A CASE FARM STUDY OF HIGH AND LOW SHEEP PERFORMANCE ON SOUTHERN NORTH ISLAND HILL COUNTRY.

D.I. GRAY

FEBRUARY 1987

A thesis presented in partial fulfilment
of the requirements for the degree of
Master of Agricultural Science in Farm
Management at Massey University.

ACKNOWLEDGEMENTS

I wish to express my considerable appreciation to Mr A.F. McRae and Mr W.J. Parker for their guidance and assistance in all aspects of this study, particularly given that this was a difficult period for both supervisors. I wish also to ap ologise to Alison and Vivienne for the large amount of family time this study required of their husbands over the last two years.

I am very grateful for the early guidance from Professor R.J. Townsley. I am also very grateful for the advice and guidance provided by Mr E. Roberts whose rather dry Welsh humour was much appreciated in the lower moments of the study.

My thanks to Mr K.I. Lowe without whose assistance, my involvement with Tuapaka would not have eventuated and to the staff at Tuapaka who willingly gave of their time and shared their experience. This was an important part of the study in terms of coming to grips with the practicalities of hill country farming. For their contributions in this area I must thank Mr A. Harwood, Mr R. McLaren and Mr T. Shannon. Many thanks also to Carol, Vicki and Diana for the wonderful hospitality over the last five years.

This study would not be possible without the data collected from Tuapaka by Miss R. Smith, Mr A. Bruere and Mr M. Dickson. Those that have experienced the climate at Tuapaka will understand the dedication required of this job.

Numerous people have assisted me in the completion of this study, some directly and others indirectly through reducing my teaching load at key times. In particular, Mr J.C. Lockhart, Ms B.W. Hawkins, Mr B.J. Ridler, Dr A. Wright, Mr S.T. Morris, Mr M. Carter and Dr D.G. McCall.

Thanks also to Glenyss Hamlin for her skill and more particularly her patience in typing this study.

I owe a large debt to my family for their support through what has proved a fairly long study period, but maybe now I can fit in the fishing trips and house renovations that have been put off over the last "few" years.

Finally, thanks to my flatmates Greg, Pete and especially Sally who have provided continual support on the home front which has been much appreciated.

ABSTRACT

Two areas of research are reported in this study. First, the comparison between the profitability of a high performance flock and a low performance flock run at a higher stocking rate on Massey University's Tuapaka hill country unit. Second, the comparison between simple feed budgeting and complex simulation modelling as methodologies used in the design of pastoral based systems.

While the higher performance flock is found to be marginally more profitable than the lower performance flock, the simple (spreadsheet based) feed budget models used for the analysis show little difference in the pattern of feed demand between the flocks. The greatest differences in profitability were due to stocking rate rather than performance. A low stocking rate system that allowed lambs to be grown out to heavy carcass weights was found to be the most profitable system for Tuapaka. A number of weaknesses can be identified in the simple feed budgeting approach however.

These include: limited feed table data on the effects of different levels of nutrition on animal performance for the periods of pregnancy and lactation; a lack of feed table data on the relationship between feed intake and wool production, and failure to take into account the interaction between pasture cover, pasture growth rates, pasture quality, animal intake and subsequent levels of animal performance. These latter two weaknesses are analysed by using spreadsheet based simulation models in the second part of the study.

The results of these analysis indicate that wool production is under-estimated by the simple feed budget model, particularly in the case of the high performance flock. Correcting this increases the profit margin between the two flocks, but does not alter the rankings.

Analysis of the effect of interactions between pasture components and animal performance over the period of lactation shows that the simple feed budget approach fails to represent the true situation in terms of the pattern of pasture growth, animal intakes and subsequent performance levels, and that this is especially so where pasture cover falls below 1000 kg DM/HA. This analysis suggests that the linear relationships assumed in the simple feed budget approach do not hold in reality.

