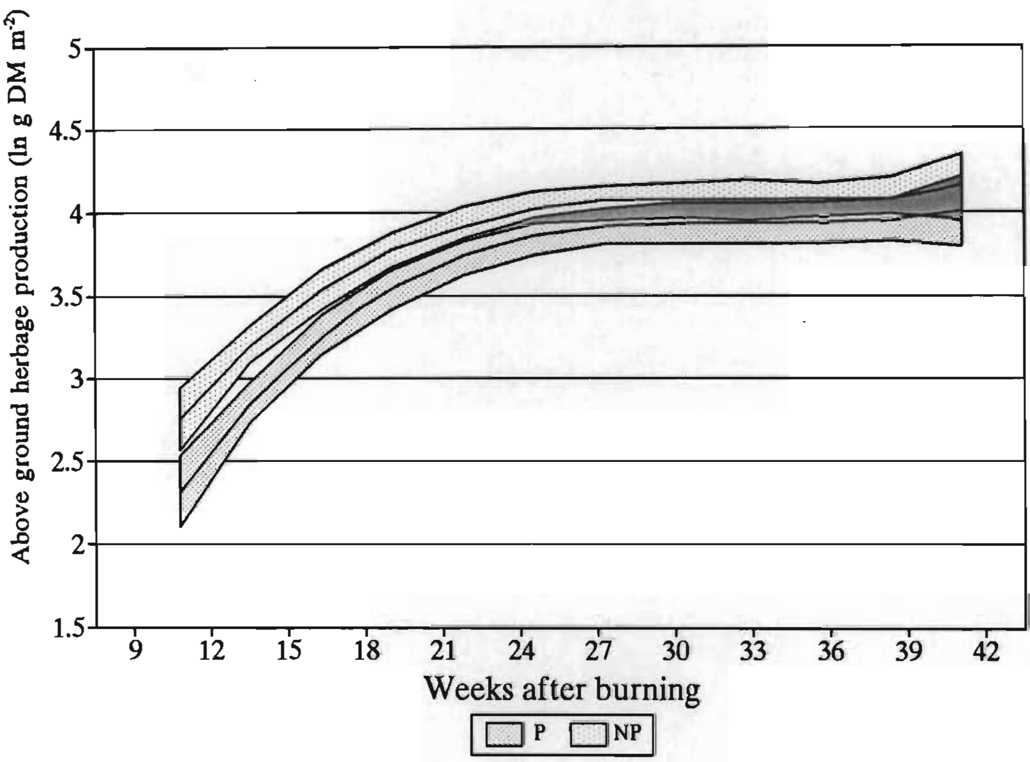

Figure 7.2 A polynomial function describing the trend in growth (natural log of above-ground dry matter herbage production), with 95% confidence limits (shaded areas), of patches (P) and non-patches (NP) through the season. The darkly shaded area indicates overlapping of confidence limits.

7.4 DISCUSSION

It should be noted that between weeks 12 and 15, and 30 and 36 after the burn, a fungus affected etiolated growth in some of the sampling areas. In addition, etiolated growth had died under some of the light-proof boxes. A possible reason for this is that the three week period under the light-proof box was too long during mid-summer, and high temperatures may have reduced etiolated growth. In areas with high summer temperatures, etiolated growth should therefore possibly be harvested at two-weekly intervals.

At the start of the grazing season, especially after a burn, plants draw on stored reserves to start the new seasons growth (Tainton 1971, 1988b). A rapid decline in the vigour of *T. triandra* was observed in the non-patches, indicating that the plants drew heavily on their stored reserves. Etiolated growth in the patches was very low at the start of the season, and a further decline could have led to the death of many tufts. The lower etiolated growth in patches at the start of the season indicates that patch grazing significantly affects regrowth potential, by decreasing the amount of stored reserves and/or reducing the number of growing points of plants in patches.

Peddie (1994) found that during autumn etiolated growth increased before decreasing again towards winter, with almost no etiolated growth at the end of the season when plant growth has ceased. This apparent photosynthate accumulation during autumn (Peddie 1994) was not observed in this study which is very surprising. Plants use most of the photosynthates produced at the start of the season to grow, but as the plants mature some of the photosynthates would be expected to be stored, especially as the whole area had remained ungrazed for a entire season. A possible reason for the apparent lack of photosynthate storage during autumn, may be due to the fact that etiolated growth had died before harvesting under some light-proof boxes during the autumn period (weeks 30 to 36) as a result of a fungal attack and high temperatures.

Importantly, at the start of the season *T. triandra* tufts within patches had significantly lower regrowth potential than in the non-patches, while at the end of the season no significant differences in etiolated growth of *T. triandra* between the two areas were observed. As the plants become dormant towards winter it is expected that the etiolated growth would decline to almost zero (Peddie 1994). With no apparent autumn photosynthate storage it cannot be inferred that a full seasons rest is sufficient in restoring the vigour of *T. triandra* in patches. However, the extra set of etiolated growth taken at the start of the 1994/95 season showed that photosynthate accumulation had occurred, as no significant differences in the vigour of *T. triandra* between patches and non-patches were observed. This confirms that a full seasons rest is sufficient in restoring the vigour of *T. triandra* in patches and corroborates the findings of Peddie (1994).

