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**EFFECT OF SLOPE CLASS ON DEFOLIATION  
FREQUENCY AND SEVERITY OF *Trifolium  
repens* BY SHEEP IN HILL PASTURES**

**A thesis presented in partial fulfilment of the requirements for the degree of  
Master in Applied Science at Massey University**

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# EFFECT OF SLOPE CLASS ON DEFOLIATION FREQUENCY AND SEVERITY OF *Trifolium repens* BY SHEEP IN HILL PASTURES

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## ABSTRACT

Hill pastures demonstrate varying intensities of grazing related to slope. A study of this effect was carried out at the Ballantrae Hill Country Research Station on set-stocked pastures that were maintained on high (H) and low (L) soil fertilizer/stocking rate treatments.

In the first experiment, 10 marked white clover stolons were observed at 1-week intervals for grazing damage in each (200 \* 300 mm) of 10 paired quadrats on both flat terrain (FT) between 0-20° and steeply sloping terrain (ST) between 30-45° in each of two treatments (H & L) in winter of 1995. The defoliation frequency (0.38 vs 0.29 ± 0.10; P<0.05) and severity (0.45 vs 0.30 ± 0.11; P<0.05) were significantly higher on the FT than on ST, but this phenomenon only occurred on the H treatment.

In order to determine the reason for causing sheep grazing discrimination between terrain, 10 sites that contained the FT and ST were selected on the L treatment. At each site, four paired turves (200 \* 300 mm) were cut, two turves were from the FT

and the other two from the ST, were transplanted into similar or contrary terrain to give all combinations of turf and terrain in spring of 1995 and again in autumn of 1996. In autumn, turf from the FT was grazed more frequently (0.38, 0.36 vs 0.15,  $0.11 \pm 0.18$ ;  $P < 0.001$ ) and severely (0.81, 0.87 vs 0.28,  $0.19 \pm 0.41$ ;  $P < 0.001$ ) irrespective of its location in the sward, but this effect was stronger within the first three weeks of the grazing period. In contrast, this phenomenon did not occur in spring, and when FT turf was transplanted into the FT it was less (0.09 vs 0.32, 0.31,  $0.37 \pm 0.23$ ;  $P < 0.05$ ) severely defoliated than the other treatments.

It is concluded that sheep generally defoliated white clover on the FT more frequently and severely than on the ST and the main reason for this discriminatory grazing was the difference in the vegetation conditions (e.g., botanical composition) of pastures. This preference for the FT was stronger during autumn, on the H treatment, and in the early stage of a grazing period. These findings suggest it may be possible to lessen discriminatory grazing in hill pastures by improving pasture botanical composition, adjusting fertilizer application rate or by seasonal manipulating of grazing policies.

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# TABLE OF CONTENTS

<b>CONTENT</b>	<b>Page</b>
<b>ABSTRACT.....</b>	<b>i</b>
<b>TABLE OF CONTENTS.....</b>	<b>iv</b>
<b>LIST OF FIGURE.....</b>	<b>vii</b>
<b>LIST OF TABLES.....</b>	<b>viii</b>
<b>LIST OF APPENDIX TABLE.....</b>	<b>x</b>
<b>LIST OF APPENDIX FIGURES.....</b>	<b>xi</b>
<b>CHAPTER 1 INTRODUCTION.....</b>	<b>1</b>
<b>CHAPTER 2 REVIEW OF THE LITERATURE.....</b>	<b>4</b>
<b>2.1 HILL PASTURE IN NEW ZEALAND.....</b>	<b>4</b>
2.1.1 Introduction.....	4
2.1.2 Key management strategies.....	5
<b>2.2 PREVIOUS RESEARCH.....</b>	<b>11</b>
2.2.1 Influence of slope class on microclimate and soil.....	11
2.2.2 Influence of slope class on pasture production.....	15
2.2.3 Influence of slope class on animal grazing behaviour.....	21

---

2.2.4 Conclusion.....	30
<b>CHAPTER 3 MATERIALS AND METHODS.....</b>	<b>32</b>
<b>3.1 SITE.....</b>	<b>32</b>
<b>3.2 EXPERIMENTAL DESIGN.....</b>	<b>32</b>
3.2.1 Time.....	34
3.2.2 Paddock and slope class.....	34
3.2.3 Treatments and measurements.....	38
<b>3.3 STATISTICAL ANALYSIS.....</b>	<b>40</b>
<b>CHAPTER 4 RESULTS.....</b>	<b>41</b>
<b>4.1 EFFECT OF SLOPE CLASS ON SHEEP GRAZING BEHAVIOUR.....</b>	<b>41</b>
4.1.1 Defoliation frequency.....	41
4.1.2 Defoliation severity.....	41
4.1.3 Relationship between defoliation frequency and severity.....	42
<b>4.2 FACTORS MODIFYING SHEEP GRAZING DISCRIMINATION FOR WHITE CLOVER BETWEEN SLOPE CLASS.....</b>	<b>46</b>
4.2.1 Soil fertilizer/stocking rate.....	46
4.2.2 Grazing season.....	46
4.2.3 Grazing duration.....	48
<b>4.3 REASON FOR SHEEP GRAZING DISCRIMINATION BETWEEN SLOPE CLASS.....</b>	<b>51</b>
4.3.1 Effect of turf transplant on sheep grazing discrimination for white clover	

---

between slope class.....51

4.3.2 Difference in botanical composition between slope class.....51

**CHAPTER 5 DISCUSSION.....54**

**5.1 EFFECT OF SLOPE CLASS ON SHEEP GRAZING BEHAVIOUR.....54**

5.1.1 Defoliation frequency.....54

5.1.2 Defoliation severity.....55

**5.2 FACTORS MODIFYING SHEEP GRAZING DISCRIMINATION FOR  
WHITE CLOVER BETWEEN SLOPE CLASS.....57**

5.2.1 Soil fertilizer/stocking rate.....57

5.2.2 Grazing season.....60

5.2.3 Grazing duration.....62

**5.3 REASON FOR SHEEP GRAZING DISCRIMINATION BETWEEN SLOPE  
CLASS.....64**

5.3.1 Effect of turf transplant on sheep grazing discrimination for white clover  
between slope class.....65

5.3.2 Variation of botanical composition between slope class.....66

**5.4 SOLUTIONS.....67**

**CHAPTER 6 CONCLUSIONS.....70**

**ACKNOWLEDGEMENTS.....79**

---

**REFERENCES.....81**

---

## LIST OF FIGURE

<b>FIGURE</b>	<b>Page</b>
Figure 3.1 Relationship between pasture slope ( $^{\circ}$ ) and sward height (cm) on (a) low soil fertilizer/low stocking rate treatment (L) and (b) high soil fertilizer/high stocking rate treatment (H) in hill pastures set-stocked with sheep during winter.....	36

---

## LIST OF TABLES

<b>TABLE</b>	<b>Page</b>
Table 3.1 Meteorological data from 1970-1995 and 1995 at Ballantrae.....	33
Table 3.2 Botanical composition on the FT and ST for both the H and L treatments in hill pastures during winter.....	37
Table 4.1 Defoliation frequency and severity of marked white clover stolons by sheep grazing on 2 slope classes for both the H and L treatments in hill pastures during winter.....	43
Table 4.2 Defoliation frequency and severity of marked white clover stolons by sheep grazing on 2 slope classes for the L treatment in hill pastures during spring and autumn.....	44
Table 4.3 Observed sheep numbers distributed on 2 slope classes for both the H and L treatments during spring.....	45
Table 4.4 Defoliation frequency and severity of marked white clover stolons by sheep grazing on 2 slope classes for the L treatment during different seasons in hill pastures.....	47

---

Table 4.5 Defoliation frequency and severity of marked white clover stolons by sheep grazing on 2 slope classes over 4 weeks for the L treatment in hill pastures during autumn.....50

Table 4.6 Botanical composition (%) on the FT and ST for the L treatment in hill pastures during autumn.....53

---

## LIST OF APPENDIX TABLE

TABLE	Page
Appendix Table 1 Ratio of the FT/ST areas on both the H and L treatments in hill pastures.....	72
Appendix Table 2 Proportion of marked white clover stolons defoliated by sheep over 4 weeks on 2 slope classes for both the H and L treatments in hill pastures during winter.....	73
Appendix Table 3 Proportion of marked white clover stolons defoliated by sheep over 4 weeks on 2 slope classes for the L treatment in hill pastures during spring..	74
Appendix Table 4 The LAR, LLR and LB Value of white clover on the FT and ST for both the H and L treatments in hill pastures during winter.....	75
Appendix Table 5 The LAR, LLR and LB Value of white clover on the FT and ST for the L treatment in hill pastures during spring and autumn.....	76
Appendix Table 6 Effect of soil fertilizer/stocking rate on the defoliation frequency and severity of marked white clover stolons by sheep grazing on 2 slope classes during winter in hill pastures.....	77

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## LIST OF APPENDIX FIGURES

APPENDIX FIGURES	PAGE
Appendix Figure 1. Relationship between defoliation severity (leaves grazed per stolon per week) and leaf accumulation rate (leaves accumulated per stolon per week) of white clover on 2 slope classes for both the H and L treatments in hill pastures during winter.....	78
Appendix Figure 2. Relationship between defoliation severity and leaf accumulation ratio of white clover on 2 slope classes for the L treatment in transplanted swards during spring.....	78
Appendix Figure 3. Relationship between defoliation severity and leaf accumulation rate of white clover on 2 slope classes for the L treatment in transplanted swards during autumn.....	78

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# CHAPTER 1

## INTRODUCTION

Hill pasture is characterised by its variation in microtopography. Microtopography is a function of differences in slope and aspect, and causes a diversity of microclimate and soil conditions. These include net radiation, temperature, soil moisture and soil fertility, and are reflected in pasture characteristics such as botanical composition, herbage accumulation rate, palatability and animal grazing behaviour (Radcliffe 1968, 1982; Rumball & Esler 1968; Gillingham 1973, 1982; Lambert & Roberts 1976, 1978; Sheath 1981; Clark *et al.* 1984; Sheath & Boom 1985; White 1990).

After more than 100 years' farming practice, most hill pastures in New Zealand have well developed tracks, slopes and banks. These tracks traverse the hills as interlacing networks moulded to slope contours. The tracks are small ledges whose inner edges cut into the hill side (called banks) and whose outer edges may project in small overhangs (called kerbs) (Radcliffe 1968), and have become the basic features of hill pasture microtopography. It is estimated that the areas occupied by tracks, banks and little-modified slopes are 40%, 10%, 50% on a Mahoenui soil or 25%, 25%, 50% on a Makara soil respectively in the hill pasture (During & Radcliffe 1962).

The influence of microtopography on soil conditions, pasture production and animal grazing behaviour has received much attention from agricultural workers in New Zealand. They found that with increasing land slope, the soil moisture and soil nutrient availability (Lambert & Roberts 1976, 1978), intensity of animal treading (Rumball 1966) and excreta return (Gillingham 1980) are all decreased. There is a uniform trend of soil nutrient transfer from bank and steep terrain to tracks, a greater variety of pasture species on steeper slopes and banks where competition *per se* is less important, and stress (low nutrient or moisture availability) is the dominant environmental variable. Herbage accumulation rate is relatively lower on sloping than on flatter terrain (Lambert *et al.* 1983, 1986). Especially, it is reported that there is a general trend towards preferential sheep grazing of pasture on tracks or easy slopes rather than banks or steep land zones (Grant & Brock 1974; Sheath 1981; Gillingham 1982; Clark *et al.* 1984a; Lambert *et al.* 1986). This general trend was further modified by soil fertility level, grazing season and grazing duration (Sheath 1981; Gillingham 1982; Clark *et al.* 1984a). An interim conclusion (hypothesis) is that the main reason for preferential sheep grazing on flatter areas is the variable vegetation conditions between microsites (Sheath 1981, 1983; Gillingham 1982; Clark *et al.* 1984a).

However, little information is available on the magnitude and especially on the reason for sheep discriminatory grazing behaviour between microsites, and this makes it difficult to provide firm recommendations on the possible solutions to lessen or solve this issue in hill pasture. Therefore, in order to discover the mechanisms of the interactions among microtopographical units, pasture production and sheep grazing

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behaviour, and further to test the validity of the above hypothesis, it is necessary to carry out further studies in hill pasture on the effects of slope class on sheep grazing behaviour. The research aims were:

- (a) To estimate defoliation frequency and severity of white clover by sheep grazing on flat terrain (FT) between 0-20° and steeply sloping terrain (ST) between 30-45° on both a high soil fertilizer/high stocking rate treatment (H) and a low soil fertilizer /low stocking rate treatment (L) in set-stocked hill pastures.
- (b) To determine the reason for sheep grazing discrimination between slope classes (i.e., between FT and ST).
- (c) To measure the effects of the slope class on pasture botanical composition.

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# CHAPTER 2

## REVIEW OF THE LITERATURE

### 2.1 HILL PASTURE IN NEW ZEALAND

#### 2.1.1 Introduction

Hill country, defined as land over 15° slope, was in natural tussock grassland, podocarp rain forest, fern, or scrub at the time of early European settlement (Joblin 1983; Scott *et al.* 1985; White 1990). It covers nearly 5 million ha (40% of farmland or 36% of the grassland) in the North Island and 4.9 million ha (51% of the agricultural land resources and 44% of the grassland in the northern South Island) in the South Island (Joblin 1983; White 1990).

