COMPARISON OF TWO METHODS OF HERBAGE PRODUCTION MEASUREMENT IN CONTINUOUSLY GRAZED HILL PASTURES

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ABSTRACT

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Herbage production of continuously grazed hill country pastures has traditionally been measured using grazing exclusion cages and a trim technique. Herbage production values obtained via this system differ from those of the surrounding grazed sward due to differences in sward structure. Herbage production of four farmlets with differing fertiliser treatments was measured by two methods over a full year. The first method involved a computer model which calculated herbage production from dry matter intake and cover change. Secondly, herbage production was measured via frame cuts, and the results of the two methods compared.

The model measured less herbage production than the frames on an annual basis in all four fertiliser treatments (0.77 of frame average for the four fertiliser treatments). The ratio of model to frame herbage production varied widely during the year, with maximum ratios of model to frame herbage production of 1.6 occurring in autumn, and the minimum of -0.02 in winter.

More herbage was produced under the frames in spring than in the grazed sward as a result of increased expression of reproductive tillers under the frames than in the grazed sward. Frames appear to underestimate herbage production in dry conditions as the trimming off of herbage at the placement of frames leads to lower levels of plant available water when compared to the surrounding sward.

The low ratios are a result of the large amounts of dead material which build up in grazed hill pastures over summer and the rapid breakdown of this material when conditions are right, in this case in early-late winter. The results suggest that there are large differences in the annual, and seasonal pattern of herbage production between that measured off grazed swards and that measured via frames. This suggests that anyone wishing to calculate expected pasture supply using frame cut information must modify frame cut values to determine production of a continuously grazed sward.

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LIST OF ABBREVIATIONS

%	percentage
^{0}	degree
^0C	degree Celsius
CH_20	carbohydrate
cm	centimetre
d	day
DM	dry matter
DMD	dry matter digestibility
et al	and others
ha	hectare
HFRO	hill farming research organisation
ie.	that is to say
kg	kilogram
LAI	leaf area index
M/D	MJME/kg/DM
ME	metabolisable energy
MJ	megajoule
mm	millimetre
m^2	square meter
N	nitrogen
P	phosphate
pers comm	personal communication
pers obs	personal observation
SSH	sward surface height
su	stock unit

1.0 INTRODUCTION

There is a wealth of data created by the historical fertiliser trial carried out at the AgResearch hill country research station Ballantrae (Lambert *et al*, 1989). There is now 20 years of data on pasture responses to differing fertility levels in a hill country environment. This information is invaluable in predicting pasture growth rates for a wide range of fertility levels in southern North Island hill country.

Pasture production estimates from continuously grazed pastures have traditionally been measured using grazing exclusion cages and a trim technique described by Radcliffe *et al*, (1968). The accuracy of the use of cages in deriving the pasture production of continuously grazed pastures has, for some years, been questioned. Vickery, 1972; Collett *et al*, 1981; Field *et al*, 1981 and Parsons *et al*, 1984 have all concluded that the use of exclusion cages may give unreliable estimates of pasture production. This is due to differences in the growth of pasture under a cage compared to the surrounding continuously grazed sward. This would lead to a different actual herbage supply to the grazing animal than that which had been calculated using frame cut information. This has implications for any farmer, adviser or researcher who wishes to calculate expected pasture supply by using this frame cut information.

This thesis reports on a trial undertaken to measure both animal intake, and pasture production via frame cuts from the same area of hill country. Measurement of animal intake was measured indirectly by using a spreadsheet model (Brookes *et al*, 1993) using animal production, pasture quality and energy requirement values (ARC, 1980). Intake was added to pasture cover change to give an estimate of the supply of herbage to the grazing animal, and this was compared with the pasture supply measured via frames. This trial was carried out from 7/10/93 to 7/10/94 to compare differences in seasonal supply of pasture as well as differences in the total annual herbage production.

2.0 LITERATURE REVIEW

2.1 HERBAGE PRODUCTION

2.1.1 PASTURE GROWTH

Pasture growth is the increase in size and weight of new leaf and stem tissue per unit time (Hodgson, 1979). Net pasture production (kgDM/ha/d) represents the amount of pasture which can be harvested from pastures per unit of time, either pasture consumed by grazing animals or removed by cutting (Korte *et al*, 1987). Harvestable yield depends not only on the gross photosynthetic uptake of matter (carbon) but also on the size of the losses of matter from the sward prior to harvest and on the partition of matter to non-harvestable parts.

The rate at which herbage accumulates in a sward protected from defoliation, net herbage accumulation (NHA), represents the balance between the rate of growth of new tissue (G) and the rates of losses to respiration (R) and mature tissue to decomposition (D), so that NHA = G - (D+R) (Hodgson *et al*, 1981). In continuously stocked swards the net rate of change in herbage mass is also affected by the rate at which herbage is consumed by grazing animals (C) so that, NHA = G -(D+R+C), and NHA may approach zero in many cases (Bircham and Hodgson, 1981). Depending on the time of year NHA may also become negative. For example going into winter pasture covers (above ground biomass) fall as C plus D is greater than G. Also hill country pastures, particularly after a dry summer, can accumulate large amounts of dead material which can quickly decompose, resulting in large amounts of dead material disappearing from the sward, leading to negative NHA rates.

Net pasture production, as defined above, can be increased by decreasing the amount of material dying and entering the litter cycle. This can be achieved by improved grazing management techniques or by increasing stocking rates (Jagusch *et al*, 1978). Jagusch *et al* (1978) states that on an annual basis increasing stocking rates will often result in an increase in pasture production because losses from death and decay are reduced.

The photosynthetic capacity of the rotationally harvested sward fluctuates from a very low rate immediately following defoliation to a rate considerably greater than that of the continuously grazed sward once high leaf area is reached (Leafe *et al,* 1974; Woledge and Leafe, 1976). At moderate pasture masses the rate of net pasture production is high, and as pasture mass increases net pasture production declines. This decline reflects a smaller proportion of new growth being utilised and increasing proportions being lost though death and decay (Korte *et al*, 1987).

Bircham and Hodgson (1983) and Grant *et al* (1983 a,b) found that the net production of green herbage (growth minus senescence) was relatively constant over a wide range of herbage masses and leaf area index (leaf area/ area of ground) in ryegrass white clover swards under continuous stocking management. In general pastures that are kept between 1000-2500 kgDM/ha show little difference in productivity (Bircham and Hodgson, 1984), and it is only at the extremes that production can become affected by increased death rates at high pasture masses, and limited by a lack of leaf area at low masses.

Management effects on NHA may operate through their influence on the rate of growth of new plant material, the rate of loss of mature tissue, or since they are frequently not independent, some combination of these two effects. The objective of management should therefore be to optimise the balance between the two rather than to attempt to maximise growth (Hodgson *et al*, 1981).

Plant growth is affected by a range of environmental factors such as the influences of temperature, moisture and nutrient supply, and by plant effects such as differences between species and the effect of reproductive growth. In hill country pastures several other factors affect plant growth. Slope, aspect and uneven distribution of dung and urine all affect hill country pasture production, and lead to a more complex pasture structure than flat land (Gillingham, 1973).

It is difficult to separate the effects of light, which drives photosynthesis, and temperature, which governs the rate at which sugars (from photosynthesis) are converted into new growth. This is because light and temperature are closely related, in general as light levels increase in spring so to do temperatures. As a rule pasture production is higher, the higher the soil temperatures in autumn, winter and early spring (Korte *et al*, 1987).

Slope and aspect affect plant growth through influences on temperature, moisture and fertility levels. This causes differences in pasture growth rates and botanical composition. Gillingham (1973) found that slope accounted for 22% of the variability of pasture growth, with pasture production tending to fall as slope increased.

Gillingham (1973) found higher mean temperatures on north than south facing slopes at all times of the year. It was also found that the soil moisture content of the topsoil was greater on south than north facing slopes at all times of the year, and that annual variations in moisture content were strongly related to slope, with maximum moisture content from June to October, then a decrease to a minimum in January and February. The north facing aspects were below wilting point from January to March, while the south facing aspects only briefly fell below wilting point from January to March. This resulted in north facing slopes producing around 10% more dry matter than south facing slopes on an annual basis. This was mainly due to better winter and early spring growth, with little difference at other times of the year.

Evans (1978) states that reduced availability of nutrients in the soil surface due to dry conditions may be important in limiting pasture growth in shallow hill country topsoils even when water is available to the plant through deep roots.

Ledgard *et al* (1982) found that the proportion of ryegrass in pastures was inversely related to slope, with no significant association between browntop and slope. Interrelationships between and within slope and soil fertility factors makes it impossible to conclusively identify the major factor associated with ryegrass content. This illustrates the point that no one factor is responsible for plant/pasture growth but rather a combination of many diverse factors.

New Zealand's hill country soils are naturally low in nutrients with phosphorus (P) and nitrogen (N) being the most limiting. P is applied to encourage clover growth which in turn encourages grass growth through N fixation. The fixation of N is a sensitive process which is limited to temperatures above 8°C and topsoil moisture levels above 70% plant available water. Lambert *et al* (1982) found that N fixation rose from 30 kg N/ha/year in a previously unfertilised hill soil to a level of 70 kgN/ha/year and 120 kgN/ha/year after several years of low and high fertiliser inputs (120 and 640 kg superphosphate/ha/year) under continuous sheep grazing.

Chapman *et al* (1983) measured leaf and tiller growth of *Lolium perenne* and *Agrostis* species, and leaf appearance rates of *Trifolium repens* in set stocked hill country pastures with high and low fertiliser inputs. It was found that there were few significant differences between fertiliser treatments, slope or aspect. Mean lamina lengths of both grass species decreased from March until September and increased gradually thereafter although lamina lengths in spring and summer were less than the previous autumn. *L. perenne* laminae were about twice the length of *Agrostis* spp. Tiller lengths followed the same seasonal pattern as lamina lengths. Leaf appearance intervals increased from about 10 days for all species in March to a maximum of 19 days for the grasses and 26 days for *T. repens* in mid winter in response to decreasing temperatures. By October leaf appearance intervals decreased to about 11 days for all species but did not decrease further over summer despite higher temperatures. Leaf extension rates for *L. perenne* and *Agrostis* spp. followed the same seasonal patterns as leaf appearance rates, with *L. perenne* leaf extension rates were about twice that of *Agrostis* spp.

2.1.2 THE EFFECT OF REPRODUCTIVE GROWTH

Reproductive tillers in spring have a high growth rate as a result of changes in several major physiological attributes. In early spring reproductive tillers acquire the ability to extend leaves of high area per unit weight (Davies, 1971; Behaeghe, 1978) despite low temperature (Peacock, 1975; Parsons and Robson, 1980) and at this time of low current assimilation, may support such growth initially from reserves (Pollok and Jones, 1979). Throughout the spring the reproductive tillers invest carbon in tissues which are most effective either directly (leaf tissue) or indirectly (elongated stem) in achieving and maintaining a canopy of high photosynthetic potential (Parsons and Robson, 1981 a,b). This enables the sward to effectively exploit an environment of increasing light energy, and a pattern of increasing photosynthetic uptake results.

The regularity of the production and senescence of leaves is interrupted by reproductive development in spring. Following the expansion of the flag leaf no new leaves appear on that tiller and new growth is directed mainly to stem elongation and the flowering head. The elongated stems and flowering heads remain longer on the plant than do the leaves of vegetative tillers so in the case of a grass crop being harvested by cutting there is an accumulation within the sward of material which would otherwise (in a vegetative sward) have been lost by senescence (Johnson and Parsons, 1985).

Treacher *et al* (1981) made direct measurements of the amount and seasonal pattern of utilised output on continuously stocked, irrigated swards of perennial ryegrass. This was done by recording the quantities of herbage eaten by sheep grazing swards maintained at three heights, 3, 5 and 7 cm. The results from this trial were compared with the amounts of herbage harvested from three ungrazed areas of the same sward by cutting to a height of 5 cm at four weekly intervals. The seasonal pattern of production (net herbage accumulation) in the cut areas demonstrated a marked peak in the rate of net accumulation in spring, followed by a decrease in mid summer. By contrast on the continuously stocked swards there was no indication of a marked seasonal pattern of herbage yield (intake) similar to that of net accumulation on the cut areas. The total quantities of herbage consumed per hectare by sheep were less in spring than the quantities harvested on the cut areas (approximately 84% of the cut sward). These differences in herbage production were associated with marked differences between treatments in the expression of reproductive development in spring. On the cut plots 60% of tillers showed reproductive development, while on the grazed areas maximum numbers of reproductive tillers were 20, 27 and 47% of tillers on the respective treatments of 3, 5, and 7 cm. These results confirm that marked differences in seasonal patterns of utilised output under cutting and continuous stocking will result from the direct effects of grazing on the growth and utilisation of grass including differences in the expression of reproductive development under cutting and grazing.

In hill country pastures the effect of reproductive growth is complicated by the diverse botanical composition of these pastures. Chapman *et al* (1983) measured reproductive development in a hill country sward maintained at covers between 1000-2400 kgDM/ha through set stocking with sheep. It was found that 75% of ryegrass (*L. perenne*) tillers showed reproductive development, while only 5% of browntop (*Agrostis* spp.) tillers produced an inflorescence.

Infrequent cutting or defoliation affects pasture quality most during reproductive development, since digestibility declines most rapidly after ear emergence in grasses (Minson *et al*, 1960).

2.1.3 DEATH AND DECAY OF HERBAGE

The natural life cycle of leaves, tillers and stolons sets a limit to the period when they can be utilised by grazing. The life span of leaves depends on factors such as species of plant and the time of year (Williamson, 1976). Leaf death rates, leaf longevity, and tiller and stolon death rates of *L. perenne*, *Agrostis* species and *T. repens* in a set stocked hill pasture were measured by Chapman *et al* (1984). It was found that leaf longevity was least in spring and summer when leaf death rates were fastest, and was greatest in winter when leaf death rates were slowest. They found that the maximum and minimum percentages of total leaf length dying/tiller per day was 1.0-1.8% for *L. perenne* and 1.5-2.5% for *Agrostis* spp. Minimum values occurred in winter and maximum values in autumn and summer. The percentage of *T. repens* leaves dying/stolon apex per day ranged from 0.9% in late winter to 1.6% in summer. Throughout the year leaf longevity was similar for all species (9-15 weeks), although *T. repens* leaves tended to live longer than grass leaves in winter, but not as long in spring and early summer. Defoliation was found to be the major factor contributing to *L. perenne* tiller death throughout the year, and few tillers died in the period April-October with the main period of tiller death associated with reproductive development during November and December when elongating tillers were often severely defoliated causing death.

The low level of reproductive development in *Agrostis* spp. (Chapman *et al*, 1983) led to a more uniform pattern of tiller death, with most death occurring over summer and autumn. Defoliation played a role in the turn over of *Agrostis* spp. tillers, particularly in summer when tillers were long enough to be severely defoliated (Chapman *et al*, 1983) but was less important than other unknown causes of tiller death. Stolon death of *T. repens* was found to peak in January when soil conditions were dry. Death due to defoliation was about 30% of all stolon death, which was in proportion to total stolon death and did not appear to be accentuated at any time during the year.

The proportion of leaf tissue grown per ramet which was not grazed ranged between maximum values of 46.1%, 63.1% and 60% for *L. perenne, Agrostis* spp. and *T. repens* respectively in early autumn, to minimum values of 19.8%, 44.6%, and 34% for the respective species in late spring-early summer. Thus, depending on time of year, utilisation of leaf tissue by grazing stock was about 54-80% for *L. perenne*, 37-55% for *Agrostis* spp., and 40-66% for *T. repens.* This pasture was maintained at mean winter and summer herbage masses of 1000 and 2400 kgDM/ha respectively (Clark *et al*, 1984), and shows the considerable quantities of herbage that enter the litter pool even in closely grazed pastures. A small proportion of dead herbage is eaten by grazing animals and the remainder is lost into the litter cycle. Clark *et al* (1982) found that the diet of set stocked sheep contained 1- 7% dead matter depending on the time of year, with maximum values in winter and minimum values in spring.

Rate of decay and disappearance of dead material from the sward is regulated by moisture availability and temperature. Warm moist conditions favour disappearance of dead leaves and stems as these conditions are suitable for bacterial and fungal growth, and also for earthworm activity (Korte *et al*, 1987).

Seasonal imbalances between pasture growth and animal demands cause major variations in pasture utilisation in all grassland farming. In hill country additional variation is commonly encountered as a result of preferential grazing of different land classes (aspect, slope, fertility) and plant types (size, species, quality) (Sheath, 1982).This often results in a build up in dry matter over late spring-summer with a subsequent increase in dead matter and a resultant fall-off in feed quality.

So long as the interval between defoliation's does not exceed 2-3 leaf appearance intervals (3-4 weeks in temperate swards depending on time of year) the amount of tissue lost to senescence is likely to be small, but substantial amounts of tissue may be lost below cutting height (Morris, 1970).