Growth measurements were started nine weeks after the burn as there was very little growth in patches at the start of the season. Growth in patches started approximately six weeks later than in the non-patches. Similar results were reported by Tainton (1988d) and Peddie

(1994). As the season progressed, however, growth in patches approached that of non-patches. However, growth in patches never reached the level of that in non-patches, possibly due to the differences in species composition between the two areas (Chapter 6). Patches were characterized by *Microchloa caffra,* which is a species of low forage production potential (Tainton *et al* 1985), whereas the non-patches were characterised by higher forage producing species such and *Trachypogon spicatus* and *Alloteropsis semialata.*

The differences in growth between patches and non-patches were relatively small compared to the differences in the vigour of *T. triandra* between patches and non-patches. Peddie (1994) also found that the vigour of two principle forage species, *T. triandra* and *Tristachya leucothrix* was greatly influenced by severe defoliation. The relatively small effect patch grazing had on the growth of an area and the relatively large effect patch grazing had on the vigour of some preferred species suggests that the vigour of species, not readily grazed by animals e.g. *Sporobolus* spp. or *Eragrostis* spp., is possibly not affected or may possibly be higher in patches than in non-patches, i.e. these species are adapted to severe and frequent defoliation. As the principle forage species (e.g. *T. triandra* and *T. leucothrix*) may have lower vigour than the less preferred species, it may have severe implications on the development of patches. This situation may lead to a shift in the competitive balance and the less preferred species are able to replace the more preferred species, leading to patch and eventually sward degradation. It is thus important for future research to measure the vigour of a variety of species, to establish if the vigour of different species is affected differently under heavily grazed, i.e. patch grazed, conditions.

CHAPTER 8

THE INFLUENCE OF A FULL SEASON'S REST ON THE REGRAZING OF PREVIOUSLY-GRAZED PATCHES BY CATTLE AND SHEEP

8.1 INTRODUCTION

Patch grazing has often been seen as the grazing of patches year in and year out, which may lead to patches becoming permanent (Hatch & Tainton 1990). If patches are not grazed during consecutive seasons, then patch grazing may not be as problematic as many authors contend (Tainton 1972; Mott 1985, 1987; Hatch & Tainton 1990; Fuls 1991; Fuls & Bosch 1991; Fuls 1992a,b; Kellner & Bosch 1992; Wandera 1993). There are suggestions that fire may be a controlling factor, in reducing the effect of this continuous patch grazing, by reducing any carry-over effects from year to year. Mott (1985) states that annual burning may not lead to the same degree of patch grazing as less frequent burning may. Annual burning is, however, not recommended in the humid grasslands of Natal (Tainton 1988d). In rotational grazing systems burning usually follows a season long rest, every forth year. The rest is an important part in this program as it allows plants a full season's undisturbed growth to accumulate reserves and set seed (Tainton 1971, 1988c). In designing management programmes for the humid grasslands, the potential for patch grazing will have to form part of that decision. The objective of this study was to investigate if animals continue to select previously grazed patches after a full seasons rest and burns prior to, and following, the season-long rest.

8.2 PROCEDURE

The study was conducted at the Kokstad Research Station as outlined in Chapter 3. During August 1992, 20 randomly selected 1 m^2 patches and 20 1 m^2 adjacent non-patches were permanently marked using steel pegs bent parallel to the ground. The camp then went into a full seasons rest and was burnt after the first spring rains in 1992 and 1993. During the 1993/94 grazing season all patches and non-patches were examined, at the end of each 14 day period of occupation (every six weeks). The 1 m^2 areas were divided into 25 equal sub-quadrats. The leaf table height of each of the 25 sub-quadrats in the 1m x 1m quadrat was measured to give an indication of sward height. Due to logistical reasons it was not feasible to conduct a detailed study of the frequency and intensity of grazing (Chapter 4). Therefore only a measure of sward height was used to examine if previously grazed patches are regrazed after a full seasons rest. As patches and non-patches were paired, paired t-tests (Steel & Torrie 1980) were used to examine differences in leaf table height.

8.3 RESULTS AND DISCUSSION

Sward heights in patches were significantly lower than in the non-patches during all grazing occupations ($P \leq 0.01$). The sward height of both patches and non-patches increased until February 1994, before starting to decline (Figure 8.1). The difference between the two areas increased steadily until the end of March 1994, before a slight decrease in the difference occurred (Figure 8.1).

It would thus seem to indicate that patches were still being grazed even after a full seasons rest and two burns. Patch grazing started immediately after stocking commenced, as the sward height of patches stayed fairly constant from the beginning of the season while the sward height in the non-patches increased immediately. A slight increase in sward height of patches, between the beginning of January and the middle of February, could be explained in that it was during this period that sward growth was at a maximum, and the animals could not maintain the patches as short as when sward growth is slower. From February onwards, sward height in both patches and non-patches declined. The differences in sward height, however, only started to decline from the middle of March. Cattle do not tend to graze plants (areas) less than 5 cm in height (Heinemann 1969, cited by Vallentine 1990), and the decrease in the differences in sward height between patches and non-patches could be an indication that forage in the patches became limiting during the late autumn period and animals, especially cattle, were forced to graze more in the non-patches.

Although one season's rest is sufficient in restoring plant vigour (Chapter 7), it does not prevent the same patches being grazed from one season to the next. This indicates that there is some inherent factor in the patches, e.g. higher plant quality, that results in animals grazing these areas repeatedly, even after two burns and after a full seasons rest. Urine and dung depositions prior to grazing may also have played a part. It may also possibly indicate that the current management recommendations do not allow for enough resting and burning, which may prevent continual patch grazing. We may therefore have to examine if sward retrogression due to patch grazing cannot be halted, or slowed down, by implementing different management systems to those recommended at present.