Over the last decade the sheep and beef stock numbers in the North Island hill pastures have declined by 13%, resulting from a 45% reduction in fertiliser use from the peak in the late 1970s and early 1980s leading to lower pasture production; and a move by farmers to increase per head annual production levels. At present this land resource carries 35% of total sheep (19 million) and 20% of total cattle numbers and

is farmed in 6800 farm holdings representing 30% of New Zealand sheep and beef farms (Mackay *et al.* 1993). Pastures on hill and high country in the northern South Island is assessed as carrying 20% of the region's current grazing stock numbers (Joblin 1983). There is still undoubted potential for large increases in farm production from hill country (Chapman & Macfarlane 1985). Potential increases in farm production of 50-100% have been proposed for North Island hill pastures (Hight 1979; Scott 1983) or with an estimated capacity to expand by 13 million stock units to support 31% of the livestock in the northern South Island hill and high country (Joblin 1983). However, many constraints (such as: social, economical and topographical factors) limit the large increases of hill pasture production (Scott *et al.* 1985). Especially, hill pasture is usually so broken topographically as to make decisions on pasture improvement and utilization much more difficult compared with the flat lowland. Under sheep grazing systems, poor pasture utilization would occur, because sheep tend to preferential graze pasture on tracks or easy slopes rather than on banks or steep land zones (Grant & Brock 1974; Sheath 1981; Gillingham 1982; Clark *et al.* 1984a; Lambert *et al.* 1986). This discriminatory grazing behaviour would give rise to large waste of herbage resources in hill pasture, especially on sloping terrain this uneven grazing would cause the reversional succession of present pasture to weeds and secondary growth. It is pointed out that the ability to achieve the potential of hill pasture production will be influenced greatly by the profitability of farming the land more intensively (Joblin 1983). Reasonable utilisation of the pasture resources and matching appropriate grazing systems with the variable pasture patterns must play an important role in achieving this aim (Clark *et al.* 1986).

## 2.1.2 Key management strategies

Even though there are various limitations existing in the hill pastures, the quality and quantity of pasture production and grazing management can be improved (Levy 1970). For example, since the 1940s, large scale economic improvement of hill pasture in New Zealand has become possible through the advent of aerial top-dressing and oversowing. The improvements from oversowing, top-dressing, subdivision and increased stocking rate were well documented at the Te Awa hill pasture research station. Pasture productivity increased from 5600 kg DM/ha to 9200 kg DM/ha and then 11500 kg DM/ha on hillsides with a resultant increase in carrying capacity of 6.5 ewe equivalents/ha (Suckling 1959, 1960, 1975). Comprehensive research work has been done and much evidence has been provided since 1949 by work on Whatawhata Hill Country Research Station, Ballantrae Hill Country Research Station and in the northern South Island (Scott 1985). Research has shown that hill country improvement can be summarised as the four "S" approach, i.e., seed-oversowing improved species; superphosphate--correction of nutrient deficiencies; subdivision--grazing control of improved pastures; and stock--increased numbers through improved grazing management (White 1990).

### 2.1.2.1 Seed--Oversowing improved species

The key to pasture improvement in New Zealand hill country is the introduction of high producing plant species, especially legumes, after the correction of the soil nutrient deficiencies (White 1990). The steep topography of most hill pastures means

that oversowing is the only feasible method of introducing new species (White 1990). By introducing suitable species (e.g., white clover), the pasture quantity and quality will improve greatly, which in turn would allow a significant increase in stock numbers. The optimum content of legumes in hill pasture should be up to 20-25% in the sward (Suckling 1959).

### **2.1.2.2 Superphosphate--Correction of nutrient deficiencies**

In hill pasture the soil is usually low in available nitrogen (N), phosphorus (P), sulphur (S) (White 1990), especially in steeply sloping areas. Unproductive species and lack of a significant legume component often occur on these sites. Without the steady input of nitrogen the spring flush of mineralised nitrogen is short-lived and not able to maintain more productive grass species. On the other hand, without appropriate phosphorus, lime and molybdenum application to stimulate legume growth and increase the nitrogen fixation rate of legumes, regular nitrogen application is impracticable in the long term due to its expense and its deleterious potential impact on soil properties (Zhou 1993). The tactical application of nitrogen, phosphorus, molybdenum and lime is probably the most effective way to increase pasture productivity and improve soil properties in hill pastures (Zhou 1993). Compared with climatic and topographical limitations in hill pastures, soil fertility is a factor that can be easily manipulated and more effective on hill farms (Lambert *et al.* 1982). Responses to fertility can be large, e.g., the response to improved fertility can be a five fold increase in pasture production compared with the native state (Scott *et al.* 1985).

### **2.1.2.3 Subdivision--Grazing control of improved pastures**

The "correct" grazing pressure is the key management requirement for good pasture production in hill pasture, and this could be achieved through subdivision and further manipulation of stocking rate (Chapman & Macfarlane 1985), because subdivision and fencing allowed a bank of feed to develop ahead of each grazing (White 1990) and grazing management could be thereafter controlled. In hill pasture, improved stock control and reduced paddock variability can be achieved in the same time by subdividing preferred from rejected areas, and where possible, fencing of pasture into topographically uniform paddocks either all "easy" or all "steep" or separated sunny and shady aspects (Sheath 1981; Gillingham 1982). Usually a 26% increase in live-weight gain could be achieved with a single subdivision fence.

### **2.1.2.4 Stock--Increased numbers through improved grazing management**

One of the major farm management decisions made by hill farmers is choice of grazing management (Lambert *et al.* 1986c). On hill country, successful grazing management requires a sound knowledge of the production and quality of pastures, the factors which control them, and also of the feed requirements of different classes of animals and the factors which affect animal performance. The following are some important aims which should be followed.

(1) **Match pasture supply and demand as closely as possible:** That is, identify

pasture deficits, locations and periods of high nutritional priority, and allocate or transfer feed into these locations and periods by long rotations (in winter) or by differential grazing of different aspects and slope classes (Sheath *et al.* 1987; White 1990).

There are two extremes of grazing pressure which limit pasture production and affect pasture demand and supply balance between pasture and grazing animals: (A) Under-grazing (lax grazing) which allows dead matter to accumulate, shades out white clover and reduces pasture density, especially on steeper or other laxly grazed zones and (B) Over-grazing (severe grazing) which also reduces pasture density and exposes bare areas for weed invasion, especially on flatter areas, such as sheep camp and tracks. Between these extremes (represented by about 2.5-3.0 and 0.8-1.0 tonnes DM/ha herbage mass respectively), sheep management systems have relatively minor effects on pasture or animal production (Chapman *et al.* 1985). However, it is usually difficult to determine a suitable grazing pressure in hill pasture because under the same stocking rate the flat area (0-12°) may be over-grazed, the easy slope (13-25°) lax-grazed and steep slopes (> 25°) may accumulate large amounts of dead material or revert to weeds and secondary growth.

**(2) Generate a desirable pasture composition:** Hill pastures usually demonstrate variable patterns of pasture micro-community related to slope classes (Rumball & Esler 1968) and seasons. The grazing management systems should be developed to control surplus summer growth, low fertility species, and weeds (Sheath *et al.* 1987; White 1990), especially on steeper or other laxly grazed areas.

Except stocking rate, the grazing management system has great influence on pasture species composition. It is reported that set-stocking could produce the same animal production as rotational grazing in hill pastures (Chapman & Clark 1984; Lambert *et al.* 1983, 1986b). However, rotational grazing has some advantages at certain times of the year over set-stocking, for example, by encouraging ryegrass, controlling roughage, or providing greater management flexibility in rationing winter feed, especially long rotations (70 days), which give more flexibility than shorter periods in winter (Smeaton & Rattray 1984). White (1990) suggested the best grazing management for hill country should include both systems.

**(3) Maintain nutritional quality of pasture:** High clover and green leaf content, low proportion of weeds and dead material in the sward is one of the most important aims of hill pasture management. Good utilization (e.g., the close matching of the variable stocking rate with the different pasture patterns between microsites or through seasons) is the key, and can be optimized by integrating different classes and species of stock in hill pasture, for example, sheep and cattle (Sheath *et al.* 1987; White 1990; Lambert *et al.* 1981).

It is reported that, under a certain stocking rate, goat grazed pastures usually have higher contents of white clover, that goats can control weeds (Lambert *et al.* 1981), and their grazing patterns are generally complementary to those of sheep, offering new options for pasture management. Higher production of meat and fibre is more likely from mixed grazing of sheep and goats than from either sheep or goats alone, particularly where weed species are acceptable to goats but not to sheep.

(4) **Sustainable management of the pastoral resources:** Managing the use, development and protection of the pastoral resources in a way, or at a rate, which enables people and community to meet their needs without unduly compromising the ability of future generations to meet their needs (Mackay *et al.* 1993).

## **2.2 PREVIOUS RESEARCH ABOUT EFFECTS OF SLOPE CLASS ON MICROCLIMATE, SOIL, PASTURE AND ANIMAL GRAZING BEHAVIOUR IN NEW ZEALAND HILL PASTURES**

### **2.2.1 Influence of slope class on microclimate and soil**

Slope class has a major impact on microclimate (e.g., net radiation, temperature) and soil conditions (e.g., soil moisture and soil fertility). However, little information is available on this aspect in New Zealand.

#### **2.2.1.1 Net radiation**

The net radiation received by pasture influences not only plant photosynthesis but also soil moisture, temperature and evapotranspiration, and is different between different slope classes (Jackson 1967). Depending on season and aspect, land slope modifies net radiation received (McAneney & Noble 1976) and usually increasing slope reduces net radiation received during warm seasons. Radcliffe & Lefever (1981) and Revfeim (1982) included global radiation estimates for sloping surfaces

calculated from horizontal surface measurements, and found that daily global radiation  $G_i$  on a surface of slope  $i$ , is commonly approximated by:

$$G_i = R_q Q_0 + f_i D_0 + p(1 - f_i) G_0$$

Where  $Q_0$ ,  $D_0$  and  $G_0$  are the daily direct, diffuse, and global radiation on a horizontal surface,  $R_q$  is the ratio of sloping/horizontal surface direct radiation,  $f_i$  is the fraction of hemispherical diffuse radiation incident on the slope, and  $p$  is the horizontal surface albedo. So, the net radiation received by hill pasture is usually modified by the surface slope.

### 2.2.1.2 Temperature

Temperature is extremely important in controlling pasture growth, composition of pasture species and for seasonal grazing management in hill pastures (White 1990). It is a factor which varies not only with season, latitude, altitude and aspects but also with slope (Scott *et al.* 1985; White 1990). In the South Island hill country, the annual variation in mean monthly temperature is about 10°C, with a further variation of some 8°C for altitude, slope and aspect (Scott *et al.* 1985). Although aspect is particularly important in modifying temperature (White 1990), slope also influences soil temperature because of its effect on net radiation received by the soil surface, and usually with a trend that increasing slope decreases soil temperature during warm seasons (White 1990). Furthermore, the combination of increasing slope/decreasing pasture cover enhances diurnal variation in soil surface temperature. This short-term

temperature variation must play a part in limiting pasture production on sloping terrains (Sheath & Boom 1985c).

### **2.1.2.3 Moisture**

Like temperature, moisture is another factor controlling pasture production and varies greatly according to latitude, altitude, slope, aspect and season (White 1990). Soils on tracks and flatter areas are consistently wetter than on banks and steep slopes (During & Radcliffe 1962) in the surface horizon (0-50 mm) probably by accumulation of slope seepage or because of less effective rewetting on sloping terrain (Radcliffe 1968; Sheath & Boom 1985c). For example, after heavy rains, tracks and flat terrains reach field capacity more quickly than banks and other sloping areas (Radcliffe 1968). The order of soil moisture between microsites in the hill pastures is usually: camp, track or path > easy slope > steep slope, kerb and bank.

### **2.2.1.4 Soil fertility**

An important feature of hill pastures is fertility transfer by stock. Slope is recognised as the major factor causing this transfer (Rumball & Esler 1968). In general, this transfer takes place from hillsides to the hillcrest and from steep slopes to flatter sites (e.g., tracks and camps) (White 1990). This uneven spread results in marked differences in soil nutrient level, hence species composition and pasture production (Rumball & Esler 1968; Radcliffe 1968; Gillingham 1973). The hillside ledges or benches (camps) made by sheep and used by them as resting places, contain

considerably more organic C and quick test P and K than tracks located below the benches (Radcliffe 1967). Where sheep camps and tracks occur, the soils are high in organic C, total N, K and P (During & Radcliffe 1962; Radcliffe 1968; White 1990). Even on sloping terrain, the rate of accumulation of dung is significantly higher on "easy" (13-25°) than "steep" (> 26°) slopes (Gillingham 1982). As slope increases, organic and mineral N in the soil decreases, organic carbon decreases and this is associated with a decline in soil water-holding capacity and bulk density (Sheath & Boom 1985c; White 1990).

Earth slumping and massive movement is visible in hill pastures, which is generally accelerated by the deforestation and inappropriate grazing management (Mackay *et al.* 1993). In grazed pastures, when land slope is > 42°, the soil losses exceed soil formation (Trustrum *et al.* 1990). On slopes of 28-42°, soil loss limits pasture growth and still contributes to sediment loading, but on slopes < 28° land is capable of sustaining pasture production (Trustrum *et al.* 1990). Under intensive cattle management, the annual topsoil loss was measured at 2.7 tonnes/ha when the mean hill slope was 21° (Lambert *et al.* 1985a). Associated with this loss of topsoil is an annual loss of 12 kg N and 1.5 kg P/ha. In a similar catchment under sheep grazing, soil and nutrient loss per ha were 1.1 tonnes, and 8 kg N and 0.7 kg P/ha (Lambert *et al.* 1985a). On hill slopes, slip scars which are regressed may never achieve more than 70-80% of the productive potential that they had when forest was initially removed (Lambert *et al.* 1984).

The importance of nutrient transfer and loss, coupled with effects of stocking rate on

nutrient cycling, must be taken into account when deciding on the correct fertilizer requirement and grazing management of a hill pasture.