2.2 DEFOLIATION BY GRAZING ANIMALS

The most important influence of grazing animals on pasture is their removal of pasture through grazing (Watkin and Clements, 1978). The timing, intensity and frequency of defoliation can markedly influence the productivity of pastures (Harris, 1978). Clark *et al*, (1984) measured the defoliation components of *L. perenne, Agrostis* spp., and *T. repens* in hill pastures set stocked with sheep. Mean minimum and maximum defoliation intervals were 11.4 and 23.5, 16.2 and 52.7, and 19.9 and 88.5 days for ryegrass, browntop and white clover respectively. Defoliation intervals were longest in winter and shortest in spring when both ewes and lambs were grazing. Mean defoliation intervals for the three species throughout the year appeared to be related to tiller and petiole length. This suggests that sheep 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 (Clark *et al*, 1984).

2.3 COMPENSATORY MECHANISMS IN CONTINUOUSLY GRAZED SWARDS

Bircham and Hodgson (1983) demonstrated the existence of a homeostatic mechanism in continuously grazed swards, whereby compensatory changes in species population density and tissue turnover on individual plant units combine to maintain relatively constant net production of green herbage over a range of herbage masses and LAI. Although individual leaves in a continuously grazed sward are highly efficient in photosynthesis, the gross photosynthesis of the sward canopy and the gross rate of production of shoot is less than in a sward grazed more leniently and maintained at a greater leaf area index (Parsons *et al*, 1983). Tiller populations tend to increase as the frequency of defoliation increases and are maintained at a higher level under continuous stocking management than rotational grazing at comparable stocking rates (Hodgson and Wade, 1978). This is due to competition between tillers being reduced, resulting in high tiller populations of smaller tillers. Chapman *et al*, (1984) measured tiller densities of hill country pastures set stocked with sheep to be 29 700 tillers/m^2, while hill country pastures rotationally grazed with sheep had tiller densities of 20 100 tillers/m^2.

The appearance of complete ground cover in continuously grazed swards is aided by the presence of exposed sheath material in closely grazed swards. Parsons *et al*, (1983) found that in a sward maintained at LAI of 1.0 the ratio of sheath area to leaf area was 37:63, however sheaths contributed less than 5% to canopy net photosynthesis. The reasons for this are that the photosynthetic efficiency of sheath is less than that of leaf/lamina (Thorne, 1959), and because young sheaths are surrounded by up to five older sheaths (Collett unpub). The oldest outermost sheath, which intercepts most of the light, would have low photosynthetic efficiency and may even be dead. Thus the impression of good ground cover and apparent high light interception in a continuously hard grazed sward is misleading in that much of the light is intercepted by tissues which contribute little to canopy photosynthesis.

The increase in tiller population density and the decline in individual leaf angle which occur in frequently and closely grazed swards maintain a greater degree of light interception than would otherwise be the case (King *et al*, 1979). Also the relatively high light levels at the base of closely defoliated swards and the increase in the proportion of young to old leaf means that young leaves will expand in high light, free from shade by older leaves and so should have high photosynthetic efficiency (Woledge, 1973, 1978). These factors are likely to result in an increase in the photosynthetic efficiency per unit area of leaf tissue in continuously grazed swards compared to rotationally grazed swards (Woledge, 1977).

Grant *et al* (1983) found that net production per unit area was reduced on swards below about 2.5cm in height but was insensitive to variation in sward surface height between 2.5 and 6.0 cm. This equated to approximately 1000-2500 kg DM/ha. They also found that senescence increased linearly with increases in sward surface height (SSH). Results emphasised the effectiveness of adjustments in tiller numbers and in production per tiller and of changes in the balance between growth and senescence in achieving sward homeostasis. They largely confirm the results of Hodgson *et al* (1981) that the scope for improving net production on continuously grazed swards through grazing management is relatively limited, and that to ensure stability and continued herbage production in grazed swards, management should be directed towards maintaining tiller densities at the highest level possible without greatly limiting animal production.

Under continuous grazing, when the intensity of grazing is controlled on the basis of sward surface height, a more uniform seasonal pattern of production arises. This considerably simplifies the control of herbage supply and the maintenance of a highly digestible and predominantly vegetative grass sward (Orr *et al*, 1988). Sward state, measured as leaf area index (LAI), or for more practical purposes sward surface height (SSH), has been shown to be more fundamental to performance than is stocking rate or allowance (Hodgson, 1985; Parsons and Johnson, 1986).

2.4 HERBAGE MASS MEASUREMENT

Herbage mass is measured for the derivation of herbage accumulation, allowance, consumption and for the prediction of animal performance (Frame, 1981). Herbage mass may be estimated by cutting samples to give mass per unit area, but despite the accuracy of each individual measurement the variability within pastures means that large numbers of samples must be cut to give an accurate representation of actual pasture herbage mass. There are physical limitations to the cutting of large numbers of samples and the cutting itself may become a significant treatment effect on the area if many samples are cut. As a consequence methods have been developed based on the double sampling procedure, whereby the results obtained from a small area by cutting are used to predict values derived indirectly from larger areas (Vilm *et al*, 1944).

Non destructive methods of estimating herbage involve the use of either the electrical capacitance type of meter (Campbell *et al*, 1962) or the simpler meters based on the measurement of height of the pasture (Phillips and Clarke, 1971) or visual estimations (Haydock and Shaw, 1975).

The electronic capacitance meter is complex and expensive and its performance has been criticised because of poor relations between herbage yield and meter reading (Bryant *et al*, 1971) and changing calibrations from day to day (Back, 1968). The calibration of the electronic capacitance meter has been shown to be affected by changes in air temperature, atmospheric humidity and the wetness of pasture (Campbell *et al*, 1962).

Visual estimations of pasture yield require more than one observer for accurate estimations (Morley *et al*, 1964) and, unless experienced observers are involved, require calibration with harvested quadrats each time a series of estimations is made.

Of the pasture height measuring meters those described by Holmes (1974) and Castle (1976) appear to perform well and have advantages over the electronic capacitance meters in being simple in construction and lightweight. Earle and McGowan (1979) describe the design and use of a rising plate meter which measures herbage mass from a combination of sward height and density, and where the plate readings are calibrated against herbage mass measured by cutting. The rising plate meter is designed with a moveable flat plate mounted on a rod with a series of notches as the scale. As the plate is placed down on the sward the resistance of the pasture pushes the plate up the rod which registers on a counter as a height measurement.

A simple height meter is the HFRO sward stick which consists of a steel rod on which a scale is printed, on this rod a clear plastic pointer is mounted which moves freely up and down the rod. The stick is placed vertically in the sward to ground level and the pointer is lowered down the rod till it touches any part of the sward and the height read off the scale on the rod.

2.5 HERBAGE PRODUCTION MEASUREMENT

Regional differences in annual herbage production have been measured using a standard system of cutting (Radcliffe *et al*, 1968; t' Mannetje, 1978). This system uses cages to exclude grazing animals from small areas, the pasture on these areas is trimmed close to ground level after which the cage is placed over the area. After a regrowth period the pasture under the cage is harvested to the trimming level and the cut herbage is washed and then oven dried at 80^{0}C for eight hours and weighed. The regrowth period is inversely proportional to pasture growth rate with shortest regrowth periods in spring and longest in winter. Generally around eight cuts are made per annum, the annual herbage production being the sum of these cuts. The annual yield obtained and the seasonal pattern observed are influenced by the system of cutting management applied. The herbage production is greatly affected by the trimming level chosen and there are problems caused by differences between trials in the definition of ground level. Variations in the duration of regrowth and in the severity of defoliation have also been shown to have a pronounced effect on the average state of the sward and so on the yield achieved (Anslow, 1967; Brougham, 1970; Parsons and Penning, 1988).

In a continuously grazed sward difficulties arise in measuring the production of herbage under a system where the gross production of herbage may be equalled by the consumption of herbage by animals and the loss of herbage in death and decay. As a result there may be no measurable net change in herbage mass. Herbage production in continuously grazed swards is best measured from the difference between herbage growth and herbage death (Korte *et al*, 1987).

Grant *et al* (1983) describes a method by which measurements of growth and senescence of leaf lamina per tiller, and of changes in tiller population densities were made to investigate the influence of sward state on leaf turnover and net production under continuous stocking. Along several transect lines 50 individual tillers are marked at their bases with a twist of plastic covered wire, and the lengths and number of individual laminae are recorded. The transects are protected from grazing with cages for several days after which the tillers are remeasured to establish length of new leaf which has emerged, and of green leaf which has senesced. To convert the linear measurements to weight the average weight per unit of immature, ie expanding laminae (to calibrate growth) and of mature green laminae (to calibrate loss to senescence) are determined at weekly intervals. By multiplying the weight of growth and senescence per tiller by the tiller density of the sward values of growth and senescence per unit area can be obtained. This technique is complex and labour intensive and as a result grazing exclusion cages are usually used to measure pasture production in continuously grazed swards.

2.6 FRAME ESTIMATE VERSUS PRODUCTION FROM A CONTINUOUSLY GRAZED SWARD

Parsons *et al* (1984) concluded that the changes in the structure and physiology of the sward following release from grazing suggested that the net accumulation of herbage in areas released from grazing, such as exclusion cages, may be an unreliable estimate of production under continuous stocking. The net accumulation of herbage within a cage depends on the extent to which an increase in photosynthesis and the gross production of shoot, following release from grazing is offset by a subsequent increase in the rate of tissue death (Parsons *et al*, 1984).

Production under cages only approximately represents production in a continuously grazed sward (Vickery, 1972; Collett *et al*, 1981; Field *et al*, 1981; Parsons *et al*, 1984) due to differing sward conditions under the cage when compared to the continuously grazed pasture. The principles of production in a sward managed by continuous grazing differ from those of a sward released from continuous grazing through being covered by a grazing exclusion cage. Under continuous stocking the removal of tissues by the grazing animal has a pronounced effect on the amount of shoot produced as well as on the extent to which that shoot is harvested. There is therefore an intimate relationship between herbage growth and herbage intake that depends on the continued presence of the animals (Parsons *et al*, 1983).

Following release from continuous grazing through the placement of exclusion cages the increasing leaf area leads to greater light interception and higher rate of photosynthesis in the pasture under the cage when compared to the surrounding continuously grazed sward (Collett *et al,* 1981; Woledge, 1973; Parsons *et al*, 1984). This increase in LAI is associated with the loss of a large proportion of the population of tillers, increased respiratory losses and an increase in the amount of tissue dying per unit of time. This increase in the amount of tissue death need not imply an acceleration of the rate of senescence, but results from an increase in the size of leaves and tillers involved in the turnover of tissue (Hunt, 1965; Robson, 1973). This happens as tiller size increases and the tiller density drops.

It is well established that shading as a result of an increase in leaf area leads to the production of fewer tillers (Colvill and Marshall, 1981), and also a proportion of the existing tillers on a grass plant are lost when the whole plant is subjected to a physiological stress such as that caused by shading (Ong, 1978).

The mobilisation of long term storage carbohydrates (Pollock and Jones, 1979) and an increase in the rate of leaf extension at a given temperature (Peacock, 1975), the maintenance of high photosynthetic capacity in successively produced leaves, particularly during periods of high leaf area index (LAI) (Woledge, 1973) have all been shown to contribute to a greater rate of net accumulation of herbage under cutting compared with grazing in spring. Estimates of the rate of accumulation of herbage within a cage are also affected by the length of the period of regrowth, (Curll, 1976) and also on the initial leaf area index (LAI).

There are also seasonal differences in photosynthesis and the loss of tillers in areas released from grazing which do not occur in swards maintained by continuous grazing and which further complicate the interpretation of data collected in cages. This is mainly caused by the partition of assimilates into elongating stems on reproductive tillers rather than to roots or the development of more vegetative tillers (Ryle, 1970). Field *et al* (1981) found that cage cut data over-estimated the dry matter production from a set stocked hill country sward from spring to autumn. It was concluded that this was due to the effect of more reproductive tillers being able to express their growth potential under the cages versus under grazing. Under continuous grazing the intensity of grazing during spring alters the degree to which reproductive development is expressed, and thus the contribution of reproductive tillers to dry matter production.

2.7 ANIMAL INTAKE

As the herbage production in this study was measured from intake, factors affecting intake are an important factor in determining the net herbage production calculated. The intake of grazing ruminants is largely determined by herbage availability and the digestibility of that herbage. The factors affecting grazing animal intakes are separated into two groups for ease of explanation. At low herbage masses animal intake is limited by the animal's ability to harvest pasture, ie pasture availability (non-nutritional factors). This is affected by pasture structure and the animal's grazing behaviour, including diet selection, grazing time, bite size and rate of biting. As pasture allowance, post-grazing and pre-grazing pasture mass increases the animals intake appears to be controlled by such (nutritional) factors as the digestibility of the feed eaten, the time the feed stays in the rumen and the concentration of the metabolic end products of digestion (Poppi *et al*, 1987).

Herbage intake is the result of the time spent grazing, in minutes per day (GT), the rate of biting during grazing measured as bites per minute (RB) and the amount of herbage eaten per bite in grams per bite (IB), so that herbage intake (I) is equal to, I=IB*RB*GT. Intake per bite and rate of biting are influenced by pasture height, density and the accessibility of preferred plant components and the mass of material that can be encompassed within a bite (Poppi *et al*, 1987). Grazing animals tend to select green herbage in preference to dead material and leaf in preference to stem material (Arnold, 1964; Guy *et al*, 1981; Hawkins *et al*, 1993), and it has been shown that the diet of sheep on continuously grazed swards is composed predominantly of leaf lamina (Barthram, 1981: Bircham and Hodgson, 1981). Hodgson (1990) describes the influences on animal intake to be a balance between feeding drive minus physical satiety minus behavioural constraints. Feeding drive is a reflection of the animal's current demand for nutrients, and in particular the degree to which energy intake falls short of energy expenditure. The potential energy expenditure of the animal is a function of the size and stage of maturity of the animal, its productive state and its genetic potential for production.

Parsons *et al* (1983 b) investigated the balance between photosynthesis, animal intake and the losses of dry matter in lenient and hard grazed swards maintained at LAIs of 3.0 and 1.0 respectively. The stocking rates used to achieve these LAI values were 24 and 47 yearling wether sheep per hectare for the lenient and hard grazed swards respectively. It was found that gross photosynthetic uptake in a sward maintained at LAI 3.0 was substantially greater than that in a hard grazed sward maintained at LAI 1.0 (300 v. 209 kg CH_2O/ha/day). Despite this animal intake per hectare on the leniently grazed sward was less than on the hard grazed sward (38 v. 53 kg CH_2O/ha/day). Only 13% of canopy gross photosynthetic uptake was continually harvested by the animals under lenient grazing compared with 25% under hard grazing.

The difference in the efficiency of harvest between the lenient and hard grazed swards did not result from the difference in the proportion lost from the swards by respiration or partitioned to roots. However a greater amount of matter was lost in shoot respiration and partitioned to the roots in leniently grazed swards. The proportion of gross photosynthetic uptake consumed by shoot respiration was similar at 35% v. 39% for lenient and hard grazed swards, and 10% was partitioned to the roots in both swards. The major difference between the two swards was in the extent to which shoot tissue was eaten rather than lost to death. Shoot production under lenient grazing was substantially greater than under hard grazing (164 v. 107 kg CH_2O ha/d), however in the leniently grazed sward only a small proportion of the shoot produced was harvested. In the hard grazed sward a far greater proportion of the shoot was harvested, so that despite the lower rate of production of shoot in the hard grazed sward, the amount harvested was greater than off the leniently grazed sward.

As the intensity of grazing is increased and the sward is maintained at a smaller LAI, animal intake per hectare is increased as a greater proportion of the shoot produced is harvested. However this increase in the efficiency of harvest is at the expense of gross photosynthetic uptake and a smaller amount of shoot is produced. At very small LAI, the reduction in the amount of shoot produced more than outweighs the benefits of the greater efficiency of harvest and intake is depressed. Thus maximum intake per hectare is achieved in a sward maintained at a LAI which is substantially below the optimum for photosynthesis (Parsons *et al*, 1983b)

In a summary of the design and interpretation of experiments to study animal production from grazed pasture Owen and Ridgeman (1968) state that provided the grass on a grazed area is uniform, so that animals cannot exercise any deliberate selection, the intake of the animals will remain constant over a wide range of low stocking rates since intake will be a manifestation of the voluntary intake of those animals and as such is unrelated to the amount of herbage (or area) available. As the number of animals per unit area (n) or stocking rate increases a point is reached when the total amount of herbage available for consumption (A) exactly equals the total voluntary intake (I) of the animals present, and $I = A/n_o$, where n_o is the stocking rate which fulfils this condition. When stocking rate increases beyond this point ($n > n_o$) more animals have to share the fixed maximum amount of forage available and $I = A/n$. Thus intake is governed in two distinct ways, intake being independent of stocking rate when n is less than or equal to n_o and varying inversely with n when n is greater than n_o.