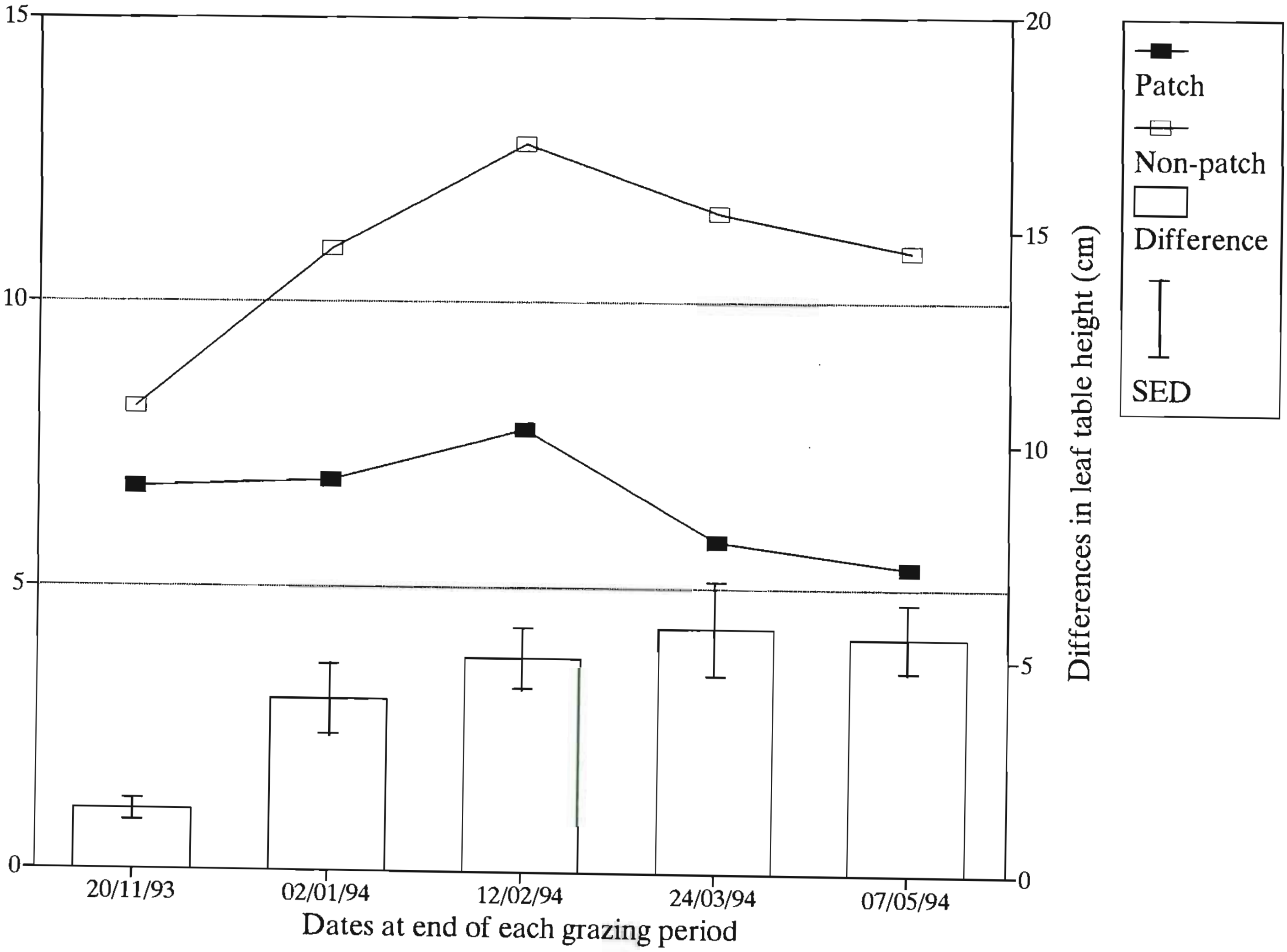

Figure 8.1 The leaf table height and the differences in leaf table height of patches and non-patches after each of five grazing periods, during the 1993/94 grazing season. SED = Standard error of the difference.

CHAPTER 9

GENERAL DISCUSSION AND CONCLUSION

Patch grazing has rarely been quantified even though it is a common occurrence (Barnes 1992) and has been linked to veld degradation (Tainton 1972). The objectives of this thesis were to examine patch grazing patterns and selected factors which may influence patch grazing in the humid grasslands of KwaZulu-Natal.

9.1 FACTORS INFLUENCING PATCH INITIATION AND DEVELOPMENT

A primary reason animals patch graze is in order to obtain forage that is physically (Arnold 1981) and nutritionally (Mott 1985, 1987) more attractive to the animal than the surrounding sward. Numerous reasons could be put forward as to why patches are more attractive to the animal. Soils are inherently variable in structure and nutrient content in an area and this variability may lead to variability in sward characteristics which may lead to patch grazing (Scholes 1990, 1993). Initial random grazing could also lead to patch grazing. Once an animal has grazed a patch, for what ever reason, the patch will continue to be regrazed because the patch should now contain regrowth which is higher in nutritional value than ungrazed areas (Ring *et al.* 1985). Andrew (1986a) also observed that animals will graze a previously grazed plant (patch) even if the plant (plants in patches) are not usually grazed by the animals. Patch grazing is therefore an interaction between the variability in sward characteristics (largely due to the variability in the micro-environment) and the grazing animal.