## **2.2.2 Influence of slope class on pasture production**

The climax vegetation in much of New Zealand hill country, especially in the North Island, was rain forest (Mackay *et al.* 1993). The present pasture was achieved artificially by burning and cutting the forest over 100 years ago (White 1990). In wetter districts of the North Island the natural succession is back to forest, and grassland farming here is a continual battle against reversion to fern, scrub, and secondary growth. The inappropriate grazing management and low fertilizer input all will give rise to this reversion and the change of pasture production patterns in hill country (Trustrum *et al.* 1984; O'Connor 1986, 1987; White 1990; Mackay *et al.* 1993).

### **2.2.2.1 Botanical composition**

Botanical composition may influence animal productivity by affecting feeding value of herbage (Ulyatt 1978), seasonality of herbage accumulation (Morley *et al.* 1969), and herbage accumulation rate (Grant *et al.* 1981). Meanwhile, pasture composition, reflecting the prevailing environment, is in turn influenced greatly by topographical, microtopographical variation and animal grazing activities. Diversity of plant micro-communities between microsites is a common feature of hill environments (Rumball & Esler 1968; Grant & Brook 1974). Corresponding distributions of ecologically-

related species produce more or less distinct micro-communities corresponding to the slope zones. The sharpness of the transitions between them appears to be mainly determined by the abruptness of the slope change (Rumball & Esler 1968).

**(1) Botanical composition on different slope classes:** Botanical composition varies with pasture slope. For example, ryegrass (*Lolium perenne* L.) is dominant on camps and tracks, just as are other high fertility responsive (HFR) grasses such as Yorkshire fog (*Holcus lanatus* L.), poa (*Poa trivialis* L., *P. annua* L.) and cocksfoot (*Dactylis glomerata* L.). Their content decreases with increasing slope. Browntop (*Agrostis capillaris* L.) and other low fertility tolerant (LFT) grasses such as sweet vernal (*Anthoxanthum odoratum*), crested dogstail (*Cynosurus cristatus*), chewings fescue (*Festuca rubra* L. Subsp. *Commutata* Gaud.), danthonia (*Rytidosperma* spp); legumes such as suckling clover (*Trifolium dubium* Sibth) and Lotus pedunculatus cv.; other species such as catsear (*Hypochaeris radicata* L.), hawkbit (*Leontodon taraxacoides* [Vill.] Meat), ribgrass (*Plantago lanceolata* L.), moss, mouse-eared chickweed (*Cerastium glomeratum* Thuill.), and also dead material increase with increased slope in hill pastures (Lambert *et al.* 1978, 1986a; Sheath & Boom 1985b).

**(2) Factors causing the difference in botanical composition between slope class:** As stock management, animal grazing behaviour, nutrient transfer and microclimate or soil moisture conditions are usually affected by topography and microtopography in hill pastures (During & Radcliffe 1962; Radcliffe 1968, 1982; Rumball & Esler 1968; Grant & Brook 1974; Lambert *et al.* 1978, 1986a; Gillingham 1980; Sheath & Boom 1985b), most variations in hill pasture species composition thereafter are

mainly related to topographical and microtopographical variation. Pattern interpretation relies on determining significant physical differences in the habitat of these micro-communities. Slope is recognised as the dominant factor, its effects on botanical composition being much more marked than those of aspect (Rumball & Esler 1968; Radcliffe 1982; Sheath & Boom 1985b), and the main reason for slope class causing the differential botanical composition between microsites may be soil fertility (Lambert *et al.* 1978, 1986a). The effects of slope class on pasture composition usually resemble those of fertiliser treatments, i.e., pastures on steeper slope are more similar to low fertility pastures, than those on flatter areas where soil fertility is higher (Lambert *et al.* 1978, 1986c). In many instances, differences between slope class can be greater than those generated by fertiliser treatments (Lambert *et al.* 1986c).

Factors other than soil fertility should not be neglected. Soil moisture, animal treading intensity and characteristics of plants are very important in deciding botanical composition in a certain terrain. For example, because of high tolerance to dry, poor soil conditions, chewings fescue is more prevalent on banks. White clover content peaks on the rolling and easy slope zones, indicating its inability to compete under high fertility camp and track conditions or to exist on dry steep slopes. Ryegrass and sometimes even clover dominance is encouraged on flat terrain where severe treading damage occurs (Lambert *et al.* 1978, 1986a; Sheath & Boom 1985b). This is a result of the relatively high competitive ability of ryegrass under high soil fertility, and its better tolerance to treading damage, and the ability of white clover to more quickly colonise areas of bare soil. Gillingham (1973) found ten other

grasses were consistently present in the sward because of relatively high adaptive ability to changing environmental conditions. They were cocksfoot, crested dogstail, annual meadow grass (*Poa annua*), sweet vernal, ratstail (*Sporobolus africanus*), Yorkshire fog, meadow rice grass (*Microlaena stipoides*), *Notodanthonia* spp., *Vulpia* spp. and soft brome (*Bromus mollis*).

So, considerable portions of hill slopes are unlikely to become ryegrass-dominant, as competitive ability and ability to withstand disturbance are less important on steep than flatter slopes. Ability to withstand stress is the primary requirement of plants on steeply sloping microsites (Lambert *et al.* 1986b).

The pasture composition variation between microsites is greater in summer and autumn than in winter and spring (Gillingham 1980). This is because the temperature and soil moisture variation between slope classes is much more severe during warm than cool seasons (Gillingham 1973, 1982). Season may be considered as a factor causing short-term (or seasonal) variation of botanical composition between microsites.

Although animal grazing discrimination between slope class is an important factor in influencing the variation of botanical composition in hill pasture, there is little information available on this aspect at present.

#### **2.2.2.2 Herbage accumulation rate**

Herbage accumulation rate (HAR) is a major determinant of animal production in grazed pasture systems. By influencing microclimate, soil fertility and soil moisture, slope class not only affects pasture composition but also widely influences pasture production. In hill pasture, slope has a marked effect on HAR of grazed pastures, as shown at several North Island sites (Radcliffe *et al.* 1968; Gillingham 1973; Lambert *et al.* 1983). HAR declined sharply with increases in surface slope over the slope range (15-27°), and annual herbage accumulation decreased about 730 kg DM/ha/a per degree slope increase (Lambert *et al.* 1983). HAR is lowest on bank and steep slopes because soils are generally shallower, of lower fertility, and drier. Those soils hold less water and take longer to re-wet after a drought than flatter sites, especially in hot and dry summers (White 1990). Only on stock camps and track areas is the potential production of hill pastures reached and here there is little difference in yield compared with lowland pastures. Usually flatter stock camp areas produced twice as much herbage as hillsides (17.9 v. 8.1 t DM/ha/a respectively) (Suckling 1959).

### 2.2.2.3 Pasture quality

Owing to the strong influence of slope on microclimate, soil moisture, soil fertility and the HAR, especially on botanical composition, pasture quality is indirectly affected by slope class.

One of the most important pasture variables affecting herbage quality is the relative amount of green leaf and dead material in the sward, for it influences diet digestibility, diet selection, diet intake and animal performance (Sheath & Rattray

1985). Dead material is mostly rejected by grazing animals (Guy *et al.* 1981). For every 1% decrease in green herbage content, sward digestibility decreases by 0.5% (Rattray & Clark 1984).

It was reported that pasture on the banks and steep slopes was usually long, rank, higher in proportion of dead material (Lambert *et al.* 1978, 1986a; Sheath & Boom 1985b) and weeds such as hardfern, bracken fern, manuka (White 1990), hence unattractive to stock and low in quality. In contrast, pasture on camps, tracks and flatter areas or south aspects was not only mainly dominated by ryegrass and other higher palatable plants but also contained more green parts and lamina, and was higher in palatability (Radcliffe *et al.* 1982). Furthermore, herbage on flatter areas and wetter southerly aspects tended to decay faster than on north and steep slopes. Thus accumulation of pasture litter was greater on northern steep slopes than on wetter flatter areas (Radcliffe *et al.* 1982), and would therefore have been of lower digestibility (Davis 1977). For example, herbage digestibility is often only 40-50% on sloping terrain (Radcliffe *et al.* 1977).

The impact of this reduced quality could give rise to grazing discrimination between microsites as animals actively select for green herbage (e.g., on flatter areas) and reject dead herbage (e.g., on sloping terrain). This could further cause larger differences in pasture quality between microsites. Therefore, grazing managements which maximize leafy pasture and minimise the amount of dead material or which can achieve uniform grazing pressure between microsites in hill pasture should be successful in raising stock productivity and maintaining a palatable sward (Radcliffe

1982).

Differences in herbage quality and quantity between flat and sloping terrain can not only cause animal discriminatory grazing behaviour, which may also in turn give rise to differences in pasture characteristics (e.g., botanical composition) between microsites in hill pastures.

### **2.2.3 Influence of slope class on animal grazing behaviour**

Seasonal imbalances between pasture growth and animal demands cause major variation in pasture utilization in all-grass farming. In hill country, additional variation is commonly encountered as a result of preferential grazing of different land classes (slope, aspect, fertility) and plant types (size, species, quality) (Sheath 1981). Actually, the regional imbalance between pasture supply and animal consumption caused by the preferential grazing on flatter areas and the rejecting for sloping terrains has become a common issue in hill pastures, which not only limits the further increase of pasture productivity, but also gives rise to the large waste and degeneration of pastures on the sloping zones. Several research has been carried out in New Zealand hill pastures to study this effect.

#### **2.2.3.1 Definition of defoliation frequency and severity**

Frequency of defoliation and the reciprocal--defoliation interval--are defined by Hodgson (1979). Severity has been used, both to define the leaf length grazed per tiller (Hodgson & Ollerenshaw 1969), and as an expression of leaf length grazed per

tiller related to leaf length initially present, by the same authors. Defoliation frequency can be expressed as the number of grazing events of a marked grass tiller during a given period, and the severity can therefore be related to the amount of herbage mass removed per unit area, or to the proportion of herbage mass removed during any defoliation event (Clark *et al.* 1984a).

### **2.2.3.2 Measurements of defoliation frequency and severity in interpreting animal grazing behaviour**

The measurement of defoliation frequencies and severities is one of the most efficient methods to determine animal grazing behaviour (Chapman & Clark 1984). Hodgson (1966) suggested that measurements of individual tillers might aid in the interpretation of cutting and grazing experiments and the formulation of grazing regimes. The frequency and severity of defoliation of individual tillers in set-stocked ryegrass swards were measured by Hodgson (1966) and Hodgson & Ollerenshaw (1969). The recorded defoliation intervals of individual tillers in set-stocked ryegrass swards by them were 7-14 and 6-10 days respectively under a range of stocking rates and sheep tended to graze tillers with the greatest green leaf length at any one time. Morris (1969) recorded defoliation intervals of 19-36 days for a set-stocked cocksfoot sward at a range of stocking rates and suggested that individual small areas in a continually grazed sward were being grazed in rotation. Clark *et al.* (1984a) found in their study that ryegrass, browntop and white clover were all defoliated more frequently and severely by sheep under set stocking than rotational grazing when rotation lengths exceeded 21 days. These studies measured increased defoliation

frequency with increasing stocking rate. Since then much research has been carried out in New Zealand to interpret animal grazing behaviour by measuring the defoliation frequency and severity under different conditions in hill pastures. Findings include:

(1) The defoliation frequency (by sheep) was more frequent under high fertility treatment than under low fertility treatment in winter-early spring for the grasses and from winter to mid summer for white clover in hill pastures (Clark *et al.* 1984a). Greater clover defoliation severity at the high fertilizer level was often observed too. But, there were very few effects of fertiliser level on grass defoliation severity (Clark *et al.* 1984a).

(2) There was a strong, general trend towards preferential grazing of pasture on easy rather than on steep land zones and animals tended to congregate on flatter areas (camps, tracks) (Grant & Brock 1974; Sheath 1981; Gillingham 1982). For example, as the rate of dung accumulation is positively related to high levels of feed intake and pasture utilisation (Sheath 1981; Gillingham 1982), the sharp increase in the dung accumulation rate with decrease in land slope can indicate the differences in pasture utilisation between different microtopographical sites (Gillingham 1982). Clark *et al.* (1984a) found in their study that ryegrass tillers on slopes  $< 12^\circ$  were grazed more frequently and severely by sheep than those on slopes  $> 25^\circ$ .

(3) The discriminatory grazing behaviour (by sheep) between microsites was usually modified by grazing season and grazing duration. For example, although sheep

defoliation frequency was much higher on flat terrain than on sloping zones, this preference was encouraged by longer rotation duration/lower stocking rate management combinations (Sheath 1981) or only occurred in summer. At other times of the year, slope had no effect on the defoliation frequency of ryegrass, browntop and white clover in hill pastures. As the pasture accessibility (i.e., slope class) does not vary with the grazing season or grazing duration, therefore, they speculated this discriminatory grazing behaviour was probably mainly related to the variable vegetation conditions between microsites (Sheath 1981; Gillingham 1982; Clark *et al.* 1984a).