2.8 THE PREDICTION OF INTAKE VIA COMPUTER MODELS

Intake of animals can be determined from maintenance requirements and animal production by multiplying each unit of animal production by the value of energy required by the animal to produce each unit of production. Computer models have been constructed to do this to simplify calculations (Brookes *et al*, 1993). These models determine energy requirement using equations given by such sources as ARC (1965, 1980) and MAFF (1975). The basis of these models is to use measured animal production and work backwards from this to a value of the amount of energy the animal must have consumed to achieve the measured production levels.

Brookes *et al* (1993) describe a model which calculates daily DM requirements for a variety of livestock classes. This model is based on published equations for energy use (ARC, 1980). The input data to run these models is animal production, ie milk yield, animal liveweight profiles, lambing %, lambing weaning and mating dates, wool production and feed quality on a half monthly basis expressed as MJME/kg DM. These data are entered into the model, which provided with the M/D value of pastures, calculates the DM required by the animals to achieve the production levels entered.

Validation of the predictions provided by the model is difficult to achieve as this requires accurate measures of net pasture production and animal intake. Holmes and Davey (1981) reviewed data from several nutritional experiments with lactating cows fed on pasture, and compared the actual measured intakes with theoretical estimates of energy requirements derived from information about cow's liveweight, milk production and changes in liveweight. It was found that in most cases there was reasonable agreement between the theoretically derived estimates of energy requirements and those measured experimentally. The values for predicted ME intake divided by the ME intake measured experimentally varied between 0.84 and 1.18. Holmes and Davey (1981) concluded that this represented reasonably close agreement between theory and practice, particularly when the large number of assumptions inherent in such calculations is considered.

Fulkerson *et al* (1986) also compared measured ME intakes with predicted ME requirements. They measured intakes of ME in grazed herbage, silage, hay and grain in dairy cows on two farmlets during two consecutive 12 month periods. Measured intakes were compared with requirements predicted from liveweight, liveweight change and milk production using the ME standards proposed by the Australian Ministry of Agriculture, Food and Fisheries (MAFF, 1975). They found that the measured ME intake was 95±6.7% of the predicted requirements. These results show that the values given by ARC and MAFF can be used with confidence when calculating the ME requirements for a specific level of animal production, and conversely, the ME consumed by animals to attain measured production.

Vera *et al* (1977) used a quantitative model to predict energy intake and utilisation by ewes in various physiological states grazing pastures. The behaviour of the model was examined and found to be consistent with published information. Partial validation of the model was accomplished by comparing the model output with actual experimental data not used to construct the model.

2.8.1 THE ENERGY REQUIREMENTS OF GRAZING RUMINANTS

The major determinants of ME requirement of grazing livestock are liveweight and body condition, stage of pregnancy, level of milk production, rate of liveweight gain or loss, composition of liveweight gain or loss, level of activity in eating and movement, and possible climatic effects (Geenty and Rattray, 1987).

Energy requirements are split for convenience into those for maintenance (no change in liveweight or energy) and production (pregnancy, lactation, liveweight change, wool growth). Maintenance requirement for grazing ruminants is not constant and can vary with size, age, quality of diet, availability of pasture, terrain and climate (Geenty and Rattray, 1987).

An animal unavoidably expends energy to maintain homeothermy and vital processes in its body, and in physical activities including those associated with feeding (ARC, 1980). At the maintenance level of feeding these basal energy requirements are exactly met so that the net gain or loss of energy from the tissues of the animal as a whole is zero.

The requirement of ME for liveweight gain varies markedly depending on the composition of the liveweight gain and pasture quality. Mature ewes require 60-80 MJME/kg liveweight gain because the gain is high in fat. Lambs and hoggets have a much lower requirement as their gain is largely lean tissue (Geenty and Rattray, 1987). After periods of weight loss, regained tissue contains much water and the ME requirement per unit of gain is low at 30-40 MJ ME/kg gain (Drew, 1973; Rattray *et al*, 1974). The NE requirements equal the heats of combustion of the fat and protein gains in the body, which are 39.3 MJ/kg for fat and 23.6 MJ/kg for crude protein (ARC, 1980). Substantial problems arise in the application of this information due to the relative proportions of fat and protein in the weight gain or loss. This varies with the animal breed, age, sex and the rate of gain or loss.

The use of ME for pregnancy is relatively inefficient. For the growth of the conceptus the efficiency varies little from 0.13 in both cows and ewes (ARC, 1980). During early pregnancy energy requirements of the growing foetus are small and total ME requirements are not significantly different from that of the non pregnant ewe. Foetal growth follows an exponential curve (ARC, 1980), and it is only during the final third of pregnancy that additional energy demands of the developing conceptus (placenta plus foetus) become significant (Geenty and Rattray, 1987). The ME requirement of pregnancy varies with the weight and number of foetuses. The main factor influencing ME requirements of ewes during lactation is the level of milk production.

The variation in the efficiency with which ME is used for production between diets results from differences in the particular nutrients metabolised and the energetic efficiency of the competing biochemical pathways (Black, 1990).

2.9 PURPOSE OF THE STUDY

The purpose of this study was to investigate the differences in the annual and seasonal pattern of herbage production measured via frames, with net herbage production estimated via animal production and cover change using a spread sheet model. It is hoped that this measurement technique will improve the understanding of the values of herbage production measured via frame cuts, and add to there usefulness.

3.0 METHOD

3.1 AREA HISTORY

This study was carried out as part of a longer running investigation conducted by AgResearch at the Ballantrae hill country research station, 20 km to the north-east of Palmerston North in the foothills of the Ruahine Range, southern Hawke's Bay. The experimental area is at 250-350 m altitude, and has an annual rainfall of around 1200 mm. The soils are yellow-brown earths and related steepland soils, Ngamoko silt loam from silty drift material, and Mangamahu steepland soil from silty sandstone (J. D. Cowie *pers comm*).

The aim of the larger study is to identify sensitive biophysical indicators of sustainability, and to use these to assess the impact of management practices and adverse environmental events on soil resources and forage supply. This is to be achieved by measuring differences in potential indicators of sustainability within grazed systems with differing management histories (Lambert *et al*, 1989), and also by initiating trials to quantify responses of key indicators to imposition of levels of management/environmental pressure (Lambert, 1994, *pers comm*).

The trial area comprises four 10 hectare farmlets with contrasting and well documented differences in management history (Lambert *et al*, 1989). The farmlets have had different fertiliser histories since 1975. During 1975-80 two farmlets received on average an annual application of 125kg superphosphate/ha (L), while the other two farmlets received 580kg superphosphate/ha (H) during the same period. Since 1981 one L (LN) and one H (HN) farmlet ceased to receive fertiliser. The other L farmlet continued to receive 125kg superphosphate/ha (LL), while the other H farmlet has received 375kg superphosphate/ha (HH) annually.

The farmlets have been set stocked with breeding ewes since 1975, and the stocking rate has been adjusted as necessary to maintain similar grazing pressure as forage supply has responded to experimental treatments. The stocking rate before the fertiliser trial began in 1975 was 6 su/ha. By 1981 it had increased to 10.9 and 14.9 su/ha on the L and H areas respectively. From 1981 to June 1993 the stocking rate of the HN area dropped to 11.0 su/ha, while the LN areas stocking rate dropped to 8.75 su/ha. During the same period the stocking rate on the HH area has increased to 16.1 su/ha, while the stocking rate on the LL area stabilised at 10.3 su/ha.

3.2 CURRENT TRIAL

As part of the Biophysical Indicator trial, in the winter of 1993 the four fertiliser treatment areas were subdivided into 36 separate paddocks varying in size from 0.37 ha to 1.18 ha (Appendix 1, Table 1). The paddocks were of varying slopes and aspects and set stocked throughout the year with a permanent core of mixed age Romney breeding ewes (testers). The stocking rate of these testers was equivalent to 80% of the "stable" stocking rates shown above, ie 6.6, 8.2, 8.8 and 13.6 su/ha for LN, LL, HN and HH respectively. Appendix 1, Table 2 shows ewe numbers and individual paddock stocking rates. These stocking rates have been at this level since June 1993. As pasture covers increased in spring dry ewes (grazers) were added to maintain a nominal pasture cover between 1400-2000 kg DM/ha. The numbers of these grazers were increased to a peak in January. Pasture growth rates fell and covers declined over the next three months, and the grazers were gradually removed. By the end of March all grazers had been taken off the trial and only the winter stocking rate of testers remained.

The paddocks were individually regarded as being in either north or south aspect classes, and either low (1-14°) or high slope (>14°) categories.

3.2.1 ANIMAL MEASUREMENTS

At the start of the trial in August 1993, the ewes that were grazed in the four fertiliser treatment areas were allocated to the newly fenced paddocks. Ewes wintered on the trial paddocks started lambing in early September and were all finished within six weeks. Lambs were weaned at the end of December, and were taken off the trial area.

All sheep on the trial were weighed every three weeks from the end of lambing till May, and then every 4 weeks up till lambing. No attempt was made to empty sheep out before weighing and sheep were usually weighed within one hour of being off the trial area. The animals were weighed in the week after pasture cover estimation (see below), which allowed the number of grazers needed to maintain cover in the target range to be calculated, and added as soon as possible. Portable electronic scales were used and liveweights taken to 0.1 of a kilogram. A colour ear tag system was used to permanently identify individual sheep.

Due to a shortage of rams to cover the 36 paddocks the testers mated in April 1994 were synchronised using CIDRs and mated as one mob off the trial area. The first peak of oestrus after CIDR removal was expected on the 1st of April, and the second on the 18th of April. The ewes were held off the trial area for six days around each peak in oestrus. A high number of rams was used (one ram for every ten ewes) at the first oestrus to cope with the expected high number of cycling ewes at any one time.

Ewes were culled at pregnancy testing when dry ewes were taken off the trial and replaced with four tooth ewes, scanned in lamb. Out of the 249 trial ewes 10 were culled as dry after the two mating periods. Ewes were also culled at Autumn shearing on the basis of age, condition and teeth.

Individual wool weights were recorded at shearing on the 25th of November and on the 18th of March, and wool growth per day (g/day) is calculated for the two periods. Wool production for individual paddocks was calculated and is shown in Appendix 1, Table 14.

3.2.2 PASTURE MEASUREMENTS

Net herbage production was measured using three grazing exclusion cages per paddock. The cages were situated on slopes and aspects representative of each individual paddock. At each cage site the cage was rotated around 4 pegs. This meant that the cage is placed over peg number 1 for the first cut interval, peg number 2 for the second cut interval and so on. Frames were cut seven times in the trial period running from 7/10/93 to 31/10/94 using the trim technique described by Radcliffe *et al* (1968). Cutting interval was inversely related to herbage accumulation rate, with a minimum interval of 30 days in spring and a maximum interval of 78 days in winter. The intervals of the seven cuts were as follows, cut one was from 7/10/93-16/11/93, cut two 16/11/93-16/12/93, cut three 16/12/93-3/2/94, cut four 3/2/94-7/4/94, cut five 7/4/94-22/6/94, cut six 22/6/94-8/9/94, and cut seven from 8/9/94-31/10/94. To make this last cut fit into the one year measurement period, the dry matter production per day was calculated and multiplied by 29 days to bring it to the trial end date on the 7/10/94.

Pasture cover was measured every three weeks from mid October to the end of January, and monthly at other times, using a rising plate meter. Ten rising plate meter readings were taken around each frame site to give 30 plate readings per paddock (at frame sites located on the average slope of the paddock). Every six weeks four calibration cuts to ground level were made per farmlet, spanning low, medium and high individual plate readings. A regression of pasture cover (kgDM/ha) versus plate readings was derived. For any one cover estimation date, the regression used was a combined relationship (M. G. Lambert, *pers comm*) from the previous two and the next one calibration cut ie, a moving average regression.

The quality of the pastures (MJME/kgDM) for each of the 36 paddocks was measured at each frame cut date from samples taken from herbage harvested from frames for DM production estimation. Sub samples from each frame were bulked across the three frame sites in each paddock for each cut date. This gave pasture quality estimates for each paddock at each cut date. The *in vitro* digestibility of the samples was determined by near infra red spectrophotometry. The ME values of the pasture were calculated using the equation, ME=0.16*DMD-0.8 (D Smith *pers comm*) and are shown in Appendix 1, Table 10.

Botanical composition of the pastures in the different fertiliser treatments was determined in November 1993, when samples were taken from the herbage cut from under frames and dissected into high fertility responsive grasses (HFRG), low fertility tolerant grasses (LFTG), legumes (LEG), and other species (OSPP). This was done for each paddock and the results are presented in Appendix 1, Table 8.

3.3 SPREADSHEET MODEL

Animal intake (kgDM/ha) was calculated from a spreadsheet model (Brookes *et al,* 1994). The model uses measured animal production and works backwards from this to a value of energy the animal must have consumed to achieve the measured production levels. This model is based on published equations for energy use (ARC, 1980). The input data to run these models is animal liveweight and production, ie milk yield, animal liveweight profiles, lambing %, lambing weaning and mating dates, wool production, and pasture quality on a half monthly basis expressed as MJME/kg DM. These data are entered into the model which calculates the DM required by the animals to achieve the production levels entered.

The testers liveweights were entered into the model as group averages as these animals only changed at culling or natural death. The lamb liveweights were also entered as a group average. The lambing percentages, numbers and weaning weights for individual paddocks is shown in Appendix 1, Table 13. The grazers, due to the changing numbers of individuals and hence variable group constitution, were entered into the model as individual animal liveweights. Numbers of grazers for each weighing date and their stocking rates are shown in Appendix 1, Tables 11 and 12.

Metabolisable energy requirement was determined for liveweight changes between weighing intervals, and was worked out for maintenance and liveweight change from the beginning to end of that interval. Pregnancy or lactation requirements were incorporated depending on the time of year. The ME cost of pregnancy is determined by the stage of pregnancy and the number of foetuses the ewe is carrying. The number of foetuses is determined from lambs born. During lambing ewes were checked at least daily and lamb numbers, and a sample of lamb birth weights recorded. The ME needed for pregnancy is the sum of the requirement for maintenance of the foetus/es, and for growth of the foetus/es. The efficiency of ME use for pregnancy, which is net energy retained in the foetus divided by the ME required. The ME requirement for lactation depends on the milk yield of the ewe, and is affected by the number of lambs the ewe is suckling and on the feeding level of the ewe. The ME requirement for wool production was divided into the two wool growth periods ending in shearing, ie one period from late November to mid March the following year, and the other from mid March to late November.

The efficiency with which ME intake is used by the animal is determined by the physiological status of the animal and the quality of the pasture. The ME required for the maintenance of the animal depends largely on the size of the animal. An allowance for climatic and activity effects on ME requirements is built into the ARC estimate for maintenance within the model.

The ME required for liveweight gain depends on the total liveweight gain and the composition of the gain. Fat tissue is 80% lipid, 20% water, with an energy value of 39

MJ GE/kg. Muscle tissue is composed of 20% protein and 80% water, with a energy value of 24 MJ GE/kg. The composition of gain depends on animal age and sex, with animals closer to mature liveweight having more fat in a kg of liveweight gain than younger, less mature animals. The ME spared by liveweight loss is calculated from the NE contained in a kg of weight loss (19 MJNE, ARC, 1980), multiplied by the efficiency value for maintenance. This is then divided by the efficiency value of ME use, to give the amount of pasture saved by the liveweight losses.

The ME intake of lambs from pasture is calculated as the energy in lamb liveweight gain, wool production and maintenance not accounted for by milk intake.

The ME requirement calculated at this point was on an individual animal basis. To determine the total intake in kg/DM/ha/day the individual ME requirement for the three stock classes (testers, grazers and lambs) were multiplied by the number of each stock class per paddock. This figure was then divided by the paddock size to determine total intake in kgDM/ha/day.

3.4 STATISTICAL ANALYSIS

The frame cut and model estimate data were analysed by analysis of variance (ANOVA) using the VITAL programme (Onstream systems Ltd). The design was a factorial combination of fertiliser treatments (4), slopes (2), aspects (2) and paddocks (8 or 10 depending on farmlet). This was an unbalanced design as the paddocks within farmlets, which were treated as replicates, were not distributed equally across farmlets in slope*aspect categories. The ANOVA removed this effect and estimated means for "balanced" farmlets.

Because of the spatial layout of the farmlets, ie contiguous paddocks, paddocks were treated as being nested within farmlet, and replication was strictly speaking internal to farmlets. It is thus not possible to say with confidence that significant differences exist amongst fertiliser treatments. All that it is possible to conclude with complete confidence is that significant differences amongst treatments were greater than differences within treatments. All significance levels referred to in this section are $P<0.05$.