In the investigations conducted, two factors were observed that may cause plants in patches to be more attractive to the animal than the surrounding sward. Patches contained higher nutrient status soils than non-patches (Chapter 6). A higher soil nutrient status soil is likely to contain a higher quality sward than a soil of lower nutrient status (Scholes 1990, 1993). Patches may consequently develop in these areas. Urine and dung deposition was the other factor that may influence sward characteristics and thereby influence patch grazing.

Numerous authors have related urine and dung deposition to the incidence of patch grazing (Joblin & Keogh 1979; Jones & Ratcliff 1983; Day & Detling 1990; Jaramillo & Detling 1992b). Few studies have, however, investigated the reaction of cattle and sheep to the presence of dung from the same or other species (Forbes & Hodgson 1985). Animals preferentially grazed urine patches for a period of two to four months (Legard *et al.* 1982). However, the current study showed that the overall effect of urine on patch grazing lasts at least six months. The preferential grazing of urine patches was observed in a sward that had not been previously grazed and through mowing sward height would not have affected grazing pattern. This has important implications for future grazing. Once these urine patches are selected for, and knowing that animals continue to graze previously grazed areas (Ring *et al.* 1985), urine patches would be expected to continue to be grazed for much longer than six months because the urine patches, excluding the fact that the sward may still be affect by the urine, will now contain regrowth which will be repeatedly grazed (Ring *et al.* 1985). Adding the fact that the urine may still have an effect on the sward, the grazed urine patches will be even more attractive to the animal than a patch unaffected by urine. This will accentuate the grazing pressure in urine patches as opposed to patches unaffected by urine. Urine patches may therefore be the focus from which patches develop. Cattle reject cattle and sheep dung patches for a period of at least six months, while sheep seem unaffected by either dung after six months. This was again observed around dung patches unaffected by previous grazing and therefore regrowth. Because patches are rejected from the outset and other areas, e.g. urine patches, are grazed, the sward surrounding dung patches becomes moribund and may therefore be rejected for longer than six months. With dung patches being rejected, the animal's potential grazing area is reduced and the grazing pressure in the urine patches may be increased even further. Urine and dung deposition may therefore be one of the most important factors in patch initiation and consequent patch development.

9.2 CONSEQUENCES OF PATCH GRAZING

The short-term effect of patch grazing is that it creates a mosaic of heavily grazed patches and the leniently/ungrazed remainder of the sward. This mosaic is most evident toward the end of the growing season and may carry over into the next grazing season if burning is not applied. This carry-over effect of patch grazing was observed by Mott (1985). Heavily grazed patches from the previous grazing season contained shorter swards than ungrazed areas even after a burn, and the plants came away at a slower rate in the patches than the non-patches due to a decrease in vigour of some of the abundant species (Chapter 7). As patches contain less herbage at the end of the grazing season than non-patches, the difference in sward height from one season to the next is likely to be accentuated if burning is not applied and animals may continue to graze the previously grazed patches (Mott 1985). Regrazing of previously grazed patches would accentuate if patches and non-patches were created as a result of urine and dung deposition respectively. The urine patches, apart from being shorter, may still be higher in nutrient content and therefore be regrazed, while the dung patches may still be moribund and therefore continue to be rejected. Urine and dung could possibly then also explain the regrazing of previously grazed patches even after a full seasons rest and/or a burn because potassium from urine may have an effect on the sward for up to two years (Blagden 1969, cited by Wolton 1979). One season is unlikely to be long enough for the complete decay of all dung pats and animals may continue to reject dung patches even after a burn, i.e. learned aversion. Continuous regrazing of patches, especially if a season's rest does not prevent the same patches from being regrazed, will place great pressure on patches and may have long-term negative consequences.

Numerous authors have related patch grazing to veld degradation in various different veld types (Mott 1985, 1987; Hatch & Tainton 1990; Fuls 1991; Fuls & Bosch 1991; Fuls 1992a,b; Kellner & Bosch 1992; Wandera 1993). In Southern Tall Grassveld (Acocks 1988), Hatch & Tainton (1990) observed that patches were characterized by Increaser II species. In this study, similar results were observed in the Highland Sourveld (Acocks 1988). An increase in Increaser II species is considered to be a form of veld degradation (Tainton 1988a). This increase in Increaser II species can be related to increased grazing pressure as high stocking rates are often the cause of large areas becoming increasingly dominated by Increaser II species (Tainton 1988a). At low stocking rates an increase in Increaser I species could be expected (Tainton 1988a). Patch grazing is the frequent and intense regrazing of certain areas within an apparently uniform sward (Chapter 4). This will increase the stocking pressure in patches relative to the remainder of the sward. The recommended stocking rates are designed to keep the species composition stable and not to push it into either the Increaser I or Increaser II stages. Patch grazing will, however, ensure that patches are grazed at a considerably higher stocking pressure than the recommended stocking rate. Because the grazing pressure is higher in the patches than the surrounding sward, patches may be forced into the Increaser II stage as the data in this study and the study of Hatch & Tainton (1990) would suggest. When patches become degraded, possibly due to a degradation of the soil (Chapter 6), and the forage in the patches becomes unacceptably poor, animals may increase the existing patches and/or create new patches. This was the basis from which Tainton (1972) argued that patch grazing may be the focus from which overall veld degradation proceeds.