(4) Sheep may graze areas of pasture on the basis of herbage length in leafy, well-utilised swards, hence patches of ryegrass will be visited more often than browntop or white clover (Lambert *et al.* 1986a). In areas where several species are mixed, white clover leaves and short tillers are more likely to escape defoliation than long tillers, and hence will have lower defoliation frequencies (Clark *et al.* 1984a; Lambert *et al.* 1986a). The very long defoliation interval for white clover in winter does not support the idea of active selection of this species (Watkin & Clements 1978), but can be explained by slow leaf appearance rates, considerable burial of stolons by earthworm casts and treading (Chapman *et al.* 1983), and very short petioles in winter (Brougham 1962). At the same time, some effects of slope on the severity of defoliation of white clover were observed. These occurred mainly in spring when fewer leaves were grazed per stolon on flatter areas than on medium or steep slopes. On flat sites, clover leaves are less accessible because of greater grass growth; on steeper slopes, grass growth is less vigorous and green clover leaves are more

accessible and identifiable (Clark *et al.* 1984a). The lower defoliation frequency (in winter) and severity (in spring) for white clover on flatter areas were misled into thinking that these areas would be less frequently and severely grazed by sheep during these seasons. However, Clark *et al.*' (1984a) study on grasses (e.g., ryegrass, browntop) did not show a different grazing pattern between microsites during winter and spring.

(5) Clark *et al.* (1984a) showed a positive linear relationship between defoliation frequency and severity, and that tillers from flat, fast growing areas (Lambert *et al.* 1983) were represented near the top of each regression, whereas data from smaller tillers from steep areas (Chapman *et al.* 1983) were located nearer the origin. Fitting the relationship through the origin allowed for the possibility that some slow-growing plant units may not be defoliated during any grazing rotation, as is often observed in winter and spring, and did not substantially alter the slope of regression lines.

(6) It is concluded that sheep usually defoliated flatter terrain more frequently and severely than sloping terrain in hill pastures. But, this general trend was usually modified by soil fertility level, grazing season, grazing duration/stocking rate combination and pasture characteristics. The main reason for giving rise to this discriminatory grazing behaviour of sheep between microsites in hill pastures probably has something to do with the variation of vegetation conditions (hypothesis).

### 2.2.3.3 Solutions

As slope class can cause extreme diversity of microclimate, soil conditions, pasture characteristics and animal grazing behaviour, so a lot of research had been carried out to investigate the possible solutions in New Zealand. They found that a more uniform grazing between the preferred easy and the rejected steep land zones could be achieved by:

(1) **Subdivision:** In hill pasture, improved stock control and reduced paddock variability can be achieved by subdividing preferred from rejected areas, and where possible, fencing of pasture into topographically uniform paddocks either all "easy" or all "steep" or separated sunny and shady aspects (Sheath 1981; Gillingham 1982).

(2) **Mixed grazing:** In order to achieve more even grazing, mixed grazing (Lambert *et al.* 1981; Clark *et al.* 1984b; Greaves & Wedderburn 1993; Nicol *et al.* 1993; Betteridge *et al.* 1994) has been recommended for steep hill country.

Goats have been observed to graze less deeply into a sward than sheep or cattle (Nicol & Russel 1993). Goats and sheep exhibit complementary grazing behaviour on hill country. For example, sheep and goats competed for forage only about 50% of the time, the goats spending much of the total grazing time grazing on kerbs, banks and coarse weeds on sloping zones, while sheep preferred to harvest forage from the remainder of the area (Lambert *et al.* 1981). The output of animal products from grazing systems on temperate swards involving combinations of cattle and sheep may be higher than the output from either species alone, for example, mixed grazing could increase animal production 10-20% compared with mono-grazing

(Nolan & Connolly 1977). Collins & Nicol (1989) demonstrated higher intake by both sheep and cattle when grazed with goats on rapidly defoliated swards, and that the diet selected by sheep and cattle grazed with goats contained more green leaf (5-11%) and less seed head (2-7%) (Nicol *et al.* 1993). Goats can control a range of coarse weeds such as blackberry, barberry, gorse, bracken fern, manuka, kanuka, heath, rushes, sweet briar, thistles, but do not prefer to graze white clover. Hence goat grazing can create swards having a low proportion of rushes and coarse weeds, and a high content of clover (Lambert *et al.* 1981).

However, goats have gained a reputation for causing soil erosion on hill country (Batten 1979; WASCO 1986), but Greaves & Wedderburn' study (1993) showed little evidence of erosion-causing behaviour of goats.

Therefore, mixed grazing can change not only herbage composition (more white clover and less weeds) and increase annual herbage accumulation (there is a close association between increased annual white clover accumulation and herbage accumulation), but also increase meat and fibre production from the more uniform pasture utilization across microsites or from the complementary grazing behaviour (Lambert *et al.* 1981; Clark *et al.* 1984b).

**(3) Higher stock density:** Shorter grazing duration/higher stock density combinations (Sheath 1981) have been recommended for hill country in terms of a more uniform utilization of pastures between microsites.

A lot of research has been carried out in hill pastures to study the influence of different grazing pressures on pastures located on sloping and flatter areas. Suckling (1964) concluded that there is an optimum stocking rate which not only gives maximum output in terms of meat and wool, but also maintains a vigorous, dense and evenly utilised pasture. He pointed out that it is necessary to consume as much as possible of available herbage as it grows, so that it remains palatable and highly nutritious at all times. His trials showed that hill pastures are utilized better, and the output of animal products is increased, by simply putting on more stock. However, at too high a stocking rate, although ryegrass increases as a component of a hill sward (Allan 1985) on flatter slopes, the legumes such as alsike clover, red clover, lucerne and Maku lotus decrease, because they are much more reliant on lax grazing management than species such as white clover, ryegrass and browntop. Moreover, the excessive grazing on flatter terrain can also give rise to the degradation in vegetation such as weed infestation, bare ground formation because of severe treading damage and pugging (Mackay *et al.* 1993). In fact, much bare ground is present on tracks (During & Radcliffe 1962).

Sheath & Boom (1985a) found that hard grazing during November-January to pasture mass levels of 1600 and 700 kg DM/ha on flat and sloping areas respectively might remove reproductive grass stems and hence reduce current herbage accumulation rates. This reduction would be of little immediate practical consequence, however, because this period is commonly one of pasture surplus in summer-moist hill country. More important are the possible carryover effects of increased summer-autumn and decreased winter-spring production. In terms of increased summer production, the

benefits of maintaining pasture density are most evident where perennial pasture species predominate on moister, flat areas. Korte *et al.* (1984) considered that the prevention and elimination of reproductive grass stem is a prime late spring management objective in lowland ryegrass dominant pastures. This would also seem to be true for higher fertility and moister areas of easier contour within a hillside mosaic. In contrast, if the grazing pressure is too hard (below 700 kg DM/ha) during this period, it is impossible to sustain longer-term productivity on drier slope areas which are dependant upon reseeding and regeneration of winter-spring growing annual populations. This disadvantage is most relevant to north-facing and/or steep hill faces (Sheath & Boom 1985a).

Utilization levels that avoid the accumulation of dead material but allow reseeding to occur is one of the most important grazing criteria for steep hill pastures. A post-grazing pasture mass of approximately 1000-1200 kg DM/ha on slopes (Sheath *et al.* 1984) or one which is maintained at 1200-1500 kg DM/ha (Hodgson & Maxwell 1984) during the main season of growth, if net herbage production is to be maximised on flatter regions, would achieve this condition in hill pastures. As grazing pressure declines, pasture on flat areas within a hillside is relatively better utilised than on sloping terrain (Sheath & Boom 1985a). When post-grazing pasture mass on flat areas is up to 2000 kg DM/ha, high accumulation of pasture mass and dead material would occur not only on slopes but also on flat areas too, which will eventually counteract their high productive potential (Sheath & Boom 1985a), especially during warm seasons. The compromise between correctly managing both flat and sloping areas on a hillside therefore depends on their relative surface area

and contribution of pasture dry matter to feed deficit periods. Hence harder grazing during warm, dry seasons (e.g., November-April) should out-produce low utilization with long spelling and/or lax grazing (Sheath & Boom 1985a). With the latter situation, the growth of new plant dry matter is counterbalanced by the death of old tissue. Also shading may affect reseeding with long spelling and/or lax grazing. Hard grazing in summer did not lead to species composition degeneration during a 3-year study period, provided pasture density is not jeopardised (Sheath & Boom 1985a).

#### **2.2.4 Conclusion**

The practical experience and research results reviewed above show that slope class has a wide influence not only on microclimate, soil conditions, pasture species composition and HAR, but also on sheep grazing behaviour. Interactions among these variables can be divided into three categories: (1) effects of slope class on microclimate and soil conditions (ecological factors), (2) effects of soil conditions on pasture species composition and HAR (primary production), (3) effects of the pasture species composition and HAR on animal grazing behaviour and animal production (secondary production). In this interaction chain (i.e., from slope class to climate and soils, primary production and secondary production), slope class, soil fertility level, pasture species composition and sheep grazing behaviour are the main variables affecting each other. For example, slope variation causes different soil fertility levels between slope class. The variable soil fertility levels further give rise to differences between microsites in pasture species composition. These differences lead to sheep discriminatory grazing behaviour between flat and sloping terrains, which in turn

strongly modifies these variables and their original relationship. In this process, slope variation is the cause, pasture species composition and sheep grazing behaviour are not only effect but also cause. Because microtopography can not be easily modified, so further study into the mechanisms of sheep discriminatory grazing behaviour is of particular significance in lessening this issue. Although a lot of research has been carried out on the first and second stages in this process, there is a lack of quantitative information on the reason for causing sheep discriminatory grazing behaviour between microsites in hill pasture, and the general trend for sheep grazing discrimination on different slope classes also needs to be further confirmed. An interim conclusion is that the main reason for preferential grazing on flatter areas is from vegetation conditions (e.g., variation in botanical composition between microsites). However, to test the validity of this hypothesis, it is necessary to carry out further studies on the reasons for sheep grazing discrimination between microsites, and the mechanisms of interaction between grazing animals and pastures on different slope classes in hill pastures.

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# CHAPTER 3

## MATERIALS AND METHODS

### 3.1 SITE

This study was carried out from June of 1995 to May of 1996 on the Ballantrae hill country research station of AgResearch, 20 km NE of Palmerston North. Average annual rainfall (1970-1995) was 1205 mm, evenly distributed throughout the year. Mean annual air temperature (1970-1995) was 12.2°C, with a maximum mean monthly air temperature of 19.0°C in February and minimum of 6.0°C in June and July (1970-1995) (Table 3.1).

The experimental sites were located within a long-term fertilizer trial described by Lambert *et al.* (1983). The altitude varies from 125-350 m; The soils are a Yellow Brown Earths, intergrades to yellow-grey earths and related steep and land soils (Lambert *et al.* 1986b). Pasture is dominated by ryegrass, browntop, sweet vernal, crested dogstail with approximately 10% legumes on an annual basis (Lambert *et al.* 1982).

### 3.2 EXPERIMENTAL DESIGN

**Table 3.1 Meteorological data from 1970-1995 and 1995 at Ballantrae\***

Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm) (1970-1995)	Mean	78.8	82.2	101.7	94.2	103.5	112.2	108.9	98.6	111.8	110.9	98.8	103.6
	Max	246.8	239.6	265.7	232.9	161.3	223.1	321.6	184.6	204.8	200.6	208.1	224.8
	Min	16.6	15.7	27.7	22.1	33.9	49.9	22.7	33.2	27.1	45.1	38.7	40.5
Rainfall (1995)	Mean	47.9	72.6	136.7	177.4	110.0	159.2	128.4	120.3	204.8	170.1	161.3	79.3
Air temperature (°C) (1970-1995)	Mean	16.6	16.6	15.5	12.9	10.4	8.6	7.8	8.5	10.0	11.5	13.2	15.1
	Max	18.4	19.0	17.9	15.2	12.0	10.7	9.4	10.9	11.8	12.8	15.4	16.8
	Min	14.7	14.4	13.0	10.1	7.9	6.0	6.0	7.2	8.2	9.9	11.1	13.2
Temperature (1995)	Mean	16.7	17.1	16.2	14.2	10.9	8.6	7.3	7.8	9.9	11.4	12.1	16.2

\* Data are from Ballantrae Hill Country Research Station of AgResearch (Barker, unpublished data)

A Paired Comparison Experimental Design was used in the field marked plant and turf transplant experiments.

### 3.2.1 Time

The experiments were carried out in three separate periods and two paddocks from June 1995 to May 1996.

In the first period (winter experiment) during 20/06 to 10/08/95, the marked plant experiment was conducted, and botanical composition data were collected by using the first-hit point analysis technique.

In the second period (spring experiment) during 14/09 to 10/10/95, the turf transplant experiment and a visual observation trial were carried out.

In the third period (autumn experiment) during 03/03 to 30/05/96, the second transplant trial was conducted, and botanical composition data were collected by harvesting samples and hand dissection into component species.

### 3.2.2 Paddock and slope class

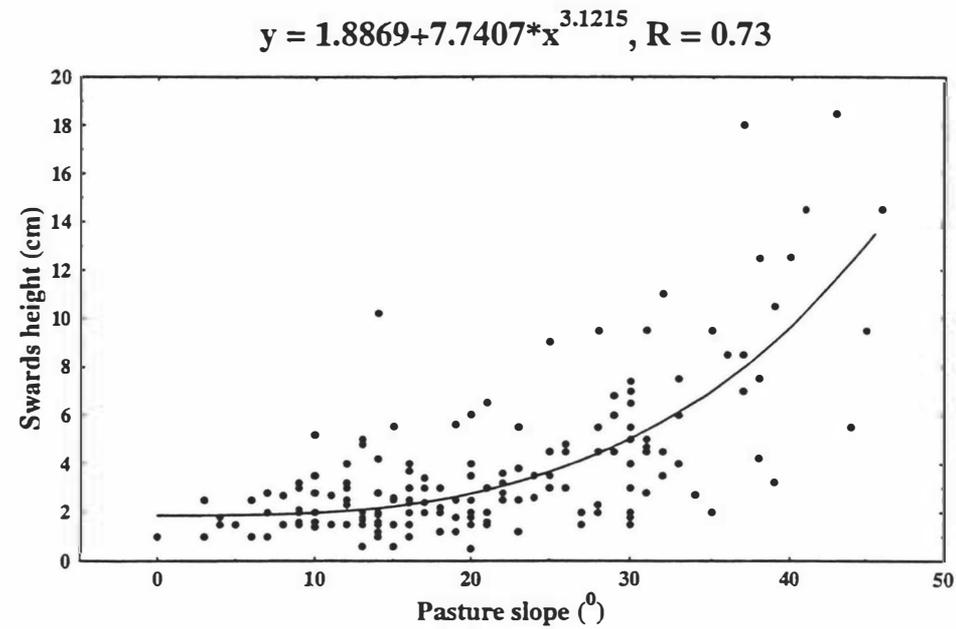
**TWO PADDOCKS:** The field experiment was carried out in two paddocks, which were part of a long-established fertilizer trial on set-stocked hill pastures (Lambert *et al.* 1983, 1986).