3.5 PERSONAL INVOLVEMENT IN MEASUREMENTS MADE

As the trial described here was part of the much larger Biophysical Indicator trial run by AgResearch, much of the data described here was collected by other people for other purposes as well as for this trial. Weighing of sheep usually involved 5-6 people, as did frame cuts, and labour was provided by technical and farm staff. I was personally involved in all weighing, frame cuts, some plating, helping at shearing and scanning, and in the collection of lamb birth weights whilst doing a daily lambing beat over lambing in both years. Once every week I observed every paddock and counted animal numbers to ensure animals were in the right paddocks, and to keep fences in good order, and the voltage of the fences high. All data entry and work on the computer model was carried out by myself.

4.0 RESULTS

4.1 THE RATIO OF MODEL TO FRAME CUT

The ratios of model and frame cut estimates of pasture production for the four fertiliser treatments, and the two slope and aspect classes are shown in Table 1 for the seven individual cuts and for the annual totals.

There were significant differences between the ratios for the four fertiliser treatments in four of the seven cut intervals, but not in the ratio of annual totals. The average ratio of the four fertiliser treatments at the seven cut dates ranged from a high of 1.60 at cut 4 to a low of -0.02 at cut 6. The average annual ratio of model to frame production for the four fertiliser treatments was 0.71. Individual fertiliser treatments ranged from 0.81 for treatments LN and HN, to 0.73 for treatment LL.

The ratio of model to frame annual production was significantly higher on the high than low slope. There were significant differences between slopes in only two of the seven cuts, cuts 4 and 6, when high slope had a greater ratio than low slope. Although not significant, the ratio in the other five cuts was consistently higher on the high slope.

Aspect had little affect on the ratio, with significant differences occurring in only cut 1 and 6, and not in the ratios of the totals for north and south aspect.

Estimates of frame and model production for individual paddocks can be seen in Appendix 1, Tables 3 and 4. The ratios of model and frame, and the models estimate of intake for individual paddocks can be seen in Appendix 1, Tables 5 and 6.

4.2 HERBAGE PRODUCTION MEASURED BY FRAME CUTS

The pasture production of the four fertiliser treatments and the two slope and aspect classes measured by the frames is shown in Table 2 for the seven individual cuts (kgDM/ha/day), and for the annual total (kgDM/ha).

There were significant differences in pasture production between the four fertiliser treatments in six of the seven cut intervals. In general there was a decline in the rate of dry matter production as fertiliser input decreased. The total annual dry matter production from the four fertiliser treatments was significantly different with treatment LN having a lower level of pasture production than the other three treatments. Treatments LL and HN were not significantly different, while treatment HH had a higher level of pasture production than the other three treatments. Pasture production (kgDM/ha/day) of low slope was significantly higher than that measured on the high slope class in five of the seven cut intervals. At other times, cuts 2 and 5, the low slope had a marginally higher level of herbage production than the high slope. The annual total (kgDM/ha) of low slope pasture production was significantly higher than that measured from high slope classes.

TABLE 1.

Ratios of model to frame cut data for the four fertiliser treatments and their average, and for slope and aspect measured over the four fertiliser treatments, across 7 cut intervals and for the annual total

	CUT 1	CUT 2	CUT 3	CUT 4	CUT 5	CUT 6	CUT 7	ANNUAL
FERT TREATMENT								
LN	1.38a	1.31a	0.73	1.74	-0.01a	-0.24a	0.27	0.81
LL	0.95b	1.15ab	0.55	1.56	0.29ab	0.00b	0.25	0.73
HN	1.01b	1.35a	0.67	1.56	0.11a	0.03b	0.33	0.81
HH	1.15b	0.81b	0.65	1.57	0.52b	0.09b	0.25	0.74
AVERAGE	1.12	1.15	0.65	1.61	0.23	-0.03	0.27	0.77
SLOPE HIGH	1.20	1.18	0.70	1.89a	0.33	0.12a	0.32	0.88a
SLOPE LOW	1.02	0.99	0.60	1.4b	0.22	-0.1b	0.24	0.68b
ASPECT NORTH	0.93a	1.11	0.63	1.60	0.38	0.04a	0.24	0.74
ASPECT SOUTH	1.30b	1.05	0.66	1.60	0.18	-0.09b	0.31	0.80

Means with different letters within columns, and within fertiliser treatment, slope or aspect categories are significantly different ($P < 0.05$)
Slope high= >14 degrees
Slope low= <14 degrees

TABLE 2.

Pasture production measured using frame cuts (kgDM/ha/day) for fertiliser treatments, and for slopes and aspects measured across the fertiliser treatments, plus annual totals (kgDM/ha).

	CUT 1	CUT 2	CUT 3	CUT 4	CUT 5	CUT 6	CUT 7	ANNUAL
FERT TREATMENT								
LN	22.9a	28.5a	36.3a	18.3	9.5a	11.9a	21.1a	6963a
LL	36.2b	46.2b	55.2b	21.3	12.6ab	12.9ab	28.3a	9673b
HN	41.3bc	41.2b	50.3b	23.7	9.9a	14.5ab	27.9a	9538b
HH	48.4c	78.6c	64.3c	22.7	16.8b	17.2b	44.5b	12793c
AVERAGE	37.2	48.6	51.5	21.5	12.2	14.1	30.5	9742
SLOPE HIGH	32.2a	45.2	46.3a	17.9a	11.9	11.0a	24.8a	8530a
SLOPE LOW	42.2b	52.1	56.7b	25.0b	12.5	17.2b	36.2b	10953b
ASPECT NORTH	40.7	47.2	52.6	21.0	11.5	16.5a	33.4	10073
ASPECT SOUTH	33.7	50.0	50.5	22.0	12.9	11.8b	27.5	9410

Means with different letters within columns, and within fertiliser treatment, slope or aspect categories are significantly different ($P < 0.05$)
Slope high= >14 degrees
Slope low= <14 degrees

There were no significant differences in the annual pasture production (kgDM/ha) between the north and south aspects. Only in cut interval 6 was there a significant difference when north aspect produced more dry matter than the South aspect.

4.3 HERBAGE PRODUCTION VIA THE MODEL

The annual pasture production measured via the model was also significantly different (Table 3) between the four fertiliser treatments, with treatment LN having a lower level of pasture than either LL, HN or HH. Treatments LL and HN were not significantly different from each other, while treatment HH had significantly higher pasture production than the other three treatments. Of the seven individual cuts, six had significant differences between the fertiliser treatments in pasture production level. The one cut period where pasture production was not significantly between fertiliser treatments was cut 4, which corresponds to the same result in cut 4 of the frame cut measurements.

There were no significant differences in the annual pasture production (kgDM/ha) between high and low slope, or the aspects of north and south. In the seven individual cuts, cut interval six had significant differences in pasture production between both slope and aspect classes. No other significant differences were measured in the other cut intervals for either slope or aspect. The significant differences in cut 6 has little relevance as although the differences between slopes and aspects the actual dry matter production for the two levels of slope and aspect ranged from 1.3 to -1.8 kgDM/ha/day.

4.4 ANIMAL INTAKE AND COVER CHANGE

The values of dry matter production (kgDM/ha/d) measured from frame cuts and those calculated from the model (intake plus cover change) for the seven cut intervals and the four fertiliser treatments, LL, LN, HN and HH, are shown in Figures 1 to 7. Annual totals for cover change, intake, model estimate and pasture production (kgDM/ha)

TABLE 3.

Pasture production calculated from the model (kgDM/ha/day) for fertiliser treatments and for slopes and aspects measured across the fertiliser treatments, plus annual totals (kgDM/ha)

FERT TREATMENT	CUT 1	CUT 2	CUT 3	CUT 4	CUT 5	CUT 6	CUT 7	ANNUAL
LN	31.6a	37.4a	26.6a	31.9	-0.1a	-2.9a	5.8a	5634a
LL	34.4a	53.3b	30.3a	33.2	3.6b	0.1b	7.2ab	7038b
HN	41.6a	55.5b	33.9a	36.9	1.1ab	0.5b	9.1bc	7694b
HH	55.4b	63.3b	41.8b	35.7	8.8c	1.5b	11.1c	9528c
AVERAGE	40.8	52.4	33.2	34.4	3.3	-0.2	8.3	7473
SLOPE HIGH	38.6	53.2	32.4	33.8	3.9	1.3a	8.0	7487
SLOPE LOW	42.9	51.5	33.9	35.0	2.8	-1.8b	8.7	7460
ASPECT NORTH	37.7	52.2	33.1	33.7	4.4	0.7a	8.1	7446
ASPECT SOUTH	43.8	52.5	33.1	35.2	2.3	-1.1b	8.5	7501

Means with different letters within columns, and within fertiliser treatment, slope or aspect categories are significantly different ($P < 0.05$)
Slope high= >14 degrees
Slope low= <14 degrees

calculated via the frames and the model is shown in Figure 8. These figures show the break down of the model into animal intake and cover change, and this allows the two components in the model to be identified.

Figures 1-7 demonstrate the wide variation that is introduced into the model estimate by pasture cover changes at different times of the year. Positive cover changes occur in cut intervals 1-4, while in cut intervals 5-7 the cover changes are negative. This reflects the seasonal imbalance between pasture growth and animal demands which causes pasture surpluses in late spring-summer, and deficits in winter-early spring, and the high rates of pasture decay in the late autumn-early winter.

Figure 1 shows that the model estimate of herbage production at cut 1 (7/10-16/11/93) is slightly higher than that measured from the frame cuts. Figure 2 shows that the model measured a greater rate of herbage production in treatments LN, LL and HN but not in HH where frames measured a greater rate of herbage production. Figure 3 shows all four fertiliser treatments produced more herbage under the frames than measured by the model. This varies from around 20% more in treatment LN to around 80% more in treatment LL. Figure 4 shows a reversal of this with the model estimate being around 60% greater than the frame estimate. Figures 5 shows the effect of negative cover changes on the model. As intake is only slightly greater than frame herbage production, the large negative cover change is likely due to the disappearance of dead material from the grazed sward. This trend is continued in Figure 6. In Figure 7 the relationship between intake and frame estimate is very weak, this is likely due to the low intake value calculated via the model. The annual values of intake, cover change, model and frame estimates are shown in Figure 8. This shows there was a close and consistent relationship between the annual totals calculated for animal intake and pasture production measured via the frames for all four fertiliser treatments. Figure 8 also shows the minor influence of annual pasture cover change on the annual total estimate of the model.

Pasture covers at frame cut dates and the total change in cover from the beginning to end of the trial are presented in Appendix 1, Table 9. Over the year average pasture covers increased by 528, 789, 693 and 846 kgDM/ha for fertiliser treatments LN, LL, HN and

Figure 1: Pasture production for cut interval 1 (7/10- 16/11/93)

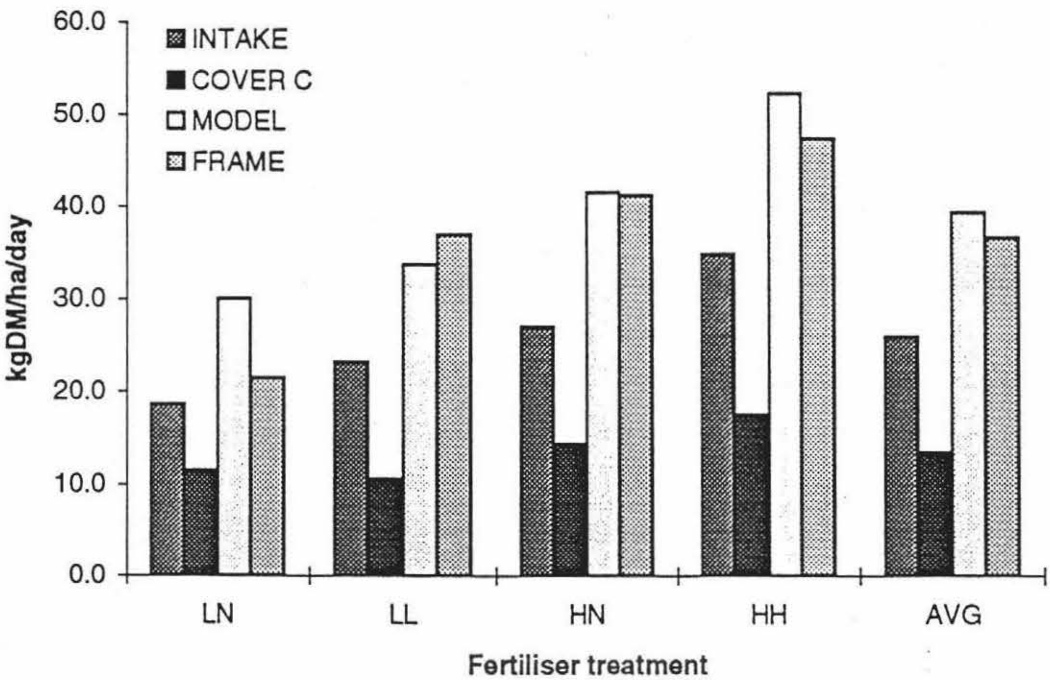


Figure 2: Pasture production for cut interval 2 (16/11 - 16/12/93)

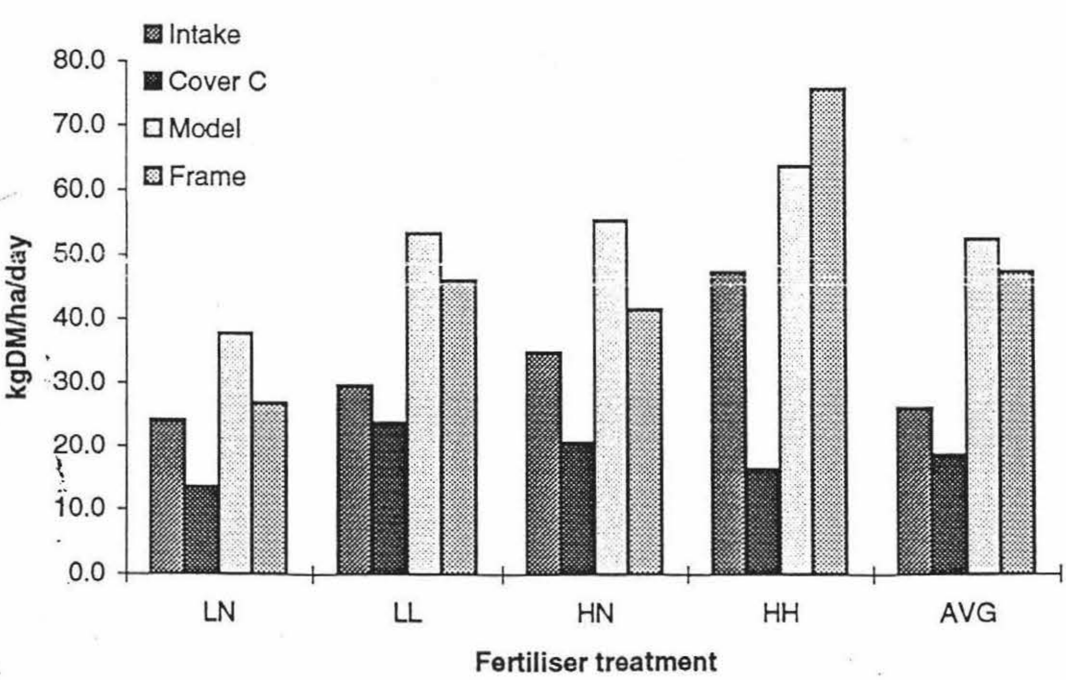


Figure 3: Pasture production for cut interval 3 (16/12/93 - 3/2/94)

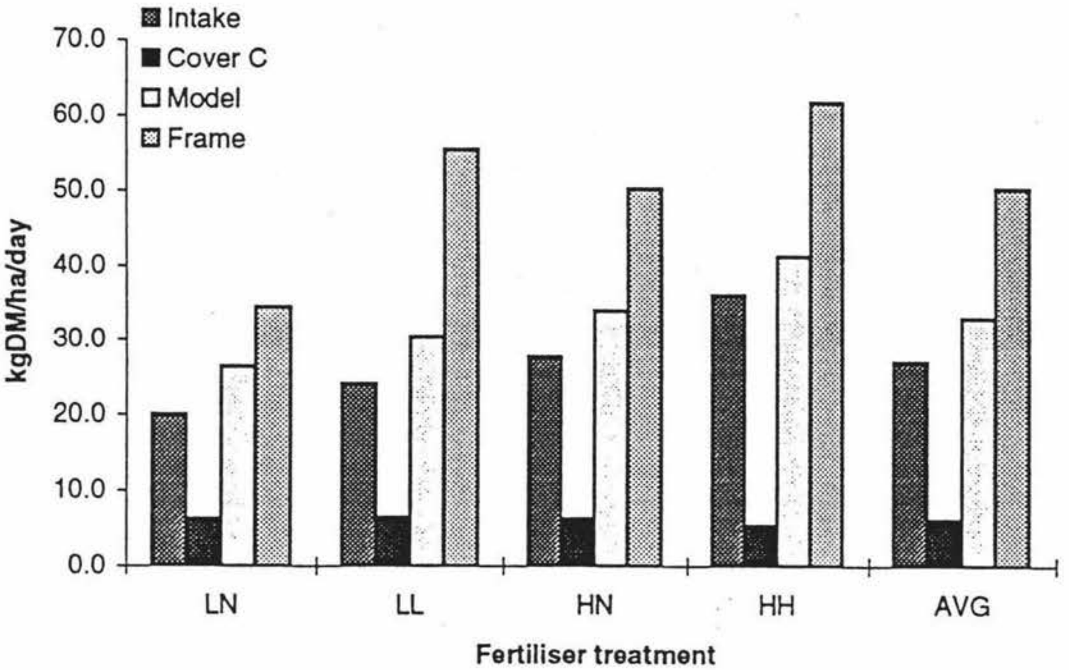


Figure 4: Pasture production for cut interval 4 (3/2 -7/4/94)