The main cause of this degradation may be the reduction in vigour of the principle food source (e.g. *Themeda triandra*). A reduction in vigour of preferred species in patches allows other species, which are adapted to frequent and severe defoliation (e.g. Increaser II species), to invade. If one were able to reduce the effect of patch grazing, and therefore reduce the effect on plant vigour, then veld degradation may be reduced or at least slowed down. Patch grazing takes place mainly during the summer and autumn periods (Chapter 4; Hatch & Tainton 1993) when the sward is characterised by high herbage availability. The autumn period is one of the most important periods for the plant, as it is during this period that the plant stores most of its photosynthates (Peddie 1994). Heavy patch grazing during this period may therefore be the main cause of the reduction in vigour and the resulting sward degradation. Autumn resting may therefore be important if one is to reduce the potential effect patch grazing may have on sward degradation.

Nothing practical can be done to eliminate urine and dung deposition, and variations in the soil are likely to occur naturally (Scholes 1993). It may therefore not be all that important to know why specific patches are initiated and other areas not. Knowing that patches will be repeatedly grazed through the season, irrespective of the cause of the patch being initiated, it may be more important to examine how to encourage the animals to graze more uniformly and thereby decrease the potential for patch grazing. Animals also continue to graze previously grazed patches after a full seasons rest. We therefore need to look at the patch grazing patterns and critically evaluate current grazing recommendations in an attempt to alleviate the problem of continued patch grazing which may possibly be the starting point of veld degradation.

9.3 EVALUATION OF CURRENT GRAZING RECOMMENDATIONS

Early grazing after a burn promotes a more even utilization of the sward than later grazing commencement. The differences in the frequency and intensity of grazing patches and non-patches were smallest when early stocking was applied (Chapter 4). The more uniform sward, as a result of early stocking after burning, is also likely to decrease the carry-over effect patch grazing may have in the following season and thereby decrease the potential for patch grazing in the second grazing season after a burn. It seems that sward height and sward regrowth are important in the patch grazing process as animals generally do not graze moribund herbage. Animals regraze previously grazed patches over consecutive seasons and even after a seasons rest (Chapter 8). This may be in response to a difference in sward height between patches and non-patches at the start of the grazing season. Early grazing after a burn, which promotes more uniform grazing, will help to reduce any carry-over effect. During winter, however, non-patches are grazed more frequently and intensively, and grazing during this period may decrease the potential carry-over effect even more and thereby decrease the potential for patch grazing in the following season. Animals tend to graze the non-patches more than the patches during winter probably because the patches contain very little forage. During winter the plants are dormant and patches will not be grazed until the start of the next season when the plants start growing again. Winter grazing would therefore force the animals to graze the non-patches. It could be expected that in early winter animals would first graze the previously grazed non-patches but as winter progresses, and the are plants not growing, animals would be forced more onto the increasingly moribund areas (e.g. dung patches). Winter grazing has no long-term effect on the sward, and increasing the stocking rate would further decrease the carry-over effect and therefore the potential for patch grazing in the following grazing season. As the sward becomes dormant towards winter in the humid grasslands of KwaZulu-Natal animals start losing condition and weight. A protein-rich winter supplement therefore has to be used to ensure that animals do not lose to much weight. Heavy overwintering with a winter lick may greatly decrease the potential for patch grazing in the following grazing season by decreasing the carry-over effect patch grazing may have on the sward.

Early grazing after a burn may reduce patch grazing but the second grazing season would need a 'therapeutic' treatment (Barnes & Dempsey 1992). Grazing would need to be deferred slightly in relation to the first grazing season after the burn. This would allow plants to accumulate more leaf material prior to grazing, therefore allowing for more photosynthesis during the early grazing season.

Patch grazing may be reduced by early grazing in the first season but patch grazing may increase in the second season because firstly, more forage will be available in the second grazing season than the first and secondly, later grazing will increase the potential for patch grazing. The second grazing season may therefore include heavy overwintering to reduce the carry over effect into the third grazing season. As mentioned earlier autumn resting may be important to reduce the potential for patch degradation. A four-camp grazing system is widely advocated for the humid grasslands of KwaZulu-Natal with a full season's rest after every third grazing season. Autumn resting may also be incorporated into the second grazing, similar to the system applied by Barnes & Dempsey (1992). With early grazing in the first season, only *c.* six months grazing and heavy overwintering in the second grazing season, patch grazing is likely to be less severe, and the autumn rest in the second grazing season may be sufficient in restoring the vigour of plants in patches (Chapter 7), and thereby reducing the potential for patch degradation. In the third grazing season the camp could then be grazed normally, as a full season's rest would follow and allow the plants in the patches to recover before the next grazing.

Different animals have different sward requirements. Sheep require short nutritious swards, while cattle are able to graze more moribund material (Barnes 1992). Sheep performance is also enhanced if early grazing is applied (Barnes 1992; Barnes & Dempsey 1992). Frequent burning in conjunction with early grazing has often been applied in sourveld to increase sheep performance (Barnes 1992). Although this may reduce the effect of patch grazing, however, frequent burning is not recommended in the humid grasslands (Tainton 1988d), and continued early grazing with frequent burning may lead to sward degradation in the long-term (Barnes 1992). This frequent burning for animals that require higher quality herbage, e.g. sheep, may be overcome by using the Venter & Drewes (1969) system as it was initially proposed. They proposed a four block system where the farm is divided into four blocks with rotational grazing within each block. The priority block could be grazed by animals requiring short and/or higher quality forage. The second and third blocks could then be grazed by animals requiring less nutritious material. An example can be used to explain the system where cattle and sheep are grazed together on a farm. Sheep could graze the priority block, cattle and sheep could then be combined to graze the second block, with cattle only, grazing the third block.