One paddock (H) had an area of 0.61 ha, and had received a high fertilizer application rate--630 kg/ha/a of superphosphate (9% P and 11% S) during 1975-1980, 375 kg/ha/a of superphosphate during 1982-1996. Stocking rate had been 16.1 s.u./ha since 1982 and soil Olsen P status on the paddock average slope (25°) was 40 mg/kg.

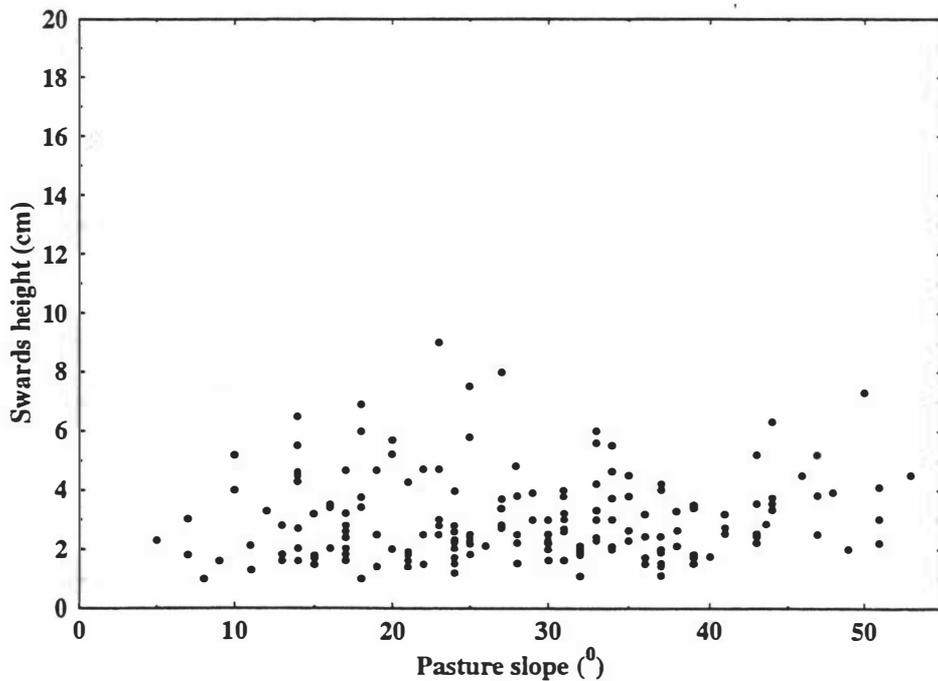
The other paddock (L) had an area of 0.98 ha, had received a low fertilizer application rate--125 kg/ha/a of superphosphate during 1975-1981, and no fertilizer was applied during 1982-1996. This paddock had been stocked at an average 9.0 s.u./ha since 1981, which was adjusted in autumn of 1996 according to its relative HAR as described by Lambert *et al* (1983), and average soil Olsen P status on the average paddock slope (17°) was 6 mg/kg.

The marked plant, visual observation and the first-hit point analysis trials were carried out in both paddocks (H & L) simultaneously. After that, in the L paddock the turf transplant and herbage sampling trials were conducted.

**SLOPE CLASS:** In each of the two paddocks (H & L), 3 transects (30 m in length) running downslope were selected so as to contain a range of microsites. At 0.5 m intervals, slope and sward surface height were measured. The plant species were recorded for each of 5 plant hits by first-hit point analysis at each interval. From this preliminary study, two slope classes--flat terrain (FT) between 0-20° and steeply sloping terrain (ST) between 30-45° were determined in each paddock, and the slopes between 20-30° were as the transition zones between these two slope classes



(a) Low soil fertilizer/low stocking rate (L)



(b) High soil fertilizer/high stocking rate (H)

Figure 3.1 Relationship between pasture slope ( $^{\circ}$ ) and sward height (cm) on (a) low soil fertilizer/low stocking rate treatment (L), and (b) high soil fertilizer/high stocking rate treatment (H) in hill pastures set-stocked with sheep during winter

**Table 3.2 Botanical composition on the FT and ST for both the H and L treatments in hill pastures during winter**

**Data are presented as the mean frequency percentages (%) of each species in the sward as determined by the first-hit point quadrat. Before analysis data were normalised by the ARCSIN transformation**

Plant				Br.	Rg.	Pa.	Fw.	Fc.	Wc.	Ms.	Cf.	Yf.	Lc.	Pp.	Dt.	
Soil fertilizer/ stocking rate	L	Slope class	ST	48.78	0.00	0.00	14.63	13.17	6.83	5.37	4.39	2.44	2.44	0.98	0.98	
			FT	48.42	0.00	0.00	14.74	11.58	6.32	4.21	4.21	8.42	2.11	0.00	0.00	
		SEM			30.76	0.00	0.00	15.99	21.14	10.84	11.69	12.80	10.47	7.45	3.62	3.62
		SIG.			NS	NS	NS	NS								
	H	Slope class	ST	20.77	14.62	23.85	10.00	1.54	7.69	12.3	0.00	9.23	0.00	0.00	0.00	
			FT	0.00	38.18	30.91	3.64	0.00	7.27	4.85	0.00	8.48	0.00	0.00	0.00	
		SEM			21.25	31.08	29.22	12.00	2.60	11.68	13.45	0.00	18.67	0.00	0.00	0.00
		SIG.			**	**	NS	+	NS	NS	+	NS	NS	NS	NS	NS

Rg--Ryegrass, Pa--Annual meadow grass, Br--Browntop, Fw--Flatweeds, Fc--Fescue spp., Wc--White clover  
Ms--Moss, Cf--Chewings fescue, Yf--Yorkshire fog, Lc--Lotus pedunculatus cv., Dt--Danthonia, Pp--Poa pratensis

SEM--Standard error of least square means; NS--No significant difference

+--P<0.1

\*--P<0.05

\*\*--P<0.01

\*\*\*--P<0.001

(Figure 3.1). As white clover occurred on each terrain (Table 3.2) and was usually with higher palatability for sheep, it was selected as the target plant for interpreting sheep grazing behaviour in this study.

### 3.2.3 Treatments and Measurements

**MARKED PLANTS:** 10 paired quadrats (200 \* 300 mm per quadrat) were selected in each of the two paddocks (H & L). For each pair of quadrats, one was sited on the FT, the other one on the ST. Within each quadrat 10 white clover growing points were marked with coloured paper clips, i.e., in total 200 marked stolons in each of the two paddocks (2 terrains \* 10 replicates \* 10 marked stolons = 200). This experiment was carried out in winter of 1995.

The defoliation frequency and severity of white clover on each terrain was estimated by observing for grazing damage of each marked plant stolon and the leaf status on each stolon over the 4 week grazing period at 1-week intervals. The stolon was recorded as ungrazed stolon (NS), or grazed stolon (GS) when any leaf on the stolon was grazed, while leaf status was recorded as ungrazed leaf (NL), grazed leaf (GL), dead leaf (DL), emerging leaf (ML) and expanded leaf (XL). When more than 50% of a leaf by area was grazed or more than 10% of a leaf by area was dead, then the leaf was recorded as GL or DL.

The defoliation frequency was calculated according to the mean proportion of white clover stolons defoliated to the total marked white clover stolons present per week

over the 4 week grazing period on each treatment (i.e., slope class or/and turf source combinations, soil fertilizer/stocking rate). Similarly, the defoliation severity was given as the mean leaf numbers grazed per stolon per week during the 4-week grazing on each treatment.

Leaf accumulation rate (LAR) =  $(XL + ML)/wk$ ;

Leaf lost rate (LLR) =  $(DL + GL)/wk$ ;

leaf balance (LB) = leaf accumulation rate - leaf lost rate =  $(LAR - LLR)$ ,

i.e.  $LB = [(XL+ML) - (DL+GL)]/wk$ .

**TURF TRANSPLANT:** 10 sites that contained FT and ST were selected in the L paddock. At each site, four paired turves (200 \* 300 mm per turf) were cut with a mean soil thickness of 8-10 cm, two turves were from the FT and the other two from the ST. These were transplanted into similar or contrary terrain to give all combinations of turf and terrain. About 10 white clover growing points were selected at random and marked in each turf (in total about 400 stolons). The status of stolon (GS, NS) and leaves (NL, GL, DL, XL, ML) on each stolon was observed and recorded weekly over 4 weeks during spring of 1996. This trial was repeated again in autumn of 1996.

During winter and spring, pastures in both paddocks were set-stocked with sheep (i.e., preliminary experiment, the marked plant experiment and transplant experiment in spring). In the drier autumn period the turves were in place 3 weeks (i.e., pasture had a 3-week spell) before being grazed, to let the turf recover for the second period

of turf transplant experiment.

**VISUAL OBSERVATION:** In order to measure time sheep spent on each terrain, sheep number present on each terrain was observed and recorded at 5-minute intervals in each of 50 randomly selected sites in both paddocks for one week during spring of 1996. The field observation was interchanged between two paddocks at half hour intervals during the trial, between 9.30 am-4.00 pm.

**HERBAGE DISSECTION:** One 200 \* 300 mm quadrat was cut to ground level adjacent to each of the transplant sites. The herbage samples were dissected in the laboratory into component species. This experiment was carried out in autumn of 1996.

### 3.3 STATISTICAL ANALYSIS

The percentage defoliation frequency data were normalised by ARCSIN transformation before analysis. The analysis of variance (ANOVA) of data and the tests for significance of differences between terrains and transplant treatments used Multiple Comparison Procedures of the General Linear Model of PC-SAS.

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# CHAPTER 4

## RESULTS

### 4.1 EFFECT OF SLOPE CLASS ON SHEEP GRAZING BEHAVIOUR

#### 4.1.1 Defoliation frequency

This experiment confirms that sheep generally defoliated the FT more frequently than ST in hill pastures. For example, sheep defoliated the FT more frequently than ST in winter for the H treatment (0.38 vs  $0.29 \pm 0.10$ ;  $P < 0.05$ ) (Table 4.1), and in autumn, which involved only the L treatment irrespective of turf source ( $0.38$  vs  $0.11 \pm 0.18$ ;  $P < 0.001$ ) (Table 4.2). But, this effect was not persistent, and it usually disappeared on the other treatments and in the other grazing seasons.

#### 4.1.2 Defoliation severity

Except in spring, the defoliation severity of white clover by sheep grazing on two slope classes was with the same trend as the defoliation frequency. For example, the defoliation severity was usually higher on the FT than on ST, but this only occurred

in winter for the H treatment ( $0.45$  vs  $0.30 \pm 0.11$ ;  $P < 0.05$ ), and in autumn for the L treatment ( $0.81$  vs  $0.19 \pm 0.41$ ;  $P < 0.001$ ) (Tables 4.1, 4.2). On the other treatments, this phenomenon did not occur.

### 4.1.3 Relationship between defoliation frequency and severity

Further analysis shows that the defoliation frequency was very closely ( $R^2 = 0.89$ - $0.99$ ) related to the severity during all the three grazing periods. Their relationship can be expressed by the following positive linear regressions:

$$\text{Winter: } Y = -0.0256 + 1.2344 * X, R^2 = 0.89$$

$$\text{Spring: } Y = -0.1160 + 2.4167 * X, R^2 = 0.99$$

$$\text{Autumn: } Y = 0.0111 + 2.1793 * X, R^2 = 0.99$$

Where, Y is the defoliation severity, X the defoliation frequency.

So, sheep demonstrated varying intensities of grazing related to slope in hill pastures. The FT was usually more heavily grazed by sheep than the ST under the same stocking rate. But, this general trend for preferential grazing towards the FT was usually modified by grazing season, grazing duration and soil fertilizer/stocking rate. Evidence on these effects are given separately in the following.