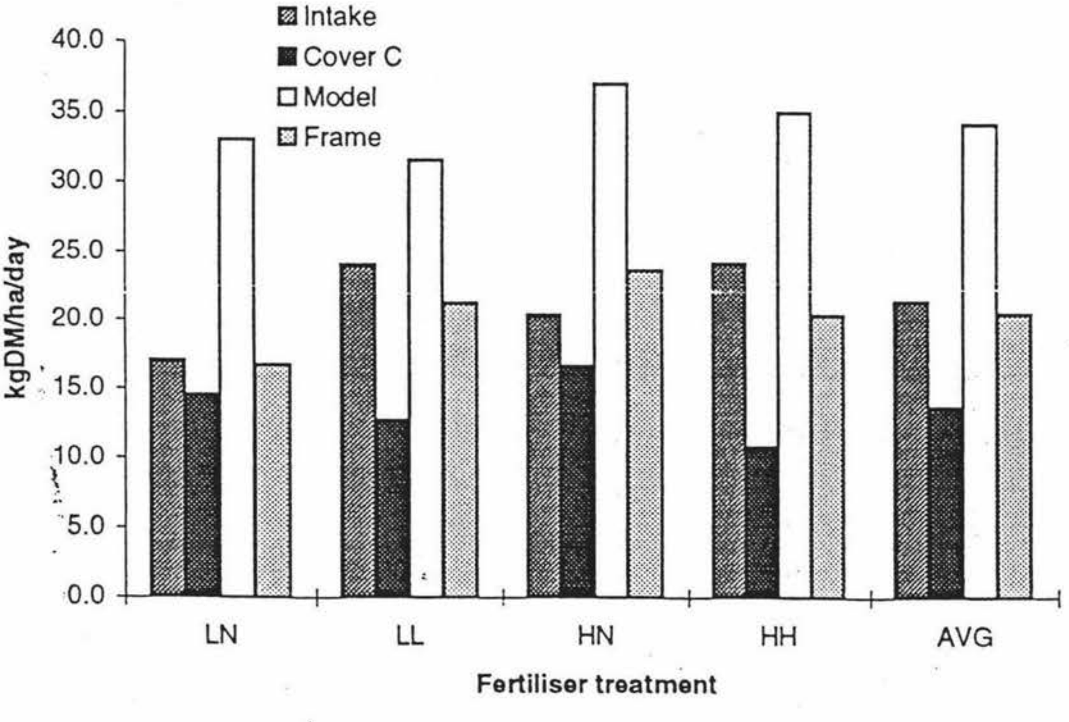


Figure 5: Pasture production for cut interval 5 (7/4 - 22/6/94)

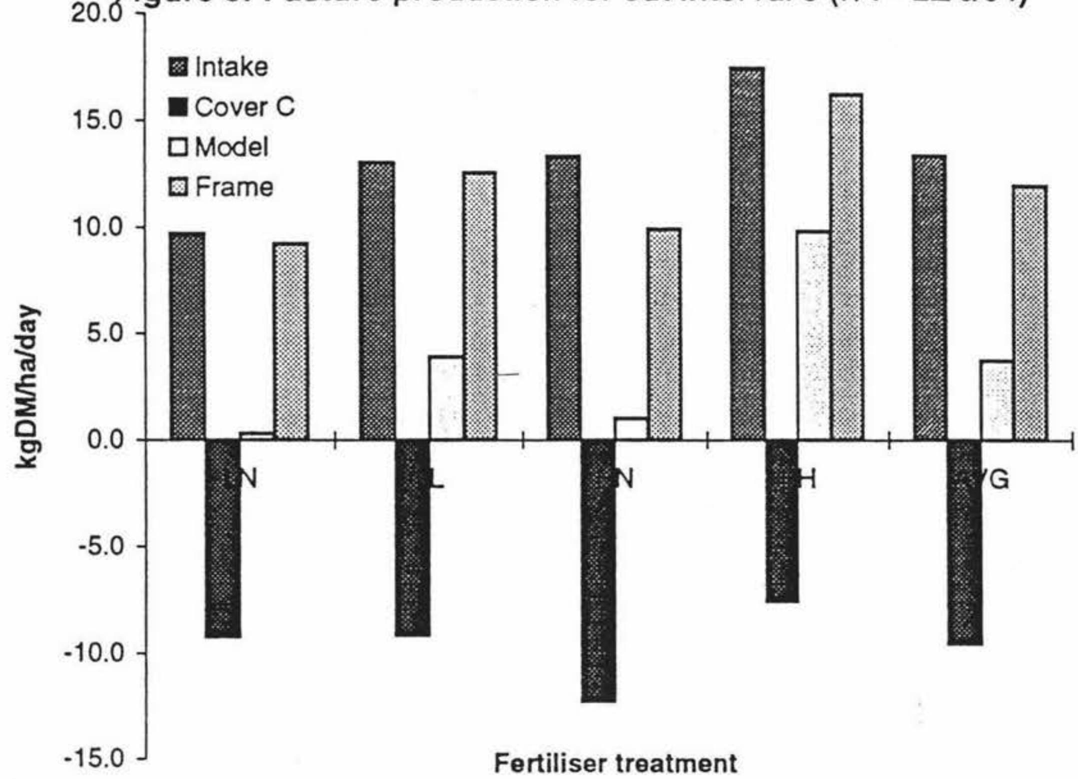


Figure 6: Pasture production for cut interval 6 (22/6 - 8/9/94)

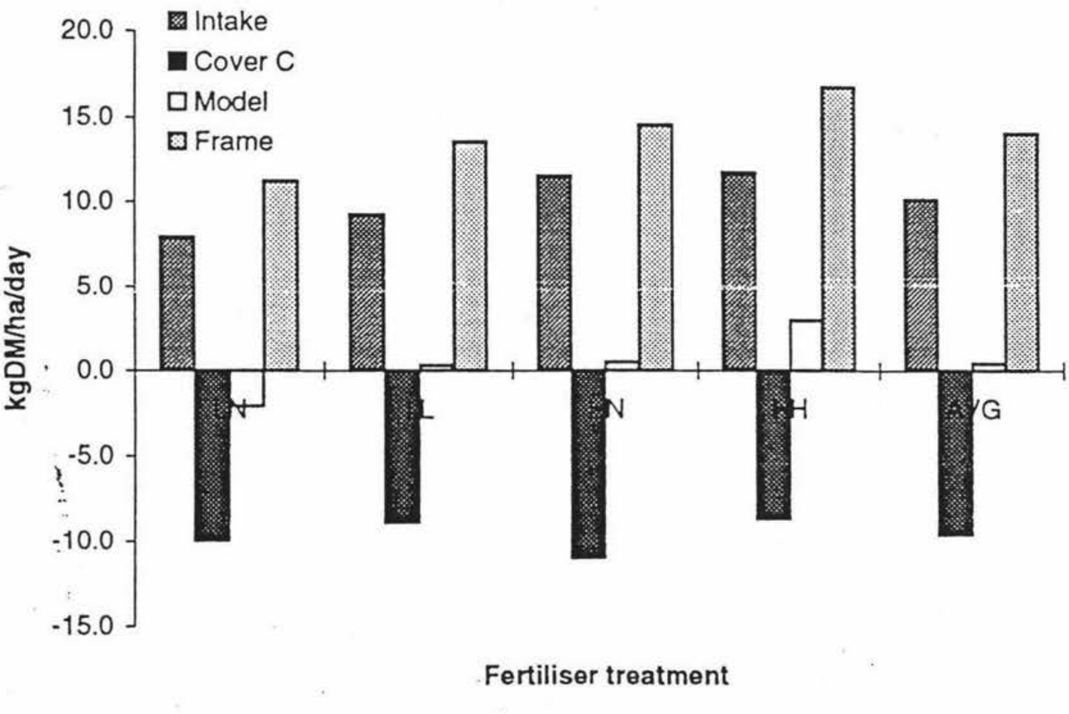


Figure 7: Pasture production for cut interval 7 (8/9 - 7/10/94)

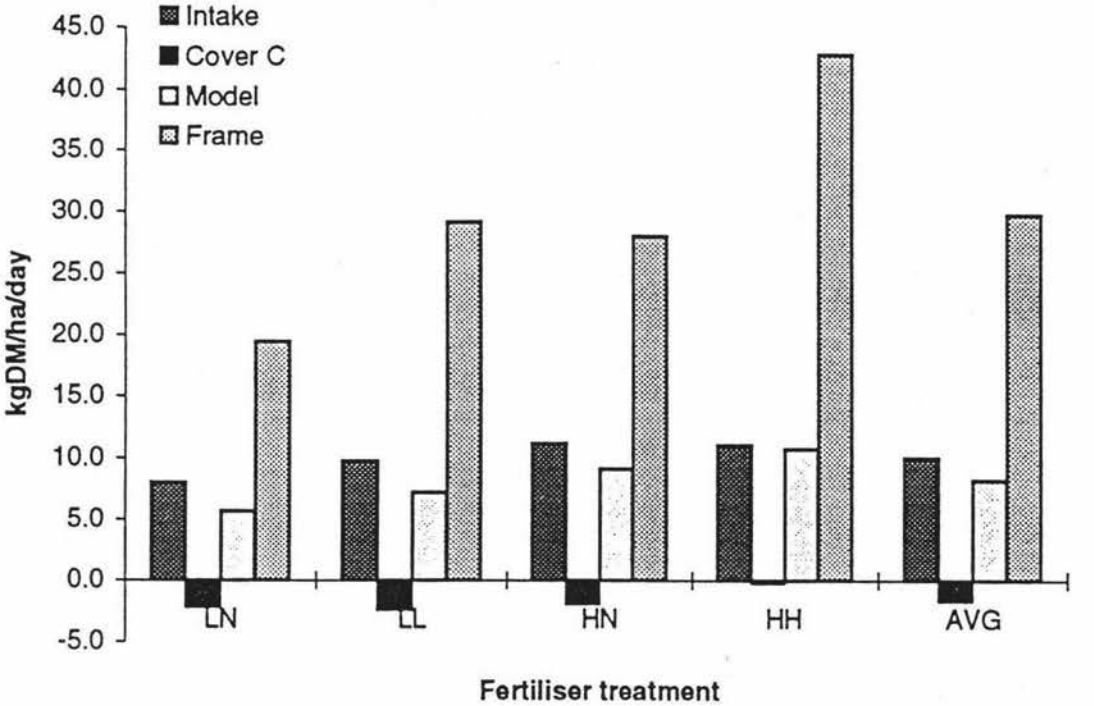
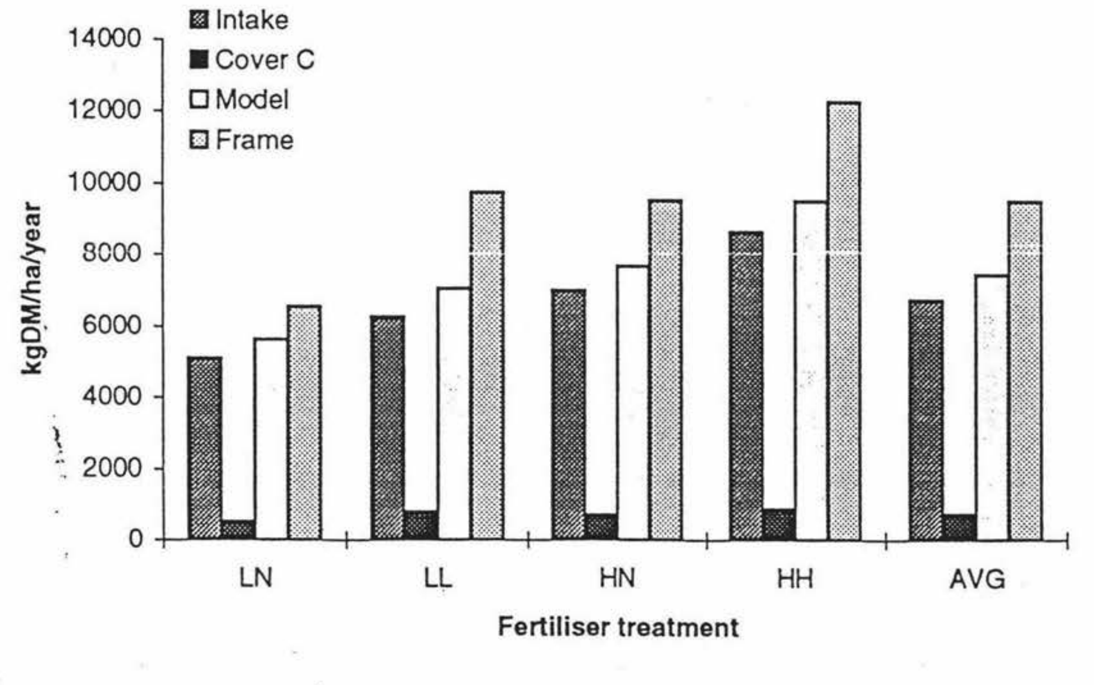


Figure 8: Pasture production estimates for the year 7/10/93-7/10/94.



HH. During the year average farmlet covers ranged from a low of 1058 kgDM/ha in the HH treatment at the start of the trial, to a high of 3803 kgDM/ha in the HN treatment on the 7/4/94.

4.5 HERBAGE QUALITY MEASUREMENTS

The ME values (of herbage sampled from under frames) ranged from a low of 8.9 MJME/kgDM in cut interval 3 for treatment LN, to a high of 11.5 MJME/kgDM for the HH treatment in cut interval 7. Fertiliser treatment LN consistently had the lowest ME value, with treatments LL and HN being very similar while treatment HH consistently had the highest ME values. The individual values of ME for each paddock and cut interval can be seen in Appendix 1, Table 10.

4.6 ANIMAL PRODUCTION

The lambing percent of the four farmlets averaged 116 percent and weaning weights ranged from an average of 22.3 kg liveweight for fertiliser treatment LN, to 27.7 kg for treatment HN. Lambing percentages and weaning weights for each paddock can be seen in Appendix 1, Table 13.

Wool production for the four fertiliser treatments averaged 3.58, 3.83, 4.12 and 3.72 kg greasy wool per ewe for treatments LN, LL, HN and HH respectively. Lamb wool weights were estimated to be 1 kg per lamb at weaning. The average wool production per ewe from individual paddocks is shown in Appendix 1, Table 14.

4.7 BOTANICAL COMPOSITION

Botanical composition of each paddock is shown in Appendix 1, Table 8. The results are presented as a percentage of the total herbage, and are divided into four classes, high fertility responsive grasses (HFRG), low fertility tolerant grasses (LFTG), legumes (LEG) and other species (OSPP). The level of HFRG increased and LFTG decreased as fertiliser input increased. The level of legumes in the pasture varied little between fertiliser treatments, but in general there was an increase in legume content as fertiliser input increased, with LN having a legume content of 9.3% and HH 15.8%.

5.0 DISCUSSION

5.1 RATIO OF MODEL TO FRAME MEASUREMENTS

The ratios of model to frame cut data shown in Table 1 show a high degree of variation between the seven cut intervals, from a maximum of 1.60 in late summer to a minimum of -0.02 in winter. This variation could be due to inaccuracies in either the estimates of the intake calculated via the model, the values of cover change, or the dry matter production measurements from under the frames, or it could be due to explainable differences between a grazed sward and a sward covered by a grazing exclusion frame. Within cut intervals trends shown in terms of intake, cover change, model and frame estimates are consistent between fertiliser treatments, differing only in magnitude.

The values of intake calculated by the model fit expected levels of adult ewe intake for differing seasons. For example the calculated intakes in October, January, March and July were 26.2, 11.5, 11.2 and 10.7 MJME/ewe/day respectively. This equates to dry matter intakes of 2.5, 1.2, 1.2 and 1.1 kgDM/ewe/day, which compare well to the intake levels given by Geenty and Rattray (1987) for adult ewes. A high level of confidence in these intake values (calculated via the model) is backed up by the results of Fulkerson *et al* (1986), Holmes *et al* (1981) and Vera *et al* (1977) who all found that intakes calculated via models, using the values of energy requirement provided by ARC (1980) and MAFF (1975), compared closely with actual measured intakes.