The vigour of *Themeda triandra* in the patches during this was significantly lower than that in the non-patches after three seasons of grazing and is a possible cause of the higher proportion of Increaser II species in the patches. An increase in the number of consecutive grazing seasons without a rest would decrease the vigour of some of the preferred species even further and thereby increase the potential for patch and sward degradation. Increasing the number of consecutive grazing seasons in each camp/block before resting above three (i.e. four camp/block rotation) may not advisable. In an attempt to prevent patches becoming permanent a four camp system may be reduced to a three camp system with a burn and a seasons rest every third year. This would increase the grazing pressure and increase the amount of resting. Wolton (1979) reported that increasing stocking rate would lead to more uniform grazing. Increasing the stocking pressure, not the stocking rate, would probably lead to more uniform grazing without degrading the sward, and would therefore reduce the effect of patch grazing. With early grazing at a higher stocking pressure in the first season after a burn patch grazing would be reduced. A three-camp system may, by reducing the effect of patch grazing in the first season after burning (early grazing), effectively allow only one season for patches to develop. Two seasons of grazing is likely to have less of an effect on plant vigour than three or more seasons of grazing and the differences between patches and non-patches may not be as great, thereby reducing the potential for sward degradation associated with patch grazing.

9.4 FUTURE RESEARCH PRIORITIES

Patch grazing may be the focus from where sward degradation proceeds. Understanding the causal mechanisms of patch grazing, such as urine and dung deposition, are important. However, it is unlikely that anything practical will be able to be done to prevent patch grazing due to such inherent factors. It may be more important to obtain an understanding of the processes which take place during patch grazing. It is, for example, important to investigate the effect of patch grazing on the vigour of a variety of species from different classes. With such information a greater understanding of patch grazing will be gained. Another important factor to investigate in future research is the effect of patch grazing under different management strategies. These would include different stocking rates, different resting strategies and times of resting, and different camping systems, such as a two or a three camp system.