**Table 4.1 Defoliation frequency and severity of marked white clover stolons by sheep grazing on 2 slope classes for both the H and L treatments in hill pastures during winter**

Soil fertilizer /stocking rate	L				H				
	Slope class	ST	FT	SEM	SIG.	ST	FT	SEM	SIG.
Frequency <sup>#</sup>		0.24	0.30	0.12	NS	0.29	0.38	0.10	*
Severity <sup>##</sup>		0.28	0.37	0.16	NS	0.30	0.45	0.11	*

**# Data are presented as proportion of grazed stolons to the total marked white clover stolons per week**

**## Data are presented as number of leaves grazed by sheep per stolon per week**

**SEM--Standard error of least square means; \*--P<0.05**

**Table 4.2 Defoliation frequency and severity of marked white clover stolons by sheep grazing on 2 slope classes for the L treatment in hill pastures during spring and autumn**  
**The observations were made on turves cut and transplanted into similar or contrasting terrain**

Slope	class	ST		FT		SEM	SIG.	
		Turf	source	ST	FT			ST
Spring	Frequency <sup>#</sup>		0.17ab	0.18ab	0.20a	0.09b	0.13	*
	Severity <sup>##</sup>		0.32a	0.31a	0.37a	0.09b	0.23	*
Autumn	Frequency <sup>#</sup>		0.11b	0.36a	0.15b	0.38a	0.18	***
	Severity <sup>##</sup>		0.19b	0.87a	0.28b	0.81a	0.41	***

# Data are presented as proportion of grazed stolons to the total marked white clover stolons per week

## Data are presented as number of leaves grazed by sheep per stolon per week

SEM--Standard error of least square means; \*-P<0.05; \*\*\*-P<0.001

**Table 4.3 Observed sheep numbers distributed on 2 slope classes for both the H and L treatments during spring; Data are presented as the mean sheep numbers distributed on each slope class recorded at 5 minute intervals**

Slope class		FT	ST	SEM	SIG.
Soil fertilizer/ stocking rate	H	2.91	1.67	1.44	***
	L	2.41	1.92	0.97	NS

SEM--Standard error of least square means; NS--No significant difference; \*\*\*--P<0.001

## 4.2 FACTORS MODIFYING SHEEP GRAZING DISCRIMINATION FOR WHITE CLOVER BETWEEN SLOPE CLASS

### 4.2.1 Soil fertilizer/stocking rate

In winter, the defoliation frequency ( $0.38$  vs  $0.29 \pm 0.10$ ;  $P < 0.05$ ) and severity ( $0.45$  vs  $0.30 \pm 0.11$ ;  $P < 0.05$ ) of marked white clover stolons by sheep were significantly higher on the FT than on ST for the H treatment, but with no significant difference between microsites for the L treatment (Table 4.1). This result is consistent with that of the spring visual observation, which shows that more ( $2.91$  vs  $1.67 \pm 1.44$ ;  $P < 0.001$ ) sheep were present on the FT and spent more time on the FT than on ST, but again this only occurred on the H treatment (Table 4.3).

Higher soil fertilizer/higher stocking rate combination would give rise to more severe sheep grazing discrimination between microsites in hill pastures.

### 4.2.2 Grazing season

For the L treatment, this general trend towards preferential grazing on the FT was further modified by grazing seasons. For example, the defoliation frequency were significantly higher on the FT than on ST, but this only occurred in autumn ( $0.38$  vs

**Table 4.4 Defoliation frequency and severity of marked white clover stolons by sheep grazing on 2 slope classes for the L treatment during different seasons in hill pastures**

Season			Winter	Spring	Autumn	SEM	SIG.
Frequency <sup>#</sup>	Slope	ST	0.24a	0.17ab	0.11b	0.12	*
	class	FT	0.30a	0.09b	0.38a	0.19	***
	SEM		0.12	0.15	0.19		
	SIG.		NS	NS	***		
Severity <sup>##</sup>	Slope	ST	0.28	0.32	0.19	0.18	NS
	class	FT	0.37b	0.09c	0.81a	0.38	***
	SEM		0.16	0.22	0.40		
	SIG.		NS	*	***		

# Data are presented as proportion of grazed stolons to the total marked white clover stolons per week

## Data are presented as number of leaves grazed by sheep per stolon per week

SEM--Standard error of least square means; NS--No significant difference; \*--P<0.05; \*\*\*--P<0.001

Letters indicate significant difference within rows

$11 \pm 0.19$ ;  $P < 0.001$ ), not in winter and spring (Table 4.4). The result of the defoliation severity is consistent with that of the defoliation frequency in winter ( $0.37$  vs  $0.28 \pm 0.16$ ; NS,  $P > 0.1$ ) and autumn ( $0.81$  vs  $0.19 \pm 0.40$ ;  $P < 0.001$ ), but not in spring. In spring, the FT was significantly ( $0.09$  vs  $0.32 \pm 0.22$ ;  $P < 0.05$ ) less severely defoliated than ST by sheep on the L treatment, this effect is opposite to that of the frequency (Table 4.4), it is also inconsistent with the results of visual observation (Table 4.3).

So, under the L treatment, this preferential grazing for the FT mainly occurred in autumn, not in spring and winter (i.e., for defoliation frequency), or only occurred in winter for the defoliation severity. Actually, between autumn and spring, there was a opposite sheep grazing behaviour on the two slope classes in terms of the defoliation severity. It can be concluded that, on the L treatment, sheep grazing behaviour in hill pastures was further modified by grazing season.

### 4.2.3 Grazing duration

Further study show that the discriminatory grazing behaviour between microsites was not only modified by soil fertilizer/stocking rate, grazing season, but also by grazing duration. For instance, although the defoliation frequency and severity were significantly ( $P < 0.05$ - $P < 0.001$ ) higher on the FT than on ST in autumn for the L treatment, it only occurred within the first three weeks (Table 4.5). At other times (in autumn grazing period), a uniform grazing of white clover stolons by sheep between slope class was achieved.

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In spring and winter, this effect did not occur, or only occurred in the first week in winter for the defoliation frequency, e.g., the defoliation frequency was higher ( $0.37$  vs  $0.26 \pm 0.14$ ;  $P < 0.1$ ) on the FT than on ST, but this only happened in the first week of the winter grazing period, after that no significant influence of slope class on sheep grazing behaviour was observed (Appendix tables 2, 3).

In this experiment, the pasture was given a 3-week spell in autumn for the transplanted turves to recover before the grazing trial started, in spring and winter, pastures were continually set-stocked by sheep.

Sheep grazing discrimination between microsites was further modified by grazing duration space on the L treatment. In the early stage of a grazing period, the general trend for preferential grazing on the FT was stronger. This effect will be discussed in terms of herbage allowance per ewe.

**Table 4.5 Defoliation frequency and severity of marked white clover stolons by sheep grazing on 2 slope classes over 4 weeks for the L treatment in hill pastures during autumn**  
**The observations were made on turves cut and transplanted into similar or contrasting terrain**

Item		Frequency				Severity			
Slope	class	ST	FT	SEM	SIG.	ST	FT	SEM	SIG.
Week	1	0.03	0.35	0.24	***	0.05	0.86	0.72	*
	2	0.15	0.39	0.30	+	0.29	0.78	0.64	+
	3	0.09	0.45	0.29	**	0.11	0.83	0.54	*
	4	0.17	0.33	0.24	NS	0.30	0.66	0.53	NS
SEM		0.18	0.28			0.32	0.69		
SIG.		NS	NS			NS	NS		

**# Data are presented as proportion of grazed stolons to the total marked white clover stolons per week**

**## Data are presented as number of leaves grazed by sheep per stolon per week;**

SEM--Standard error of least square means; NS--No significant difference; +-P<0.1; \*-P<0.05; \*\*--P<0.01; \*\*\*--P<0.001

### **4.3 REASON FOR SHEEP GRAZING DISCRIMINATION BETWEEN SLOPE CLASS**

#### **4.3.1 Effect of turf transplant on sheep grazing discrimination for white clover between slope class**

The results from the turf transplants show different effects with season. In spring white clover in the FT turf transplanted into FT was significantly (0.09 vs 0.20;  $P < 0.05$ ) less frequently defoliated than it being transplanted into the ST, or it was less severely (0.09 vs 0.37;  $P < 0.05$ ) defoliated by sheep than white clover in all the other transplant treatments (Table 4.2).

In autumn the white clover in the turf from the FT was grazed more frequently (0.38, 0.36 vs 0.15, 0.11;  $P < 0.001$ ) and severely (0.81, 0.87 vs 0.28, 0.19;  $P < 0.001$ ) irrespective of its location in the sward (Table 4.2).

Turf transplant had little effect on sheep grazing discrimination between microsites. Vegetation conditions might be the main variable for causing sheep discriminatory grazing behaviour between microsites in hill pastures. This effect would be further studied in the following herbage dissection trial.

#### **4.3.2 Difference in botanical composition between slope class**

Botanical composition, measured by harvesting herbage samples adjacent to each of the transplant sites and hand dissection into component species in the autumn, confirms that botanical composition varied with slope class. Browntop was the dominant species on both slope classes for the L treatment, but its content in the sward was higher ( $P < 0.1$ ) on the ST (20%) than on FT (14%). The contents of ryegrass, white clover and Yorkshire fog were significantly ( $P < 0.1$ ) lower on the ST (0.07, 2.60 and 0.65%) than on the FT (2.23, 6.94 and 3.00%) respectively while dead material content was constant (43-44%) across both slope classes (Table 4.6). These effects were more stronger in the winter preliminary experiment (Table 3.2).

Therefore, Variable pasture botanical composition between microsites was probably the main vegetative factor for causing the discriminatory grazing behaviour of sheep in hill pastures.

**Table 4.6 Botanical composition (%) on the FT and ST for the L treatment in hill pastures during autumn**

Data are presented as the mean dry matter percentages (%) of each species in the sward as determined by herbage dissection, before analysis data were initially normalised by the ARCSIN transformation

Plants			Br.	Sv.	Cf.	Yf.	Dt.	Cd.	Rg.	Co.	Pp.	Wc.	Lc.	Sc.	Ms.	OS.	DD.
L	Slope	ST	20.47	9.15	1.79	0.65	1.40	0.04	0.07	0.18	0.00	2.60	1.50	0.00	9.93	7.77	44.44
	class	FT	14.28	4.20	3.73	3.00	2.07	2.27	2.23	0.00	0.05	6.94	1.89	0.92	6.25	8.83	43.39
	SEM		7.53	7.76	2.24	2.88	3.85	2.08	2.76	0.40	0.11	5.58	2.91	1.67	9.11	4.32	13.69
	SIG.		+	NS	+	+	NS	*	+	NS	NS	+	NS	NS	NS	NS	NS

Rg--Ryegrass, Br--Browntop, Wc--White clover, Sv--Sweet vernal, Cd--Crested dogstail, Co--Cocksfoot, Sc--Suckling clover, OS--Other species, DD--Dead material,

Ms--Moss, Cf--Chewings fescue, Yf--Yorkshire fog, Lc--Lotus pedunculatus cv., Dt--Danthonia, Pp--Poa pratensis

SEM--Standard error of least square means; NS--No significant difference

+--P<0.1

\*--P<0.05

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# CHAPTER 5

## DISCUSSION

Hill country is usually so broken topographically as to make management strategies with respect to slope class impractical. However, it may often be advantageous to take into account the effect of slope on pastures when deciding on grazing management (Suckling 1975), and pasture renovation policies (Lambert & Roberts 1978).

### 5.1 EFFECT OF SLOPE CLASS ON SHEEP GRAZING BEHAVIOUR

#### 5.1.1 Defoliation frequency

Generally, defoliation frequency of the marked white clover stolons by sheep grazing in the set-stocked hill pastures was significantly higher on the FT than on ST in winter for the H treatment and in autumn for the L treatment (Table 4.1, 4.2). This result is consistent with that of Clark *et al.* (1984a) and basically confirms that sheep shows a general trend towards preferential grazing of pastures on tracks or easy

slopes rather than banks or steep land zones (Grant & Brock 1974; Sheath 1981; Gillingham 1982; Lambert *et al.* 1986). As sheep usually spent more time on the FT than on ST or more sheep generally presented on the FT than on ST in spring for the L treatment (Table 4.3), sheep grazing discrimination between microsites could have something to do with either the accessibility (e.g., pasture slope) or vegetation conditions (e.g., herbage quality and quantity) of pastures. The reason will be discussed later by the results of turf transplant and herbage dissection experiments.

### 5.1.2 Defoliation severity

Defoliation severity is usually expressed as the leaf length grazed per tiller relative to leaf length initially present for grasses (Hodgson & Ollerenshaw 1969; Hodgson 1979). For white clover, the number of leaves removed from stolon apices at each defoliation was the equivalent measure of defoliation severity (Clark *et al.* 1984a). So, in this study, the "defoliation severity" was given as the number of leaves grazed by sheep per marked white clover stolons per week. Results show that the "defoliation severity" was influenced greatly by pasture slope. This was the same trend as defoliation frequency during all the three seasons for both the H and L treatments (Tables 4.1, 4.2). It was also found that the defoliation frequency and "severity" were positively related to each other very closely ( $R^2 = 0.89-0.99$ ) on all the treatments (slope classes and soil fertilizer/stocking rate) during all the three seasons and that their relationship could be expressed by positive linear regressions. This result is consistent with that of Clark *et al.* (1984a).

Sheep generally show no active selection of white clover as they usually graze white clover according to its proportion in the grazing horizon in mixed swards (Clark *et al.* 1982). Therefore, the higher defoliation frequency and severity on the FT and the close positive relationship between the frequency and severity imply that the FT was probably more heavily grazed by sheep than ST.

Furthermore, the LAR and DL of white clover during all the three periods were constant across both slope classes for two treatments (H & L), and the turf transplant had little effect on them. But, the LB varied with slope class. For example, except in spring, on the ST the LB was positive or the LAR was higher than the LLR for the H treatment in winter or for the L treatment in autumn while the FT shows the opposite effect under the same conditions (Appendix tables 4, 5).

So, sheep grazing discrimination rather than other uncontrollable environmental factors was the main reason for causing the LB variation between slope classes during winter and autumn, or the difference in the leaf growth rate between microsites and after transplant would not significantly modify the real defoliation pattern of this plant by sheep grazing on different slope classes. So white clover is a ideal target plant in hill pasture for interpreting sheep discriminatory grazing behaviour between microsites. The implications of these results are: (a) the results obtained in this study would be reliable; (b) the FT was more heavily grazed by sheep than ST; (c) at the present stocking rate, the ST on the H treatment would be lax grazed in winter or on the L treatment in autumn while the FT might be over-grazed under the same conditions; (d) as LAR was positively related to the

defoliation frequency very closely ( $R^2 = 0.89$ ) on both slopes in winter (Appendix figures 1, 2, 3), the higher defoliation severity would stimulate more white clover growth during this period.