The accuracy of the values of herbage production measured from under the frames is difficult to question as it is an established method which measures actual physical production. It would appear that in closely grazed pastures where little dead material builds up, and measurements are largely green material, frames provide an accurate means of measuring pasture production. When grazed swards build up significant levels of dead material, as happens in summer in most hill country swards, the accuracy of herbage production values derived via frame cuts from these areas becomes questionable. This is due to the differing levels of dead material between the grazed sward and that under the frame. This occurs as existing pasture is trimmed off when a frame is first placed. This removes much of the existing dead material and thus the frame site differs from the grazed sward. This can cause differences between the pasture growth rate calculated from frame cuts and that of the grazed pasture as this dead material can rapidly decompose in moist, warm conditions. This can be seen in cut intervals 5 and 6 (Figures 5 and 6) when frame production is equal to or greater than animal intake, yet there are large decreases in cover as dead material built up over the dry summer-autumn decomposes which causes pasture covers to drop.

The pasture cover measurements are likely to introduce a degree of inaccuracy to the model estimate. The rising plate meter was developed for dairy pastures on flat land dominated by green perennial ryegrass (Earle and McGowan, 1979). L'Huillier and Thomson (1988) compared the use of the pasture probe, rising plate meter, sward height and visual assessment methods for the estimation of herbage mass in dairy pastures. They found that variation between calibrations from different days, seasons, and sites was large, and that only dead material content was identified to influence this variation. The use of rising plate meters in short and dense pastures, with seasonally high levels of dead material, characteristic of continuously grazed swards is likely to cause wide ranges in the estimated pasture cover and thus cover change. Dead reproductive tillers that have been grazed off leaving a tough stalk are likely to have a greater physical strength, and a greater resistance to the plate. The result of this is that the plate may be held higher up in the sward and give a exaggerated high reading. Within the 36 separate paddocks there was a wide range in the effectiveness of the variable stocking rate in maintaining pasture covers in the projected range of 1400-2000 kgDM/ha. This resulted in some paddocks expressing more reproductive growth than others (*pers obs*), and this would have impacted on the accuracy of plate readings between paddocks.

The higher estimation of herbage growth under frames than calculated via the model during cut interval 3 (16/12/93-3/2/94) (Figure 3) was possibly caused by the effect of reproductive growth being able to express itself to a greater extent under the frames than in the continuously grazed pasture causing higher growth rates under the frames than in the grazed sward (Parsons and Robson, 1981; Davies, 1971; Behaeghe, 1978). The timing of this effect will be affected by the botanical composition of the pastures, and their respective flowering periods. Korte *et al* (1987) give the dates of seed head appearance in Manawatu hill pastures as early October to late December for perennial ryegrass (*Lolium perenne*) and mid December to early February for browntop (*Agrostis capillaris*). Due to the earlier flowering period of ryegrass it would be expected that pastures with a high percentage of ryegrass would show an earlier increase in herbage accumulation under frames than pastures dominated by browntop. This is shown in cut interval 2 (16/11-16/12/93) (Figure 2) when fertiliser treatment HH is the only treatment showing a significantly greater ($P < 0.05$) herbage production under frames than in the surrounding grazed pastures. This can be attributed to the higher level of ryegrass in the high fertility farmlet (Appendix 1, Table 8). In cut interval 3 (16/12/93-3/2/94) all four farmlets showed a greater herbage production under the frames than in the surrounding grazed pastures. This corresponds with the flowering period of browntop and hence greater production under frames (Korte *et al*, 1987; Parsons and Robson, 1981; Davies, 1971; Behaeghe, 1978).

The ratios of model to frame data in cut interval 4 (3/2-7/4/94) show a reversal of the trends shown in cut interval 3, with herbage production measured via the model (over the four fertiliser treatments) averaging 1.66 times that measured under the frames (Figure 4). During this cut interval, intake calculated via the model was greater than the frame estimate in three of the four fertiliser treatments (Figure 4). At the same time covers were increasing at an average of 13.7 kgDM/ha/day. This means that either intake and cover change were overestimated or that pasture production in the continuously grazed sward was greater than that under the frames. Intake over this period averaged 17.0, 20.3, 20.3 and 24.1 kgDM/ha/day for the four fertiliser treatments, and as pasture cover was consistently increasing (Appendix 1, Table 7) it would seem that less dry matter was produced under the frames than in the continuously grazed pasture.

During this period the trial area was experiencing a drought, with 201 mm of an average 262 mm falling during January to March. A graph of soil moisture contents is given in Appendix 1, Figure 1 showing the prolonged period of moisture stress over the period. Moisture stress on the grass plant seems to be exaggerated when the pasture is severely grazed or trimmed as when placing a frame. Jantti and Kramer (1956) state that defoliated plants draw less water from the soil, since with the leaves removed, water potentials cannot be lowered to the same extent as that for intact plants. It follows that at similar soil water contents, shorter pastures will have a smaller reservoir of available water from which to draw and consequently a reduced ability to produce. Trimming herbage off frame sites in dry conditions is likely to limit the subsequent production on these areas relative to a continuously grazed sward maintained at a cover of 2-3000 kgDM/ha. This would explain the apparently greater herbage production from the grazed sward than that under the frames.

The ratios of model estimate to herbage production measured under frames for cut interval 5 (7/4-22/6/94) and 6 (22/6-8/9/94) averages 0.32 and 0.03 (Figures 5 and 6). This low ratio was due to a large negative cover change making the model estimate (intake plus cover change) very small or negative by cancelling out intake when added together. Intake over the two cut intervals was similar to the level of pasture production measured under the frames (Figures 5 and 6). The negative cover change was due to the large amount of dead material disappearing from the grazed sward once moisture stress had been alleviated by late autumn rains, and conditions for the decomposition of dead material improved. This occurred in the grazed sward, but not under the frames as most dead material would have been trimmed off when the frame was placed.

In cut interval 7 (8/9-7/10/94) (Figure 7) the ratio is 0.27 reflecting the low intake calculated via the model. The low intake seems unlikely to be due to low pasture covers limiting the intake of the ewes as covers at the start and end of this period averaged 2000 and 1949 kgDM/ha. Thus the low calculated intake must have been due to the large weight loss over this period. The model is designed to cope with the weight loss incurred at lambing and recognises this as conceptus not ewe tissue loss. The actual weight loss calculated by the model depends on the number of foetuses and the weight of the ewe, from which lamb birth weight is calculated.

The weight loss of ewes over the spring period was large, but due to the lack of weighing over this period it is not possible to identify precisely when the weight loss occurred although it is likely that the majority occurred at lamb drop. It seems likely that the computer model underestimated the magnitude of the weight loss and has attributed some of weight loss due to lambing as actual ewe tissue loss and thus has substituted the ME in the weight loss with ME intake.

Due to the relatively low number of frame cuts over the year these effects will often overlap and cause difficulties in identifying the true cause of differences between frame and model estimates of herbage production, and the magnitudes of these differences.

5.2 THE EFFECT OF FERTILITY, ASPECT AND SLOPE

The significant differences in herbage production between the fertiliser treatments, and that slope had a significant effect on dry matter production measured from frame cuts reinforces the results of Lambert *et al* (1983), who state that slope related factors are probably the biggest single determinant of herbage accumulation variability in southern North Island hill country. They found that slope of measurement site had a strong negative relationship with herbage accumulation rate (HAR). Between slopes of 15 -27^0 annual herbage accumulation decreased by about 370 kgDM/ha/year per degree increase in slope.

Aspect effects were found to be unimportant to annual herbage production which backs up the findings of Lambert *et al* (1983) who found that that aspect effects were less marked than those of slope, and significant only in seasonal production in the Ballantrae environment.

5.3 PASTURE QUALITY

The pasture used to determine the quality of herbage on offer to grazing sheep was taken from herbage harvested from under frames. This herbage would have differed from that on offer to grazing animals in the surrounding sward in such aspects as the size and number of tillers and differing amounts of dead matter. The grazed sward has a higher dead matter content than that under the frame as most material, dead or otherwise, is trimmed off when the cage is placed.

The size of tillers in the surrounding grazed pasture limits the diet of grazing sheep predominantly to leaf lamina (Barthram, 1981; Bircham, 1981). When digestibility or MD estimates are obtained from pasture samples harvested to ground level and the diet selection of the grazing animal is ignored, the intake requirement will be over estimated (Poppi *et al*, 1987).

This will occur as stem material is included in the pasture sample, but does not make up a significant amount of the diet of continuously grazed sheep. As stem material has a lower digestibility than leaf material, the inclusion of stem in the estimate of herbage quality will lower the value of the estimate of the sheep's diet used in the model.

This will be partially offset by the fact that regrowth under the frames contains little dead material, thus the pasture sample taken from under the frames will contain less dead material than the surrounding sward, and hence, the sheeps diet. The degree to which these opposing factors cancelled one another is not known.

The model calculates energy requirements in MJME, and this figure is divided by the pasture quality estimate (ME) to give a value of kilograms of dry matter eaten. Using a pasture quality estimate in the model that is lower than the actual sheep's diet will cause the model to overestimate the dry matter consumed by grazing animals.

6.0 CONCLUSIONS

Animal intakes can be calculated from animal production information by use of computer spreadsheet models using information about the energy requirements of grazing animals provided in the literature. This method provides an alternative method of measuring pasture production in continuously grazed pastures.

Differences between herbage production measured via frames and via the model arise largely as a result of the increased expression of reproductive tillers under frames than in the surrounding continuously grazed sward. Also the differences in dead matter content between the grazed sward and the sward under the frame cause large differences in herbage production estimates by the two methods in autumn and early winter when large amounts of dead matter disappear from the grazed sward.

The rising plate meter is not well suited to the short dense swards created by continuous sheep grazing, and the values of cover and hence cover change derived via this method are likely to introduce a element of error into the model estimate of herbage production. If this technique was to be used over periods shorter than a year, cover estimates would need to be more accurate to improve the relationship of the model.

The results of this study indicate that the pasture production values of continuously grazed swards measured by grazing exclusion cages differ to the growth of the grazed sward as measured by intake plus cover change. Two significant differences occur between the growth rates measured under frames and those in the surrounding grazed pasture. Firstly in late spring frames overestimate the growth rate of the surrounding grazed pasture due to greater expression of reproductive tillers under the frames causing higher pasture growth rates. Secondly in autumn there is a large negative cover change in the grazed pasture as accumulated dead matter breaks down. This does not occur under the frames as the frame sites are trimmed at frame placement, thus disposing of most of the dead matter. This means that covers will often fall in autumn despite frame growth rates indicating pasture covers should be increasing. This has implications for anyone wishing to make use of pasture growth rate data calculated from frame cuts for practical feed budgeting, in that expected growth rates may differ widely from the actual growth rates. These differences need to be taken into account to provide accurate estimations of herbage supply to grazing animals.

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APPENDIX 1, TABLES 1-14, FIGURE 1

Table 1

Paddock areas, slope and dominant aspect

	Area (ha)	Slope	Aspect
LN 1	0.91	20	N
LN 2	0.75	26	N
LN 3	0.86	18	N
LN 4	0.78	24	N
LN 5	1.11	9	N
LN 6	0.37	23	N
LN 7	0.87	24	S
LN 8	0.98	17	S
LN 9	1.13	23	S
LN 10	1.03	23	S
AVG	0.88	21	
LL 1	0.47	25	N
LL 2	0.55	23	N
LL 3	0.67	20	N
LL 4	0.68	27	N
LL 5	1.18	8	N
LL 6	0.96	13	S
LL 7	0.95	16	S
LL 8	1.12	17	S
AVG	0.82	19	
HN 1	0.68	28	N
HN 2	0.66	25	N
HN 3	0.49	33	S
HN 4	0.85	22	N
HN 5	0.40	15	S
HN 6	0.72	7	S
HN 7	1.08 *	14	N
HN 8	0.86	18	S
AVG	0.72	20	
HH 1	0.64	21	N
HH 2	0.89	23	N
HH 3	0.59	24	N
HH 4	0.56	27	N
HH 5	0.55	23	S
HH 6	0.61	25	S
HH 7	0.61	20	N
HH 8	0.84	11	N
HH 9	0.72	23	N
HH 10	0.73	14	N
AVG	0.67	21	

* 0.95 ha from 7/10/93-21/4/94

Table 2

Tester numbers and stocking rates over the trial

	(7/10/93-12/8/94)			(12/8/94-7/10/94)	
	NO'S	SR		NO'S	SR
LN 1	6	6.59		6	6.59
LN 2	5	6.67		5	6.67
LN 3	5	5.81		6	6.98
LN 4	5	6.41		5	6.41
LN 5	7	6.31		7	6.31
LN 6	2	5.41		2	5.41
LN 7	5	5.75		5	5.75
LN 8	6	6.12		5	5.10
LN 9	7	6.19		8	7.08
LN 10	6	5.83		6	5.83
AVG	5.4	6.11		5.5	6.21
LL 1	3	6.38		4	8.51
LL 2	4	7.27		4	7.27
LL 3	5	7.46		5	7.46
LL 4	5	7.35		5	7.35
LL 5	9	7.63		9	7.63
LL 6	7	7.29		8	8.33
LL 7	7	7.37		7	7.37
LL 8	9	8.04		8	7.14
AVG	6.1	7.35		6.3	7.63
HN 1	6	8.82		7	10.29
HN 2	5	7.58		6	9.09
HN 3	4	8.16		4	8.16
HN 4	7	8.24		8	9.41
HN 5	3	7.50		6	15.00
HN 6	6	8.33		7	9.72
HN 7	9	8.33	*	10	9.26
HN 8	7	8.14		7	8.14
AVG	5.9	8.14		6.9	9.89
HH 1	8	12.50		8	12.50
HH 2	12	13.48		13	14.61
HH 3	8	13.56		8	13.56
HH 4	7	12.50		7	12.50
HH 5	7	12.73		7	12.73
HH 6	8	13.11		8	13.11
HH 7	8	13.11		8	13.11
HH 8	11	13.10		11	13.10
HH 9	10	13.89		10	13.89
HH 10	10	13.70		10	13.70
AVG	8.9	13.17		9.0	13.28

* 8.33 su/ha from 21/4/95-12/8/94

Table 3

Dry matter production for individual cuts (kgDM/ha/day), and the annual total (kgDM/ha) measured from frame cuts

	CUT 1	CUT 2	CUT 3	CUT 4	CUT 5	CUT 6	CUT 7	Total
LN 1	32.1	28.0	34.6	11.2	9.7	7.4	26.4	6604
LN 2	29.8	33.1	35.2	7.5	12.2	13.1	40.8	7518
LN 3	38.9	39.4	38.5	24.2	14.5	24.5	21.4	9776
LN 4	26.7	26.2	25.0	17.0	11.7	11.3	14.6	6343
LN 5	21.6	27.2	46.5	25.0	6.2	11.7	20.3	7504
LN 6	8.5	22.0	28.1	14.3	5.6	13.8	9.5	5053
LN 7	12.6	24.5	28.3	20.5	3.5	10.5	12.7	5369
LN 8	8.4	31.8	31.2	14.7	2.3	7.1	8.5	4716
LN 9	23.3	17.8	39.9	22.4	22.2	9.8	29.5	8138
LN 10	13.5	18.0	37.0	10.8	4.6	2.4	10.3	4412
AVG	21.5	26.8	34.4	16.7	9.2	11.2	19.4	6543
LL 1	32.9	45.6	52.9	8.3	8.7	15.3	33.1	8615
LL 2	40.7	36.6	47.5	13.0	9.5	8.7	29.7	8134
LL 3	28.5	35.3	60.5	18.9	10.0	11.8	21.1	8645
LL 4	35.4	43.6	54.7	11.0	10.5	13.4	26.3	8705
LL 5	31.2	37.8	50.1	33.2	11.3	12.7	24.5	9489
LL 6	58.7	79.3	67.8	45.6	14.7	24.2	46.4	15266
LL 7	33.9	45.8	54.6	18.3	22.4	8.4	24.0	9617
LL 8	34.8	44.3	55.0	21.0	12.7	13.3	27.7	9550
AVG	37.0	46.0	55.4	21.2	12.5	13.5	29.1	9752
HN 1	40.9	38.9	55.3	27.0	14.7	9.5	23.9	9765
HN 2	32.6	33.5	37.2	20.2	5.8	10.0	15.2	7073
HN 3	27.8	28.6	29.4	13.3	6.4	9.5	8.5	5723
HN 4	56.8	51.5	38.5	33.7	9.0	17.8	22.3	10548
HN 5	50.8	34.8	58.7	28.8	14.1	18.8	50.1	11765
HN 6	49.6	40.8	59.5	31.6	12.3	18.7	39.5	11650
HN 7	49.4	38.9	76.3	23.1	11.3	23.6	49.9	12466
HN 8	21.4	64.0	47.4	11.2	5.8	8.1	14.3	7291
AVG	41.2	41.4	50.3	23.6	9.9	14.5	28.0	9538
HH 1	37.2	50.7	62.5	10.4	17.5	16.5	34.3	10332
HH 2	43.2	60.3	74.7	19.9	17.8	22.5	40.4	12727
HH 3	46.9	91.6	55.5	17.5	18.3	17.4	44.3	12484
HH 4	44.1	75.5	43.8	11.6	16.1	18.4	29.1	10407
HH 5	34.7	88.7	64.6	23.5	13.2	9.5	29.7	11299
HH 6	50.7	79.2	58.0	24.9	24.1	10.9	36.1	12538
HH 7	27.7	66.0	55.6	13.8	10.4	11.2	41.5	9553
HH 8	65.8	69.8	62.5	19.3	13.3	23.1	65.0	13705
HH 9	53.2	88.1	63.8	31.7	15.9	13.6	50.2	13623
HH 10	71.9	87.2	77.4	30.5	15.7	23.8	57.1	15909
AVG	47.5	75.7	61.8	20.3	16.2	16.7	42.8	12258