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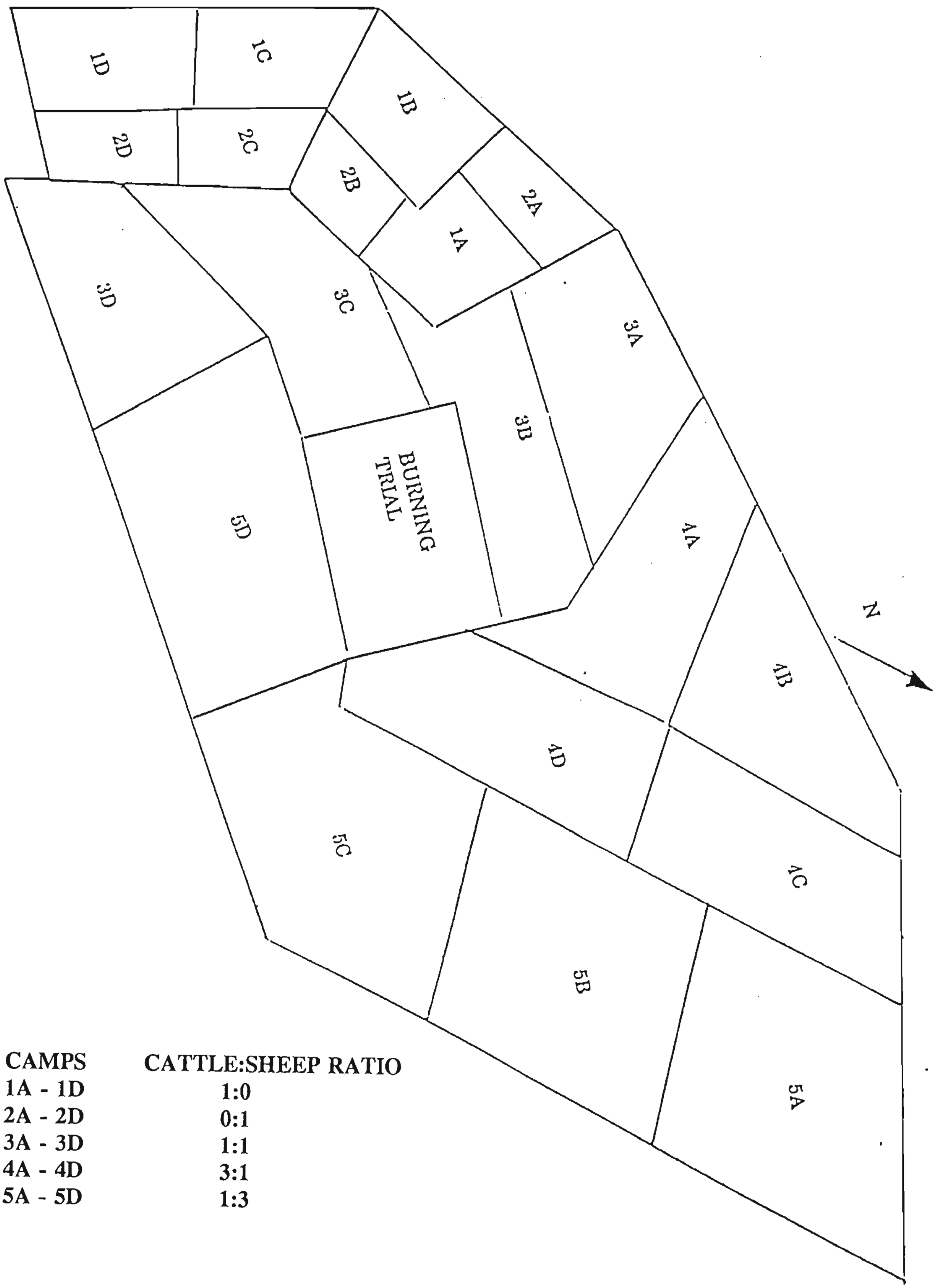
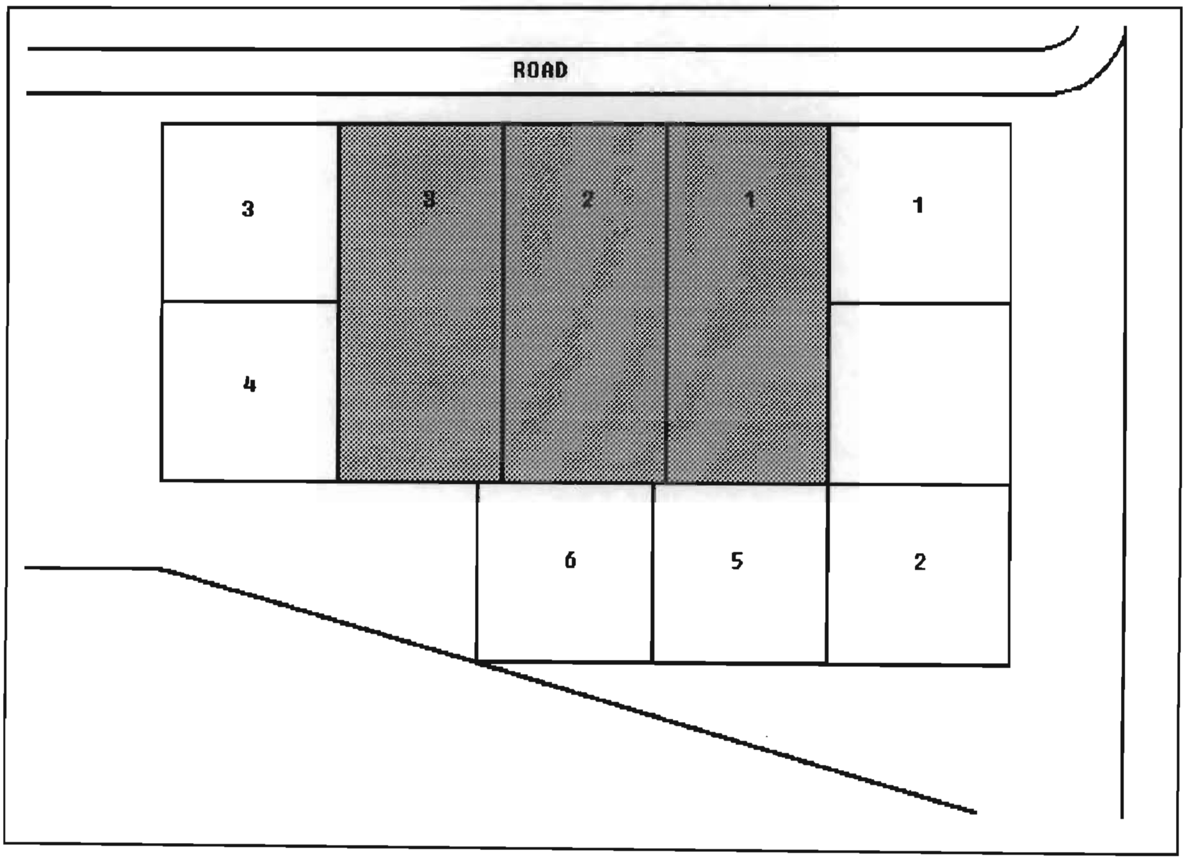
Appendix 3.1 Trial layout at Kokstad Research Station. The only camps that were used in this trial were camps 3A and 3C, both in the 1:1 cattle:sheep ratio.