## **5.2 FACTORS MODIFYING SHEEP GRAZING DISCRIMINATION FOR WHITE CLOVER BETWEEN SLOPE CLASS**

From the above discussion we can see although this study has confirmed that sheep usually defoliated the FT more frequently and severely, but this general trend greatly varied with grazing season, grazing duration, ratio of the FT/ST areas, soil fertilizer/stocking rate. For instance:

### **5.2.1 Soil fertilizer/stocking rate**

Defoliation frequency and severity of white clover by sheep were higher on the FT than on the ST on the H treatment, but not on the L treatment (Table 4.1).

This result is basically consistent with that of Clark *et al.* (1984a) who showed that the defoliation frequency (by sheep) was more frequent under a high fertility treatment than a low fertility treatment in winter-early spring for the grasses and from winter to mid summer for white clover. This might be because, though the differences in the defoliation frequency and severity of white clover between our two

treatments (H & L) were modest and not significant, the defoliation frequency and severity were higher on the H (0.29-0.38%) than on the L treatment (0.24-0.30%) (Appendix table 6), so the opportunity for preferential grazing between the FT and ST was enhanced on the H treatment. Therefore, a lower fertilizer application rate (e.g., between 125-375 kg/ha/a of superphosphate) would be beneficial in terms of more uniform sheep grazing across different slope classes if the diet intake and animal production were not taken into consideration.

But, this result is not utterly consistent with the evidence of Sheath (1981) who showed a more equitable utilization of pastures (based on the total herbage DM) between microsites in shorter grazing duration/higher stock density combinations or when herbage allowance per ewe was lower. This is because, in the present experiment (based on the white clover), the H treatment was not only with a higher stocking rate (i.e., lower herbage allowance per ewe) but also with a higher fertilizer application rate (i.e., higher herbage allowance per ewe due to a higher HAR), and the grazing duration was the same as that on the L treatment, so these present experimental results probably came from the interaction between the effects of soil fertility level and stocking rate. However, there was no direct evidence to give a satisfactory explanation to this phenomenon, which deserves further study.

Moreover, by the first-hit point analysis (preliminary experiment) in the winter, we found that the sward height was positively related to pasture slope on the L treatment, but not on the H treatment (Figure 3.1), in which sward height was quite uniform across different slope classes. This result implies that the opportunity for

preferential grazing towards the FT was lower on the H than on the L treatment compared with the longer pasture on the ST for the L treatment, which is inconsistent with the results of the above defoliation frequency. There is no obvious explanation for this effect.

However, the preliminary study on pasture botanical composition gives the supporting evidence for the phenomenon of the different responses of the discriminatory grazing behaviour between slope classes to the two soil fertilizer/stocking rate treatments in winter. Botanical composition data, collected by the first-hit point analysis, show that on the L treatment, browntop (48-49%) was the dominant species on both slopes, and there were no significant difference in botanical composition between slope classes under this treatment while for the H treatment pasture on the ST was mainly annual meadow grass (24%), browntop (21%) and ryegrass (15%), pasture on the FT was mainly ryegrass (38%) and annual meadow grass (31%). Browntop was absent on the FT of the H treatment. The differences in botanical composition between the FT and ST were much larger on the H than on the L treatment (Table 3.2). So, this larger difference in botanical composition between slope class on the H treatment would possibly enhance the grazing discrimination of this treatment.

Furthermore, in this experiment, the ratio of the FT/ST areas within each paddock was different ( $0.54$  vs  $2.15 \pm 1.84$ ;  $P > 0.1$ , NS), in a certain degree, between the H and L paddocks (Appendix table 1), so it might be another factor causing different levels of the preferential grazing on the FT between the H and L treatments, because it was reported that "the preferential grazing of pasture on easy land decreased as the

ratio of easy/steep areas increased" (Sheath 1981). The implications of this phenomenon is that subdividing pasture into topographically uniform paddocks or into higher ratio of the FT/ST areas (e.g., in the L paddock) would be beneficial in terms of a more uniform sheep grazing between microsites in hill pastures. Of course, it might not be a main factor for causing the grazing discrimination in this experiment.

Therefore, the general trend for preferential grazing by sheep on the FT was further modified by the combined effect of soil fertilizer/stocking rate, usually this preference was stronger under higher soil fertilizer/stocking rate. The main reason for causing this phenomenon was probably the variation of pasture species composition between microsites.

### **5.2.2 Grazing season**

Under the L treatment, sheep defoliated white clover on the FT more frequently than ST, but this phenomenon only occurred during autumn, not during winter and spring. The defoliation severity was similar to the defoliation frequency in winter and autumn except in spring sheep showed more severe defoliation on the ST than on FT (Table 4.4).

In spring, the result of visual observation (Table 4.3) is not consistent with that of the above marked white clover. This is because the sheep numbers recorded in the visual observation trial included all status of sheep presented on each terrain (e.g.,

grazing sheep, standing sheep and so on). Therefore, this method could be only used for investigating animal common behaviours in pastures, but not suitable for interpreting animal grazing behaviour under different pasture conditions. This effect shows although more sheep present on the FT (e.g., as a rest place) in spring, it does not necessarily resulted in a more frequently or severely grazing on these areas.

Pasture was continually set-stocked over winter and spring while in autumn it had a 3-week spell for turf recovering before grazing experiment started, so more herbage mass per ewe in autumn (though which was not measured) might be available to grazing animals, especially in the early stage of this grazing period, and this would increase the grazing discrimination, because the preferential grazing was most apparent when pasture allowance was higher or where pasture offered per ewe was increased (Sheath 1981; Gillingham 1982; Sheath & Rattray 1985). Moreover, in autumn, most plants were up to the peak of reproductive growth. Hence pastures become long, rank and higher in proportion of seed heads and reproductive stems during this period, especially on browntop dominated, laxly grazed steeply sloping areas. This situation would not only change the balance between herbage supply and animal demand, but also lead to decrease in herbage palatability. This decrease is usually more severe on the ST than on FT, this would surely increase the opportunity for preferential grazing on the FT.

In contrast, during winter and spring, white clover generally has more buried stolons (Clark *et al.* 1984a), and the petioles are shorter (Brougham 1962). Especially during spring, most grasses reached peak growth period, which would greatly overpass or

inhibit that of white clover. So white clover was less accessible because of greater grass (e.g., ryegrass) growth on the FT. on the ST, grass growth was less vigorous, and the elevated white clover stolons and leaves were more accessible and identifiable.

Therefore, the more uniform defoliation frequency of white clover between microsites during winter and spring (or for defoliation severity in winter) on the L treatment still could not prove that there was no significant grazing discrimination existing between microsites during these seasons. However, another study on ryegrass (Clark *et al.* 1984a) did not find a different grazing pattern on different slope classes by sheep during the same period in the same area. So, all these findings only imply that season might be a significant factor in modifying sheep grazing discrimination between microsites. This effect should be taken into account when making decisions on seasonal animal grazing management in hill pastures. The mechanisms about this effect deserve further study.

### 5.2.3 Grazing duration

Sheep grazing discrimination between slope classes was not persistent, but further modified by grazing duration. For example, this preference was usually more obvious during early stage of a grazing period (e.g., in autumn). After the early stage (e.g., the third week in autumn), there was no significant difference in the grazing frequency and severity between the two slope classes (Table 4.5), which are consistent with the results of Sheath (1981).

Before the autumn grazing experiment, pasture was given a 3-week spell to let turf recover, so during early stage of the autumn grazing period, the herbage allowance offered per ewe was probably higher than the later stage, the opportunity for preferential grazing would be enhanced. This was partially proved by the winter and spring grazing trials (Appendix tables 2, 3), which show no effect (in spring) or little effect (within the first week in winter) of grazing duration on the grazing discrimination when pastures were continually set-stocked over these seasons. If the "diminishing returns" relationship that exists between pasture allowance and animal intake is considered (Allden & Whittaker 1970; Hodgson 1976; Rattray *et al.* 1979), it becomes apparent that the high initial allowances of the longer grazing or rotation duration allow maximum daily intakes to occur over a much longer relative time period. Therefore, more uniform grazing between/on the preferred FT and the rejected ST or more uniform over-grazing as suggested by Spedding (1965) may be achieved with shorter grazing duration/higher stocking rate combinations (i.e., lower herbage allowance per ewe). The same principle may well hold for other preference factors such as aspect and vegetative type (Sheath 1981).

So, except botanical composition, the herbage mass or herbage allowance per ewe would be another factor which would modify sheep grazing discrimination between microsites in hill pastures. If this effect could be validated, the discriminatory grazing issue could be more easily manipulated by seasonal adjusting stocking rate after balancing the per head and per hectare animal production, compared with the improvement of pasture botanical composition, which was not only influenced by climate and soil conditions but also by animal grazing behaviour. Actually, in so

topographically broken hill pastures, sward improvement, in terms of a uniform pasture botanical compositions between microsites, is very hard to achieve. The effects of grazing duration and herbage allowance per ewe on sheep grazing discrimination between microsites deserve further study.

As the pasture accessibility (i.e., slope class) is a very stable environmental variable, and does not vary with the grazing season, grazing duration or being modified by soil fertilizer/stocking rate, so the different effects of soil fertilizer/stocking rate, grazing season and grazing duration on sheep defoliation frequency and severity had basically implied that pasture botanical composition, herbage allowance per ewe or stocking rate would be the main reasons for causing sheep grazing discrimination between microsites in hill pastures. This effect from vegetation can be seen more clearly in turf transplant and herbage dissection trials, which are discussed as the following.

### **5.3 REASONS FOR SHEEP GRAZING DISCRIMINATION BETWEEN SLOPE CLASS**

It is a generally accepted fact that goats spending much of the total grazing time grazing on kerbs, banks and coarse weeds on sloping zones, while sheep tended to congregate on flatter areas (camps, tracks) (Grant & Brock 1974; Sheath 1981; Gillingham 1982), and usually stand on tracks grazing upslope and preferred to harvest forage from the remainder of the area (Lambert *et al.* 1981). So, this phenomenon was often misled into thinking that pasture slope or pasture accessibility was the main reason for causing sheep grazing discrimination between microsites in

hill pastures. The following turf transplant and herbage dissection experiments were designed to investigate this effect.

### **5.3.1 Effect of turf transplant on sheep grazing discrimination for white clover between slope class**

Generally, the defoliation frequency and severity of the marked white clover stolons by sheep grazing in the mixed hill pastures was higher on the FT than on ST (Table 4.1, 4.2). The turf transplant results show that in autumn the turf from the FT was grazed more frequently and severely than turves from the ST when it was transplanted either into a ST or a FT (Table 4.2). When turf (i.e., either from the FT or ST) was transplanted to different microsites, the defoliation frequency and severity were higher on the FT than on ST source of turf in autumn. The result that the FT turf being transplanted into the FT was less frequently and severely defoliated in spring is not consistent with that of other seasons in this study, but is consistent with that of Clark *et al.* (1984a), who found that white clover and ryegrass on the flatter area were significantly less frequently and less severely defoliated than those on steeper zones by sheep during spring in Ballantrae hill pastures. A possible reason for this phenomenon in spring was probably because: (1) the flatter area was usually used by sheep as a camp or rest place, the plants on this terrain were flattened and often dirty, especially for white clover stolons; (2) relatively slower leaf appearance rates, considerable burial of stolons by earthworm casts and treading (Chapman *et al.* 1983), or shorter petioles of white clover, compared with (3) the greater grass (e.g., ryegrass) growth on the these areas during this period.

As turf transplant had little effect on the original grazing discrimination between microsites, so, the reason for causing sheep grazing discrimination on different slope classes may be mainly due to vegetation differences. The slope class (i.e., pasture accessibility) might be an indirect factor, its effect on sheep discriminatory grazing behaviour between microsites might mainly come from its direct influence on soil conditions such as soil fertility and moisture, further on pasture characteristics such as botanical composition (Rumball & Esler 1968; Radcliffe 1982; Sheath & Boom 1985b), sward height and HAR (Lambert *et al.* 1986).

### **5.3.2 Variation of botanical composition between slope class**

Sward height (Harris 1973; Birch 1977), botanical composition (Ulyatt 1978) and HAR (McMeekan 1960; Suckling 1959) were the main vegetation factors which not only influence

diet digestibility and feeding value of herbage but also diet selection, diet intake and animal performance.

#### **5.3.2.1 Botanical composition was the main factor in vegetation for causing the grazing discrimination between microsites**

The results of autumn herbage sampling and dissection experiment show that pasture botanical composition varied greatly with slope class. As slope decreased, white clover, ryegrass and some other high-fertility-responsive grasses (e.g., Yorkshire fog and poa spp) increased, moss, browntop and some of the low-fertility-tolerant grasses

(e.g., sweet vernal) decreased, while dead material was constant across both slope classes on the L treatment (Table 4.6). These results confirm the results of earlier trials (Lambert *et al.* 1978, 1986a; Sheath & Boom 1985b) except that the dead material content increased in the sward with pasture slopes in their experiments.

These changes might be not only mainly attributable to different soil fertility levels and grazing pressure but also, in a certain degree, to the different trampling pressure and soil moisture conditions between slope classes.

In this study, as the variation of sward surface height between slope class is inconsistent with that of defoliation frequency and severity, the content of dead material was constant across slopes and the effect of herbage allowance per ewe still needs to be validated, so the differences in pasture botanical composition between microsites may be the main factor in vegetation, which could be determined in this experiment, for causing sheep preferential grazing on the FT in hill pastures.

This effect should be discussed in terms of herbage palatability. However, at present, little information is available on this aspect.