Table 4

Model estimate of pasture production for individual cuts (kgDM/ha/day) and for the annual total (kgDM/ha)

	CUT 1	CUT 2	CUT 3	CUT 4	CUT 5	CUT 6	CUT 7	TOTAL
LN 1	34.0	37.4	19.6	30.8	-0.4	1.1	9.8	5725
LN 2	23.1	43.0	17.9	33.3	-0.5	-0.9	9.0	5347
LN 3	26.4	39.0	24.4	33.8	0.1	-1.0	8.0	5722
LN 4	36.6	47.6	36.1	31.2	5.7	-0.9	6.7	7180
LN 5	24.4	46.7	19.0	30.1	1.7	-4.2	2.8	5091
LN 6	32.1	-10.6	39.5	29.9	-4.0	-1.0	3.1	4490
LN 7	37.0	37.7	30.5	32.6	2.3	-6.7	1.1	5843
LN 8	28.0	40.8	23.2	30.2	0.9	-5.1	6.2	5233
LN 9	37.8	46.8	33.3	34.8	-2.8	0.6	8.4	6816
LN 10	21.8	48.5	19.3	28.5	0.4	-3.2	1.4	4890
AVG	30.1	37.7	26.3	31.5	0.3	-2.1	5.7	5634
LL 1	30.1	56.9	38.8	33.0	2.3	4.1	6.8	7582
LL 2	33.3	54.0	30.7	29.4	10.4	1.2	9.2	7456
LL 3	31.6	53.2	20.5	34.0	3.3	3.1	6.5	6690
LL 4	29.5	58.4	27.5	34.9	5.7	3.2	9.0	7423
LL 5	36.7	47.8	40.5	36.9	1.7	-3.3	3.6	7189
LL 6	53.5	53.7	38.1	35.9	1.3	-1.3	10.0	8163
LL 7	32.1	46.2	23.4	28.8	4.7	-2.7	5.8	5943
LL 8	23.8	56.8	24.0	31.2	1.6	-1.8	6.8	5978
AVG	33.8	53.4	30.4	33.0	3.9	0.3	7.2	7053
HN 1	22.6	61.7	20.4	35.2	2.9	4.4	9.4	6810
HN 2	24.1	61.2	36.6	28.7	1.4	1.9	7.8	6889
HN 3	43.7	55.4	30.8	35.8	2.2	5.9	12.4	8158
HN 4	46.3	52.4	36.1	31.6	7.7	0.3	5.1	7940
HN 5	88.4	33.1	45.0	52.9	-5.7	-6.6	14.8	9546
HN 6	41.7	54.0	36.2	42.8	-0.7	-2.2	8.4	7772
HN 7	31.6	64.1	25.1	33.1	2.6	-0.0	5.7	6861
HN 8	34.0	61.5	40.7	35.0	-1.9	0.2	9.3	7544
AVG	41.6	55.4	33.9	36.9	1.0	0.5	9.1	7690
HH 1	38.3	58.6	36.4	37.5	10.5	4.6	8.7	8845
HH 2	48.3	69.8	49.4	32.8	14.4	5.9	10.7	10379
HH 3	56.2	71.0	38.2	47.6	11.2	2.6	15.2	10739
HH 4	53.1	71.1	40.1	27.0	11.5	2.3	9.9	9263
HH 5	49.9	66.2	38.5	30.2	7.4	3.9	10.8	8958
HH 6	57.7	57.8	34.6	37.8	8.7	-0.1	11.0	9088
HH 7	44.2	67.7	38.8	32.2	5.7	3.2	3.5	8513
HH 8	62.2	60.7	48.9	30.2	9.1	2.2	16.2	9938
HH 9	54.4	55.6	45.4	38.0	7.3	4.0	8.7	9576
HH 10	59.2	58.5	43.0	35.8	12.2	1.4	12.6	9883
AVG	52.4	63.7	41.3	34.9	9.8	3.0	10.7	9518

Table 5

Ratio of model estimate to frame cut estimates

	CUT 1	CUT 2	CUT 3	CUT 4	CUT 5	CUT 6	CUT 7	Total
LN 1	1.06	1.34	0.57	2.75	-0.04	0.15	0.37	0.87
LN 2	0.77	1.30	0.51	4.43	-0.04	-0.07	0.22	0.71
LN 3	0.68	0.99	0.64	1.40	0.01	-0.04	0.38	0.59
LN 4	1.37	1.82	1.44	1.83	0.48	-0.08	0.46	1.13
LN 5	1.13	1.72	0.41	1.20	0.27	-0.36	0.14	0.68
LN 6	3.79	-0.48	1.40	2.09	-0.72	-0.07	0.33	0.89
LN 7	2.94	1.54	1.08	1.59	0.67	-0.63	0.09	1.09
LN 8	3.35	1.28	0.74	2.06	0.40	-0.72	0.73	1.11
LN 9	1.63	2.63	0.83	1.56	-0.12	0.06	0.28	0.84
LN 10	1.62	2.69	0.52	2.65	0.09	-1.31	0.14	1.11
AVG	1.40	1.41	0.76	1.88	0.04	-0.19	0.29	0.86
LL 1	0.91	1.25	0.73	4.00	0.26	0.27	0.21	0.88
LL 2	0.82	1.47	0.65	2.26	1.09	0.14	0.31	0.92
LL 3	1.11	1.51	0.34	1.80	0.33	0.26	0.31	0.77
LL 4	0.83	1.34	0.50	3.17	0.55	0.24	0.34	0.85
LL 5	1.18	1.27	0.81	1.11	0.15	-0.26	0.15	0.76
LL 6	0.91	0.68	0.56	0.79	0.09	-0.05	0.21	0.53
LL 7	0.95	1.01	0.43	1.57	0.21	-0.32	0.24	0.62
LL 8	0.68	1.28	0.44	1.48	0.13	-0.14	0.25	0.63
AVG	0.91	1.16	0.55	1.56	0.31	0.02	0.25	0.72
HN 1	0.55	1.59	0.37	1.30	0.19	0.47	0.39	0.70
HN 2	0.74	1.83	0.99	1.42	0.25	0.19	0.51	0.97
HN 3	1.57	1.93	1.05	2.69	0.34	0.62	1.45	1.43
HN 4	0.82	1.02	0.94	0.94	0.85	0.02	0.23	0.75
HN 5	1.74	0.95	0.77	1.84	-0.40	-0.35	0.30	0.81
HN 6	0.84	1.32	0.61	1.35	-0.06	-0.12	0.21	0.67
HN 7	0.64	1.65	0.33	1.43	0.23	-0.00	0.11	0.55
HN 8	1.59	0.96	0.86	3.13	-0.33	0.03	0.65	1.03
AVG	1.01	1.34	0.67	1.56	0.11	0.03	0.33	0.81
HH 1	1.03	1.16	0.58	3.60	0.60	0.28	0.25	0.86
HH 2	1.12	1.16	0.66	1.65	0.81	0.26	0.27	0.82
HH 3	1.20	0.77	0.69	2.72	0.61	0.15	0.34	0.86
HH 4	1.21	0.94	0.92	2.32	0.71	0.13	0.34	0.89
HH 5	1.44	0.75	0.60	1.29	0.56	0.41	0.36	0.79
HH 6	1.14	0.73	0.60	1.52	0.36	-0.01	0.31	0.72
HH 7	1.59	1.02	0.70	2.34	0.55	0.29	0.08	0.89
HH 8	0.94	0.87	0.78	1.57	0.68	0.09	0.25	0.73
HH 9	1.02	0.63	0.71	1.20	0.46	0.29	0.17	0.70
HH 10	0.82	0.67	0.56	1.18	0.77	0.06	0.22	0.62
AVG	1.10	0.84	0.67	1.72	0.60	0.18	0.25	0.78

Table 6

Model estimate of intake (kgDM/ha/day) for frame cut intervals and the annual total (kgDM/ha).

	CUT 1	CUT 2	CUT 3	CUT 4	CUT 5	CUT 6	CUT 7	TOTAL
LN 1	20.9	26.8	19.8	16.4	8.7	8.0	9.2	5194
LN 2	20.6	23.1	14.2	15.8	10.6	8.6	7.4	4894
LN 3	18.3	21.8	18.7	16.7	11.3	8.9	7.8	5139
LN 4	24.1	34.2	26.5	19.6	13.3	10.4	10.9	6664
LN 5	15.7	22.8	15.2	16.7	9.3	6.3	7.6	4526
LN 6	15.9	15.4	30.2	15.8	9.1	8.0	7.3	5098
LN 7	18.8	27.5	25.0	17.6	8.3	6.0	6.7	5208
LN 8	13.9	22.6	17.2	16.9	7.3	5.9	7.7	4381
LN 9	21.3	26.5	22.0	19.3	11.0	10.6	8.5	5850
LN 10	16.4	20.1	11.3	15.6	8.0	6.4	6.5	4100
AVG	18.6	24.1	20.0	17.0	9.7	7.9	8.0	5105
LL 1	20.4	34.2	32.6	18.6	13.9	11.2	11.2	6871
LL 2	23.2	33.1	24.7	18.0	18.0	8.8	12.9	6693
LL 3	22.6	25.9	21.3	20.5	11.7	8.6	9.2	5843
LL 4	24.8	30.2	25.5	17.8	16.2	10.5	11.1	6638
LL 5	26.9	22.3	27.5	22.6	13.8	8.6	7.5	6449
LL 6	27.7	40.3	26.9	25.2	12.7	11.1	10.1	7337
LL 7	19.6	25.7	17.2	19.7	8.9	8.2	8.5	5194
LL 8	20.5	24.9	16.6	19.9	9.2	6.9	7.3	5089
AVG	23.2	29.6	24.0	20.3	13.0	9.2	9.7	6264
HN 1	25.4	28.3	23.6	16.0	12.7	12.1	12.7	6304
HN 2	25.9	29.8	25.0	18.2	13.6	10.6	9.4	6430
HN 3	34.3	40.7	26.8	20.3	14.6	12.1	11.7	7581
HN 4	26.2	36.5	29.4	20.7	14.9	11.6	10.3	7219
HN 5	29.4	50.2	38.8	25.2	14.3	15.2	16.9	8933
HN 6	24.7	33.3	31.8	23.2	12.0	10.1	7.2	6915
HN 7	24.6	30.1	19.5	17.0	12.8	10.5	9.7	5986
HN 8	26.5	29.8	25.7	22.1	11.8	10.1	11.0	6612
AVG	27.1	34.8	27.6	20.3	13.3	11.5	11.1	6998
HH 1	25.0	37.7	34.6	23.3	18.5	12.2	11.0	7981
HH 2	35.0	46.7	38.8	26.8	21.0	14.0	13.0	9454
HH 3	39.3	52.1	38.1	33.8	18.1	12.0	12.1	9799
HH 4	37.1	53.3	31.5	19.3	14.5	12.4	13.7	8314
HH 5	32.3	50.0	31.3	19.5	15.9	11.2	10.7	7952
HH 6	36.3	47.3	32.9	23.3	15.7	10.4	10.2	8257
HH 7	32.8	43.2	29.4	23.6	14.9	10.6	9.1	7752
HH 8	41.3	47.4	37.8	22.5	20.6	11.9	12.4	9203
HH 9	32.5	47.5	42.5	24.6	18.0	10.7	9.0	8817
HH 10	37.2	47.4	43.4	24.6	16.8	11.4	8.7	9008
AVG	34.9	47.3	36.0	24.1	17.4	11.7	11.0	8654

Table 7

Pasture cover change between frame cut dates (kgDM/ha/day) and over one year

	CUT 1	CUT 2	CUT 3	CUT 4	CUT 5	CUT 6	CUT 7	TOTAL
LN 1	13.1	10.6	-0.2	14.4	-9.1	-6.9	0.6	531
LN 2	2.4	19.9	3.8	17.6	-11.0	-9.5	1.6	453
LN 3	8.1	17.2	5.8	17.1	-11.2	-9.9	0.2	583
LN 4	12.5	13.4	9.6	11.6	-7.7	-11.3	-4.2	516
LN 5	8.7	23.9	3.8	13.5	-7.6	-10.5	-4.8	565
LN 6	16.3	-25.9	9.3	14.1	-13.2	-9.0	-4.2	-609
LN 7	18.2	10.1	5.5	15.0	-6.0	-12.7	-5.6	636
LN 8	14.1	18.1	6.0	13.3	-6.4	-11.1	-1.5	852
LN 9	16.5	20.3	11.3	15.5	-13.8	-10.0	-0.2	966
LN 10	5.4	28.3	8.0	12.8	-7.6	-9.6	-5.1	790
AVG	11.5	13.6	6.3	14.5	-9.3	-10.0	-2.3	528
LL 1	9.7	22.6	6.2	14.4	-11.6	-7.2	-4.4	711
LL 2	10.1	20.9	6.0	11.4	-7.6	-7.6	-3.8	762
LL 3	9.0	27.3	-0.8	13.5	-8.4	-5.5	-2.7	847
LL 4	4.7	28.2	2.0	17.1	-10.5	-7.3	-2.1	785
LL 5	9.8	25.6	13.0	14.3	-12.1	-11.9	-3.9	740
LL 6	25.8	13.4	11.2	10.7	-11.4	-12.4	-0.2	827
LL 7	12.6	20.5	6.2	9.1	-4.2	-10.9	-2.7	748
LL 8	3.3	31.9	7.4	11.3	-7.6	-8.8	-0.5	890
AVG	10.6	23.8	6.4	12.7	-9.2	-8.9	-2.5	789
HN 1	-2.8	33.4	-3.1	19.2	-9.8	-7.7	-3.3	505
HN 2	-1.8	31.4	11.6	10.5	-12.1	-8.7	-1.6	459
HN 3	9.4	14.7	4.0	15.5	-12.5	-6.2	0.7	577
HN 4	20.1	15.9	6.7	11.0	-7.2	-11.3	-5.2	721
HN 5	58.9	-17.2	6.2	27.7	-20.0	-21.8	-2.1	613
HN 6	16.9	20.7	4.3	19.6	-12.7	-12.2	1.2	857
HN 7	7.0	34.1	5.6	16.1	-10.3	-10.6	-3.9	876
HN 8	7.5	31.7	15.0	12.8	-13.7	-9.9	-1.6	933
AVG	14.4	20.6	6.3	16.6	-12.3	-11.0	-2.0	693
HH 1	13.3	20.9	1.8	14.1	-8.1	-7.6	-2.3	863
HH 2	13.3	23.1	10.6	6.0	-6.6	-8.1	-2.3	925
HH 3	16.9	18.9	0.0	13.8	-6.9	-9.4	3.1	940
HH 4	16.0	17.9	8.5	7.7	-3.0	-10.1	-3.9	949
HH 5	17.6	16.2	7.2	10.7	-8.5	-7.3	0.1	1005
HH 6	21.4	10.5	1.7	14.5	-7.0	-10.5	0.8	832
HH 7	11.4	24.4	9.4	8.7	-9.2	-7.3	-5.6	761
HH 8	20.9	13.3	11.1	7.7	-11.6	-9.7	3.8	735
HH 9	21.9	8.1	2.9	13.5	-10.8	-6.7	-0.3	759
HH 10	22.0	11.1	-0.4	11.2	-4.6	-10.0	3.8	875
AVG	17.5	16.4	5.3	10.8	-7.6	-8.7	-0.3	864

Table 8

Botanical composition of the 36 paddocks.