CAMPS	CATTLE:SHEEP RATIO
1A - 1D	1:0
2A - 2D	0:1
3A - 3D	1:1
4A - 4D	3:1
5A - 5D	1:3

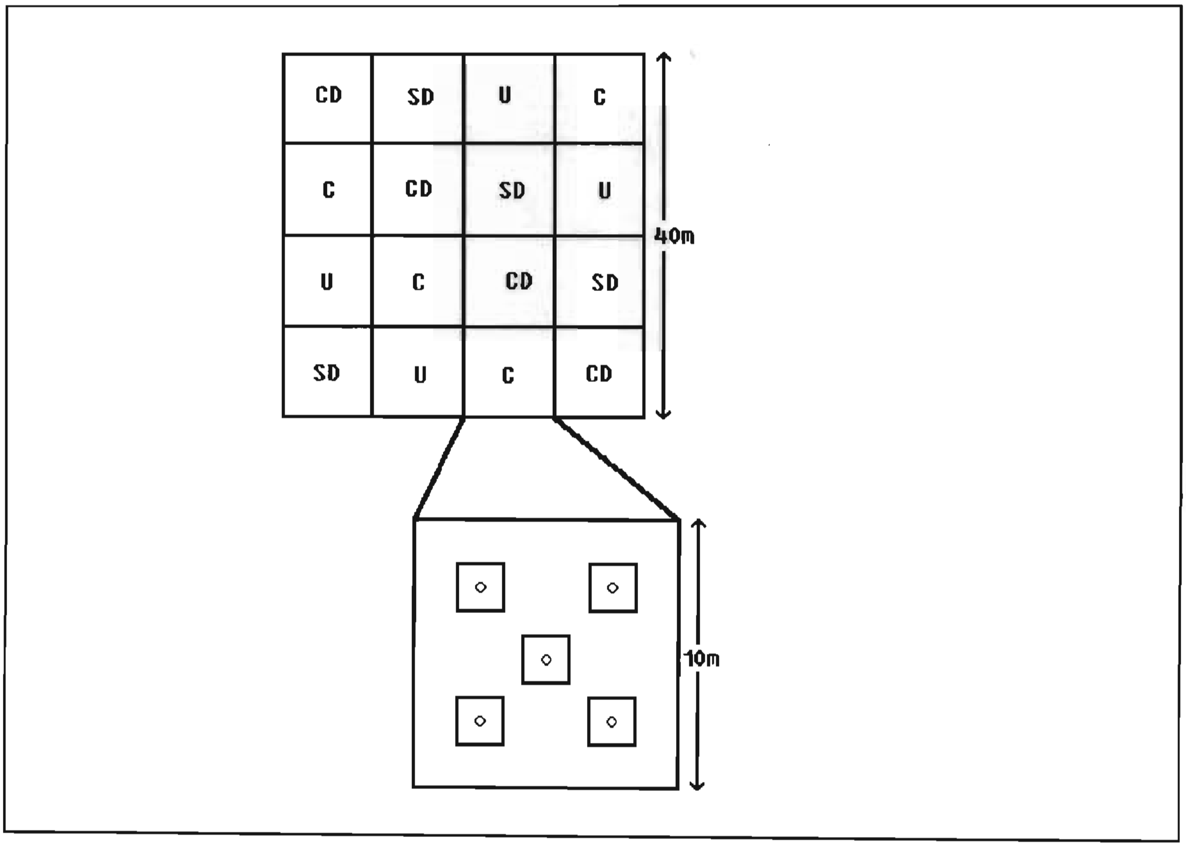
Appendix 4.1 Trial layout of Study I (Chapter 4) and Study II (Chapter 5). The three camps of Study I are shaded and the six camps of Study II not.



Appendix 5.1 Chemical composition of simulated urine used by Day & Detling (1990).

Compound	Concentration ($g\ l^{-1}$)
Urea	13.65
$MgCl_2.6H_2O$	0.75
$MgSO_4.7H_2O$	0.73
$CaCl_2.2H_2O$	0.09
KCL	7.02
$KHCO_3$	6.83
NaCl	1.21

Appendix 5.2 A map showing the Latin square design (Steel & Torrie 1980) used in Study II. Each square in the Latin square contained five replicates of a particular treatment, which was placed into the centre of a 1m x 1m quadrat.



Appendix 5.3 The frequency of grazing interaction table. Frequency of grazing is expressed in terms of a preference rating

Animal type	Age of deposition (months)	Treatment		
		Cattle dung	Sheep dung	Urine
Cattle	0	-18.65	-5.95	3.25
Cattle	3	-4.70	-1.40	4.70
Cattle	6	-3.60	-4.25	2.20
Sheep	0	-3.20	3.30	2.15
Sheep	3	-3.85	-3.05	-0.90
Sheep	6	0.15	-0.25	5.65

LSD ($P \leq 0.05$) = 4.577
LSD ($P \leq 0.01$) = 6.015

Appendix 5.4 The intensity of grazing interaction table. Intensity of grazing is expressed in terms of a preference rating

Animal type	Age of deposition (months)	Treatment		
		Cattle dung	Sheep dung	Urine
Cattle	0	-49.90	-17.58	13.18
Cattle	3	-8.78	-2.48	10.78
Cattle	6	-5.76	-6.42	4.42
Sheep	0	-2.99	8.48	5.21
Sheep	3	-5.56	-4.08	-2.12
Sheep	6	-0.28	-1.64	12.38

LSD ($P \leq 0.05$) = 8.90
LSD ($P \leq 0.01$) = 11.70

Appendix 6.1 Equation used to calculate the mean pore size distribution at different supply potentials (Marshall & Holmes 1988).

$$h = \frac{2\gamma}{\rho g r}$$

h = Suction (m)

γ = Surface tension (0.072 N m^{-1})

ρ = Density of water (1000 kg m^{-3})

g = Gravity (9.81 m s^{-2})

r = Pore radius (m)

Appendix 6.2 Species acronyms used in this document.

SPECIES NAME	SPECIES ACRONYM
Alloteropsis semialata	Ase
Brachiaria serrata	Bse
Digiteria setifolius	Dse
Digiteria trichoelenoides	Dtr
Diheteropogon amplectens	Dam
Elionurus muticus	Emu
Eragrostis capensis	Eca
Eragrostis curvula	Ecu
Eragrostis plana	Epl
Eragrostis racemosa	Era
Eulalia villosa	Evi
Harpochloa falx	Hfa
Helictotrichon turgidulum	Htu
Heterogogon contortus	Hco
Koeleria capensis	Kca
Microchloa cafra	Mca
Setaria nigrirostris	Sni
Sporobolus africanus	Saf
Themeda triandra	Ttr
Trachypogon spicatus	Tsp
Tristachya leucothrix	Tle
Forb species	Forb
Sedge species	Sedge
Senecio retrorsus	Senecio