## 5.4 SOLUTIONS

The results of this study suggest that sheep grazing discrimination between microsites is a common phenomenon in hill pasture utilization, but this issue could be lessened by: (1) measures which relate to give a uniform botanical composition between

microsites, such as suitable fertilizer application rate (e.g., between the rates of the H and L treatments), suitable stocking rate or by mixed grazing (sheep, cattle and goats); (2) seasonal grazing management (e.g., the policies based on cool and warm seasons), suitable grazing duration (e.g., shorter grazing duration/higher stocking rate combinations) and suitable herbage allowance (e.g., lower herbage allowance per ewe); (3) subdividing pasture into topographically uniform paddocks or into higher ratio of the FT/ST areas.

However, according to this study, although the higher fertilizer application rate (e.g., the H treatment) could improve pasture botanical composition such as higher ryegrass and lower browntop content in the sward on H treatment, both the differences in botanical composition and grazing discrimination between microsites would be obviously enhanced. In contrast, under the lower fertilizer application rate (e.g., the L treatment), though the differences in botanical composition between microsites would be small, both the FT and ST would be dominated by browntop or other low quality plants (Table 3.2). So, in practice, when making decisions on fertilizer application systems all these factors should be taken into consideration.

Previous studies show mixed grazing (sheep, cattle and goats) could exhibit complementary grazing behaviour in hill pastures (Lambert *et al.* 1981), could increase animal production 10-20% (e.g., more meat and fibre) compared with mono-grazing (Nolan & Connolly 1977), could change pasture composition (more white clover and less weeds) and increase annual herbage accumulation (Lambert *et al.* 1981; Clark *et al.* 1984b), however, the effect of this measure deserves further study

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in hill pastures.

Moreover, subdividing pasture into topographically uniform paddocks or into higher ratio of the FT/ST areas would be beneficial in term of a more uniform sheep grazing intensities between microsites in hill pasture. But, this usually means a smaller fencing area or higher fencing expenses, anyway the effect of this measure needs to be validated.

Therefore, seasonal manipulating on grazing management polices such as suitable stocking rate and grazing duration might be one of the easier and main strategies for lessening this issue in hill pastures. However, at present, little information is available on these aspects, which deserve further study.

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# CHAPTER 6

## CONCLUSIONS

From the above discussion, the following conclusions can be drawn.

- 1) Slope class had a profound effect on the defoliation frequency and severity of white clover by sheep in hill pastures. Sheep demonstrated a general, obvious behaviour of preferential grazing towards the FT and rejecting the ST.
- 2) But, this general trend was further modified by many factors such as: grazing season, grazing duration, and soil fertilizer/stocking rate. The preference for the FT was usually stronger during autumn; on the H treatment; and in the early stage of a grazing period.
- 3) Because botanical composition varied greatly with slope class, dead material content was constant between microsites and turf transplant between microsites had little effect on the grazing discrimination, the differences in pasture botanical composition would be the main factor for causing sheep discriminatory grazing between microsites in hill pastures.

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- Therefore, we can speculate that the variation of soil conditions (e.g., soil fertility) between microsites causes the difference in pasture botanical composition, this difference would further give rise to the variation in herbage quality or palatability between microsites, which may be the main reason for causing sheep grazing discrimination between slope classes, and this effect is modified additionally by the herbage allowance per ewe. However, there is little information available on the relationship between botanical composition and the grazing preference, and the effect of herbage allowance per ewe on the grazing behaviour, to test the validity of this hypothesis, further studies are necessary.
- 4) It may be possible to lessen the discrimination against steep terrain microsites in hill pastures by improving pasture botanical composition through adjusting fertilizer application rate or by seasonal manipulating of grazing policies, which deserve further study.

**Appendix Table 1 Ratio of the FT/ST areas on both the H and L treatments in hill pastures**  
**Data are presented as ratio of the total frequency of each terrain in the "Running string" measurement**

Soil fertilizer/stocking rate	L	H	SEM	SIG.
Ratio of the FT/ST areas	2.15	0.54	1.84	NS

SEM--Standard error of least square means

NS--No significant difference

**Appendix Table 2 Proportion of marked white clover stolons defoliated by sheep over 4 weeks on 2 slope classes for both the H and L treatments in hill pastures during winter**  
**Data are presented as proportion of grazed stolons to the total marked white clover stolons per week**

Soil fertilizer/ stocking rate		L		SEM	SIG.	H		SEM	SIG.
Slope	class	ST	FT			ST	FT		
Weeks	1	0.23	0.32	0.17	NS	0.26	0.37	0.14	+
	2	0.24	0.32	0.26	NS	0.29	0.34	0.15	NS
	3	0.25	0.29	0.19	NS	0.32	0.43	0.19	NS
	4	0.24	0.28	0.19	NS	0.30	0.39	0.18	NS
	SEM	0.18	0.12			0.15	0.17		
	SIG.	NS	NS			NS	NS		

NS--No significant difference; +--P<0.1  
SEM--Standard error of least square means

**Appendix Table 3 Proportion of marked white clover stolons defoliated by sheep over 4 weeks on 2 slope classes for the L treatments in hill pastures during spring**

**The observations were made on turves cut and transplanted into similar or contrasting terrain  
Data are presented as proportion of grazed stolons to the total marked white clover stolons per week**

Slope	class	ST	FT	SEM	SIG.
Weeks	1	0.1061	0.04	0.12	NS
	2	0.1501	0.07	0.18	NS
	3	0.2669	0.15	0.30	NS
SEM		0.24	0.19		
SIG.		NS	NS		

NS--No significant difference

SEM--Standard error of least square means

**Appendix Table 4 The LAR, LLR and LB value of white clover on the FT and ST for both the H and L treatments in hill pastures during winter**  
**Data are presented as the leaf numbers per stolon per week**

Soil fertilizer/ stocking rate		L		SEM	SIG.	H		SEM	SIG.
		ST	FT			ST	FT		
Leaf Number	GL	0.28	0.37	0.16	NS	0.30	0.45	0.11	*
	DL	0.01	0.02	0.02	NS	0.01	0.03	0.03	NS
	LLR (GL + DL)	0.29	0.39	0.16	NS	0.31	0.48	0.11	*
	LAR (XL + ML)	0.35	0.39	0.08	NS	0.40	0.43	0.07	NS
	LB	0.05(NS)	0.01(NS)			0.08(+)	-0.05(+)		

LAR--Leaf accumulation rate; LLR--Leaf lost rate; LB--Leaf balance; GL--Grazed leaf; DL--Dead leaf; XL--Expanded leaf; ML--Emerging leaf

Symbols in the bottom row indicate significant difference between LLR and LAR

SEM--Standard error of least square means; NS--No significant difference

+-P<0.1

\*--P<0.05

**Appendix Table 5 The LAR, LLR and LB value of white clover on the FT and ST for the L treatment in hill pastures during spring and autumn**

Data are presented as the leaf numbers per stolon per week

Treatment		Slope class	S	T	F	T	SEM	SIG.
		Turf source	ST	FT	ST	FT		
Spring	Leaf number	GL	0.32a	0.31a	0.37a	0.09b	0.23	*
		DL	0.10	0.13	0.12	0.07	0.08	NS
		LLR (GL + DL)	0.43a	0.44a	0.49a	0.15b	0.26	*
		LAR (XL + ML)	0.47	0.45	0.48	0.47	0.14	NS
		LB	0.04(NS)	0.01(NS)	-0.01(NS)	0.3(**)		
Autumn	Leaf number	GL	0.19b	0.87a	0.28b	0.81a	0.41	***
		DL	0.07	0.10	0.09	0.05	0.07	NS
		LLR (GL + DL)	0.26b	0.97ab	0.37ab	0.86a	0.40	***
		LAR (XL + ML)	0.52	0.58	0.50	0.50	0.17	NS
		LB	0.26(+)	-0.39(**)	0.13(*)	-0.36(**)		

LAR--Leaf accumulation rate; LLR--Leaf lost rate; LB--Leaf balance; GL--Grazed leaf; DL--Dead leaf; XL--Expanded leaf; ML--Emerging leaf  
 Letters indicate significant difference within rows, symbols in the LB row indicate significant difference between LLR and LAR  
 SEM--Standard error of least square means; NS--No significant difference; +-P<0.1; \*-P<0.05; \*\*--P<0.01; \*\*\*--P<0.001

**Appendix Table 6 Effect of soil fertilizer/stocking rate on the defoliation frequency and severity of marked white clover stolons by sheep grazing on 2 slope classes during winter in hill pastures**

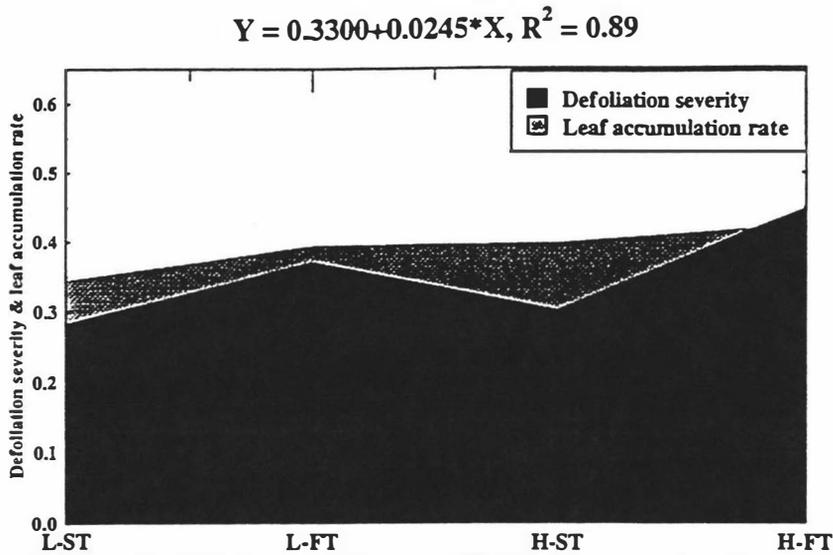
Slope class	ST				FT			
	L	H	SEM	SIG.	L	H	SEM	SIG.
Soil fertilizer/ stocking rate								
Frequency <sup>#</sup>	0.24	0.30	0.27	NS	0.29	0.38	0.13	*
Severity <sup>##</sup>	0.28	0.37	0.29	NS	0.30	0.45	0.14	*

**# Data are presented as proportion of grazed stolons to the total marked white clover stolons per week**

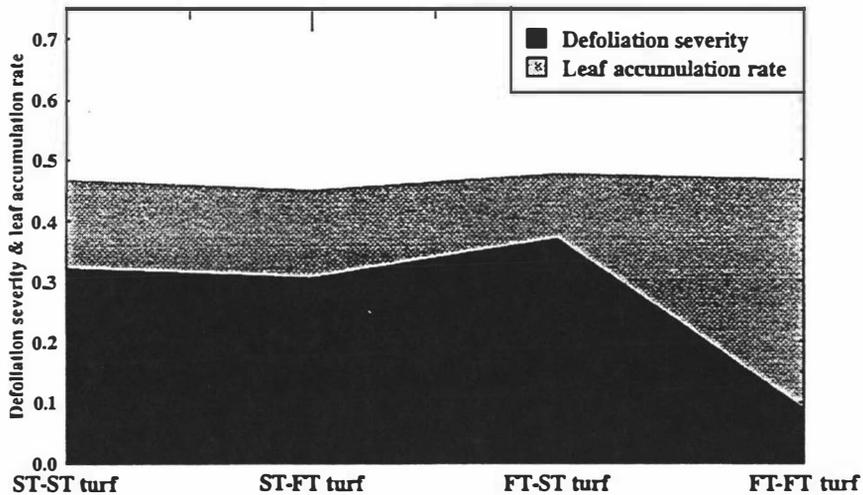
**## Data are presented as number of leaves grazed by sheep per stolon per week**

**SEM--Standard error of least square means**

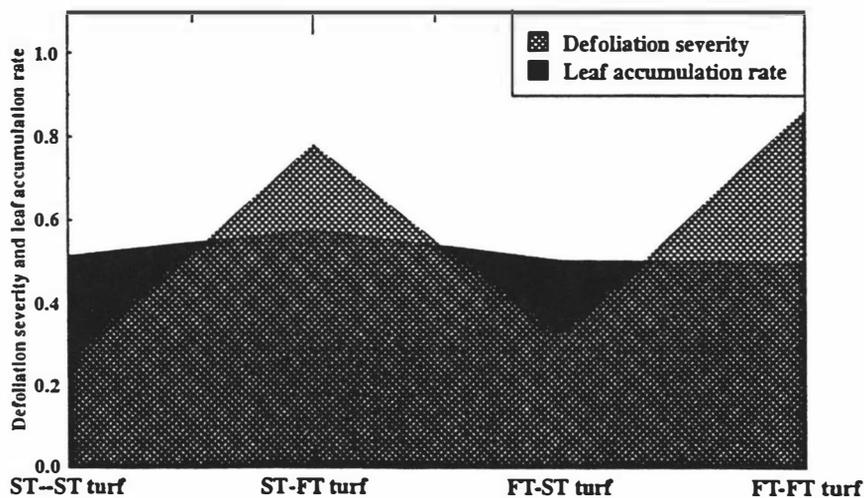
**NS--No significant difference; \*--P<0.05**



Appendix Figure 1: Relationship between defoliation severity (leaves grazed per stolon per week) and leaf accumulation rate (leaves accumulated per stolon per week) of white clover on 2 slope classes for both the H and L treatments in hill pastures during winter



Appendix Figure 2: Relationship between defoliation severity and leaf accumulation rate of white clover on 2 slope classes for the L treatment in transplanted swards during spring



Appendix Figure 3: Relationship between defoliation severity and leaf accumulation rate of white clover on 2 slope classes for the L treatment in transplanted swards during autumn

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