	HFRG%	LFTG%	LEG%	OSPP%
LN 1	5.05	70.00	17.95	6.99
LN 2	2.91	70.35	14.53	12.21
LN 3	9.19	82.92	4.74	3.16
LN 4	4.52	77.41	10.61	7.47
LN 5	9.73	64.19	3.51	22.57
LN 6	2.61	92.79	1.20	3.41
LN 7	45.53	35.22	9.31	9.94
LN 8	3.02	71.14	5.37	20.47
LN 9	5.63	80.65	4.08	9.64
LN 10	4.44	55.46	8.40	31.69
AVG	9.26	70.01	7.97	12.75
LL 1	1.25	78.28	15.16	5.31
LL 2	0.99	91.35	2.55	5.11
LL 3	6.70	61.10	26.50	5.70
LL 4	22.98	58.48	8.19	10.35
LL 5	19.54	57.28	16.72	6.46
LL 6	36.18	45.44	16.95	1.42
LL 7	47.52	36.48	12.96	3.04
LL 8	4.40	77.31	7.87	10.42
AVG	17.45	63.22	13.36	5.98
HN 1	21.81	55.96	11.83	10.40
HN 2	7.74	77.67	11.56	3.03
HN 3	15.86	47.63	21.87	14.64
HN 4	45.60	42.76	7.93	3.70
HN 5	40.44	41.98	7.81	9.77
HN 6	42.69	43.56	9.28	4.48
HN 7	30.43	56.97	7.48	5.12
HN 8	9.11	71.37	8.68	10.85
AVG	26.71	54.74	10.80	7.75
HH 1	21.11	56.77	17.61	4.51
HH 2	24.43	48.50	19.26	7.81
HH 3	25.22	36.52	34.37	3.90
HH 4	27.74	53.92	9.40	8.93
HH 5	30.41	44.33	21.13	4.12
HH 6	40.51	43.90	9.74	5.85
HH 7	10.90	64.93	16.11	8.06
HH 8	39.92	49.76	7.01	3.31
HH 9	39.91	50.97	8.76	0.35
HH 10	41.88	41.01	15.36	1.74
AVG	30.20	49.06	15.88	4.86

Table 9

Pasture covers at frame cut dates, and the total change in cover over the year (kgDM/ha)

	7/10/93	16/11/93	16/12/93	3/2/94	7/4/94	22/6/94	8/9/94	7/10/94	Total
LN 1	1637	2159	2477	2469	3377	2689	2150	2168	531
LN 2	1563	1660	2258	2442	3549	2710	1969	2016	453
LN 3	1458	1781	2297	2579	3658	2807	2035	2041	583
LN 4	1500	1998	2401	2869	3597	3015	2137	2016	516
LN 5	1123	1470	2189	2375	3222	2645	1826	1687	565
LN 6	2903	3554	2775	3229	4117	3116	2416	2294	-609
LN 7	1279	2006	2310	2580	3526	3069	2078	1915	636
LN 8	1164	1730	2274	2567	3408	2923	2060	2016	852
LN 9	1025	1686	2297	2849	3823	2774	1996	1991	966
LN 10	1049	1264	2114	2505	3314	2738	1987	1839	790
AVG	1470	1931	2339	2646	3559	2849	2065	1998	528
LL 1	1255	1642	2321	2626	3532	2650	2093	1966	711
LL 2	1279	1684	2310	2604	3322	2745	2151	2041	762
LL 3	1017	1376	2196	2159	3012	2375	1944	1864	847
LL 4	1206	1395	2241	2337	3416	2621	2051	1991	785
LL 5	1074	1466	2233	2871	3775	2858	1928	1814	740
LL 6	1164	2197	2598	3147	3823	2959	1996	1991	827
LL 7	1091	1594	2209	2511	3083	2766	1919	1839	748
LL 8	1000	1133	2090	2451	3163	2588	1904	1890	890
AVG	1136	1561	2275	2588	3391	2695	1998	1925	789
HN 1	1385	1271	2273	2119	3330	2586	1985	1890	505
HN 2	1507	1435	2379	2949	3612	2689	2012	1966	459
HN 3	1490	1866	2308	2504	3477	2530	2046	2067	577
HN 4	1270	2075	2552	2882	3574	3024	2141	1991	721
HN 5	1353	3711	3195	3500	5245	3723	2026	1966	613
HN 6	1083	1761	2382	2593	3828	2862	1906	1940	857
HN 7	888	1168	2190	2464	3481	2701	1878	1763	876
HN 8	1083	1383	2334	3070	3878	2834	2064	2016	933
AVG	1257	1834	2452	2760	3803	2869	2007	1950	693
HH 1	976	1506	2133	2222	3112	2499	1904	1839	863
HH 2	1066	1599	2291	2811	3190	2691	2057	1991	925
HH 3	1000	1676	2243	2244	3111	2588	1851	1940	940
HH 4	1042	1682	2219	2636	3120	2889	2103	1991	949
HH 5	985	1690	2176	2527	3204	2558	1988	1991	1005
HH 6	1083	1938	2252	2333	3245	2710	1892	1915	832
HH 7	927	1384	2116	2574	3120	2424	1851	1687	761
HH 8	1230	2065	2464	3009	3495	2616	1856	1966	735
HH 9	1181	2059	2302	2442	3290	2473	1949	1940	759
HH 10	1091	1972	2304	2284	2988	2638	1854	1966	875
AVG	1058	1757	2250	2508	3188	2608	1931	1923	864

Table 10

ME values (MJME/kgDM) derived from cage cut herbage

	16/11/93	17/12/93	3/2/94	7/4/94	22/6/94	8/9/94	31/10/94
LN 1	10.5	9.6	8.7	8.2	9.3	9.2	10.4
LN 2	10.2	9.8	8.9	8.5	8.8	9.2	10.3
LN 3	10.5	10.4	9.0	9.2	9.9	10.7	10.7
LN 4	10.2	9.6	8.9	8.6	9.3	9.2	10.4
LN 5	10.5	10.3	9.0	9.7	9.0	9.4	10.4
LN 6	9.7	9.6	8.7	8.9	8.2	8.3	10.0
LN 7	10.3	10.0	8.9	9.6	10.5	8.6	10.7
LN 8	9.8	9.9	8.9	9.1	8.7	9.0	10.8
LN 9	10.9	10.1	9.4	9.1	8.7	9.6	10.6
LN 10	10.0	9.9	9.0	9.0	9.2	8.5	10.8
AVG	10.2	9.9	8.9	9.0	9.2	9.2	10.5
LL 1	10.5	9.8	9.7	8.8	9.3	10.5	10.9
LL 2	10.6	9.8	9.0	7.9	9.6	10.0	10.7
LL 3	10.6	9.8	9.4	9.5	9.3	10.6	11.0
LL 4	10.7	9.7	9.0	8.8	9.3	10.2	10.8
LL 5	11.1	10.2	8.9	8.9	8.7	9.5	10.4
LL 6	11.4	10.5	9.7	9.8	9.3	11.7	10.8
LL 7	11.1	10.3	9.2	9.6	9.3	9.0	10.6
LL 8	10.7	9.8	9.4	10.0	9.3	10.2	11.0
AVG	10.8	10.0	9.3	9.2	9.3	10.2	10.8
HN 1	10.7	9.5	9.5	9.3	10.4	10.0	11.4
HN 2	10.2	9.5	9.2	9.0	10.3	9.9	10.8
HN 3	9.7	9.7	7.9	8.9	8.7	8.3	10.0
HN 4	10.9	10.1	9.5	8.8	10.2	11.1	10.6
HN 5	11.3	10.8	9.9	9.5	11.1	10.3	10.9
HN 6	11.3	10.5	9.7	9.6	11.3	11.3	11.2
HN 7	11.2	10.1	9.2	9.8	10.5	11.0	11.0
HN 8	11.1	10.6	8.9	9.6	9.6	8.4	10.6
AVG	10.8	10.1	9.2	9.3	10.3	10.0	10.8
HH 1	11.3	10.5	9.7	9.6	10.6	11.9	11.1
HH 2	11.0	10.8	9.6	9.4	10.5	11.5	11.0
HH 3	11.3	10.3	9.3	9.8	11.0	11.5	11.5
HH 4	11.1	10.0	10.1	10.0	11.2	11.7	11.3
HH 5	11.4	10.7	10.3	10.1	10.8	10.9	11.5
HH 6	11.7	10.8	9.9	10.1	11.0	11.8	10.5
HH 7	10.6	10.5	9.5	9.8	11.0	10.8	11.2
HH 8	11.4	11.2	10.2	10.0	11.4	11.1	10.9
HH 9	11.4	10.6	9.8	9.4	10.9	11.6	11.6
HH 10	11.4	10.8	9.9	10.2	11.2	11.8	11.1
AVG	11.3	10.6	9.8	9.8	11.0	11.5	11.2

Table 11

Numbers of grazers per paddock at weighing dates

	4 NOV	23 NOV	14 DEC	6 JAN	27 JAN	15 FEB
LN 1	1	3	8	10	10	9
LN 2	1	1	3	3	3	3
LN 3	1	2	4	5	6	6
LN 4	1	3	7	8	9	9
LN 5	1	1	3	3	3	3
LN 6	1	3	5	6	8	6
LN 7	2	4	8	8	9	9
LN 8	1	2	4	5	5	5
LN 9	2	3	5	5	6	6
LN 10	1	1	2	2	2	1
AVG	1.2	2.3	4.9	5.5	6.1	5.7
LL 1	1	2	5	6	7	6
LL 2	1	2	5	6	6	6
LL 3	0	0	3	3	3	3
LL 4	1	1	4	4	3	3
LL 5	0	1	3	4	5	5
LL 6	2	4	9	11	12	12
LL 7	1	2	4	4	4	4
LL 8	1	1	2	2	0	0
AVG	0.9	1.6	4.4	5.0	5.0	4.9
HN 1	0	0	3	3	3	3
HN 2	0	1	4	6	7	7
HN 3	0	2	4	5	5	5
HN 4	0	3	8	9	10	10
HN 5	1	3	8	9	10	10
HN 6	0	2	6	7	8	8
HN 7	0	0	2	2	2	2
HN 8	0	0	3	5	6	6
AVG	0.1	1.4	4.8	5.8	6.4	6.4
HH 1	0	2	3	3	1	1
HH 2	0	2	7	7	7	8
HH 3	0	2	4	4	4	4
HH 4	0	2	4	4	3	3
HH 5	0	2	4	4	2	2
HH 6	0	3	5	5	5	5
HH 7	0	0	1	1	1	1
HH 8	0	3	10	12	13	13
HH 9	0	3	8	8	8	8
HH 10	0	3	8	8	8	7
AVG	0.0	2.2	5.4	5.6	5.2	5.2

Table 12

Stocking rate of grazers

	4 NOV	23 NOV	14 DEC	6 JAN	27 JAN	15 FEB
PC1	1.10	3.30	8.79	10.99	10.99	9.89
PC2	1.33	1.33	4.00	4.00	4.00	4.00
PC3	1.16	2.33	4.65	5.81	6.98	6.98
PC4	1.28	3.85	8.97	10.26	11.54	11.54
PC5	0.90	0.90	2.70	2.70	2.70	2.70
PC6	2.70	8.11	13.51	16.22	21.62	16.22
PC7	2.30	4.60	9.20	9.20	10.34	10.34
PC8	1.02	2.04	4.08	5.10	5.10	5.10
PC9	1.77	2.65	4.42	4.42	5.31	5.31
PC10	0.97	0.97	1.94	1.94	1.94	0.97
AVG	1.45	3.01	6.23	7.06	8.05	7.31
PW1	2.13	4.26	10.64	12.77	14.89	12.77
PW2	1.82	3.64	9.09	10.91	10.91	10.91
PW3	0.00	0.00	4.48	4.48	4.48	4.48
PW4	1.47	1.47	5.88	5.88	4.41	4.41
PW5	0.00	0.85	2.54	3.39	4.24	4.24
PW6	2.08	4.17	9.38	11.46	12.50	12.50
PW7	1.05	2.11	4.21	4.21	4.21	4.21
PW8	0.89	0.89	1.79	1.79	0.00	0.00
AVG	1.18	2.17	6.00	6.86	6.95	6.69
PE1	0.00	0.00	4.41	4.41	4.41	4.41
PE2	0.00	1.52	6.06	9.09	10.61	10.61
PE3	0.00	4.08	8.16	10.20	10.20	10.20
PE4	0.00	3.53	9.41	10.59	11.76	11.76
PE5	2.50	7.50	20.00	22.50	25.00	25.00
PE6	0.00	2.78	8.33	9.72	11.11	11.11
PE7	0.00	0.00	1.85	1.85	1.85	1.85
PE8	0.00	0.00	3.49	5.81	6.98	6.98
AVG	0.31	2.43	7.72	9.27	10.24	10.24
BH1	0.00	3.13	4.69	4.69	1.56	1.56
BH2	0.00	2.25	7.87	7.87	7.87	8.99
BH3	0.00	3.39	6.78	6.78	6.78	6.78
BH4	0.00	3.57	7.14	7.14	5.36	5.36
BH5	0.00	3.64	7.27	7.27	3.64	3.64
BH6	0.00	4.92	8.20	8.20	8.20	8.20
BH7	0.00	0.00	1.64	1.64	1.64	1.64
BH8	0.00	3.57	11.90	14.29	15.48	15.48
BH9	0.00	4.17	11.11	11.11	11.11	11.11
BH10	0.00	4.11	10.96	10.96	10.96	9.59
AVG		3.27	7.76	7.99	7.26	7.23

Table 13

Lamb numbers, lambing % and weaning weights.

	Numbers	Lambing %	14 DEC
LN 1	7.0	116	22.6
LN 2	6.0	120	22.8
LN 3	6.0	120	22.7
LN 4	7.0	140	23.1
LN 5	9.0	128	18.7
LN 6	2.0	100	22.6
LN 7	5.0	100	26.9
LN 8	8.0	133	18.5
LN 9	8.0	114	25.6
LN 10	8.0	133	19.9
AVG	6.6	120	22.3
LL 1	3.0	100	27.2
LL 2	5.0	125	22.6
LL 3	6.0	120	23.6
LL 4	6.0	120	25.3
LL 5	12.0	133	21.8
LL 6	10.0	143	24.6
LL 7	7.0	100	23.2
LL 8	11.0	122	19.4
AVG	7.5	120	23.5
HN 1	7.0	116	23.8
HN 2	6.0	120	26.3
HN 3	5.0	125	26.0
HN 4	7.0	100	28.0
HN 5	3.0	100	35.6
HN 6	6.0	100	28.2
HN 7	9.0	100	25.7
HN 8	7.0	100	28.0
AVG	6.3	108	27.7
HH 1	8.0	100	22.7
HH 2	13.0	108	23.4
HH 3	11.0	138	22.6
HH 4	10.0	143	20.6
HH 5	10.0	143	21.0
HH 6	10.0	125	23.8
HH 7	8.0	100	26.3
HH 8	14.0	127	25.3
HH 9	10.0	100	24.5
HH 10	10.0	100	25.9
AVG	10.4	118	23.6

Table 14

Fleece+skirtings weights (kg/tester)

	24:11:93	18:3:94	TOTAL
LN 1	2.05	1.47	3.52
LN 2	2.23	1.68	3.91
LN 3	2.15	1.65	3.80
LN 4	2.05	1.73	3.78
LN 5	1.92	1.67	3.59
LN 6	1.56	1.16	2.72
LN 7	1.96	1.52	3.48
LN 8	2.08	1.51	3.59
LN 9	1.99	1.85	3.84
LN 10	1.99	1.58	3.57
AVG	2.00	1.58	3.58
LL 1	2.34	1.85	4.19
LL 2	2.34	1.56	3.90
LL 3	2.05	2.02	4.07
LL 4	2.06	1.71	3.77
LL 5	1.87	1.81	3.68
LL 6	2.11	1.74	3.85
LL 7	1.88	1.84	3.72
LL 8	1.83	1.61	3.44
AVG	2.06	1.77	3.83
HN 1	2.49	1.92	4.41
HN 2	2.46	1.78	4.24
HN 3	2.40	1.72	4.12
HN 4	2.17	1.78	3.95
HN 5	1.89	1.85	3.74
HN 6	2.23	1.91	4.14
HN 7	2.10	1.98	4.08
HN 8	2.30	1.96	4.26
AVG	2.26	1.86	4.12
HH 1	2.14	1.97	4.11
HH 2	1.93	1.98	3.91
HH 3	1.95	1.77	3.72
HH 4	2.05	1.81	3.86
HH 5	1.77	1.71	3.48
HH 6	1.85	1.59	3.44
HH 7	1.69	1.88	3.57
HH 8	1.91	1.73	3.64
HH 9	1.89	1.70	3.59
HH 10	1.93	1.99	3.92
AVG	1.91	1.81	3.72

Figure 1. Soil Moisture as a Percentage of Soil Volume From 0-30 Centimetres