The conclusions from this study are that a high performance, low stocking rate system would be more profitable than a low performance, high stocking rate system for the Tuapaka hill country unit, but that it would offer little advantage in terms of better matching feed demand and feed supply.

Complex simulation modelling has a number of advantages over the simple feed budgeting technique. However, the use of these models is dependent on the validation of the models and the construction of models that are "user-friendly". The study identified a number of areas where further work is required in the validation of some of the more complex inter-relationships.

Simple feed budgeting is quick and simple to use, and in a gross sense provides feasible results provided pasture cover levels are maintained within certain bounds. The definition of the upper and lower bounds requires further work, a review of the literature suggests they are 1000 and 1700 kg DM/HA.

The use of spreadsheet technology proved highly effective for the development of simple feed budget models. However, there were a number of constraints evident when spreadsheets were used for the construction of more complex models. These included, capacity, calculation time and limitations in terms of the availability of mathematical formulae. With further developments in this technology expected, spreadsheets should prove a useful tool in the development of more complex simulation models.

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Chapter One

1.0 Introduction.

The financial structure of hill country farming in New Zealand has undergone rapid change since the election of the Labour Government in 1984 and the subsequent adoption of an unsubsidised market led economy (Douglas,1984). Thus, while meat and wool exports, the traditional products off hill country, made up 67.5% of agricultural receipts in 1985, and agriculture overall contributed 70% of New Zealand's net export receipts, farm incomes for the 1985/86 year fell 52% from the previous year (NZMWBES, 1985). This reduction was attributed to lower output, higher input costs and lower farm gate prices.

Brazendale (1985) reviewed Government Policy changes with respect to agriculture, and analysed the initial impact of these on a group of southern North Island hill country farmers. He concluded that "farmers not only have little incentive to reinvest in farming, but they are being forced to reduce on-farm expenditure in order to stay financially viable". Under these conditions further increases in hill country productivity or in farmer returns cannot be expected to come from large investments of capital back into the farming sector, as was the case through the late seventies and early eighties (Taylor, 1986). Farmers instead, will adopt low cost systems and attempt to improve returns from current resources. In this respect, Parker (1984) on the basis of a survey of Wairarapa hill country farmers, considered that large gains in productivity could be made through relatively small, and inexpensive changes to management practices.

Hill country farmers will therefore benefit from research into the reallocation of the resources available to them and alternative methods of managing these. This study, is set within this context and looks at one aspect of hill country sheep farming which could potentially improve farmers' financial returns - the improved allocation of a usually limiting winter and spring pasture resource to ewes of different pregnancy status.

1.1 Motivation for the Study.

Diversification options for hill country farmers are commonly limited by a range of factors including topography, proximity to markets for produce, climate, high capital requirements and availability of labour. Horticulture, deer, goats and forestry which have substantially increased on hill country during the last decade (Percival and Hawke, 1985; Taylor, 1985; Spiers, 1986), for example, all require large inputs of capital normally beyond the means of an individual farmer. The response to this constraint has included the establishment of farming partnerships, syndicates and the setting up of public companies some of which have been listed on the stock exchange (Broad, 1986; Wood, 1986). However, for the majority of hill country farmers the only viable option available to them to increase productivity and financial returns is to improve their current farming system. This may simply involve an improvement in the efficiency of resource use or more radically, a reallocation of resources to develop a new production system.

The design and control of new [2] farming systems is one of the roles of [3] management (Wright, 1984). This is a complex process because the designer requires detailed information about the components of the system and how they interact. The lack of objective data describing the inter-relationships between various components in the system, mainly because of their biological complexity, has been the main factor restricting progress in the design of improved farming systems relative to other fields such as industrial design. Nevertheless, a number of researchers have looked at the design of pastoral based systems, using a range of techniques. For example, McRae (1975) studied bull beef systems, and Miller (1983) dairy systems using a linear programming approach. Bircham (1984) and McCall (1984) developed simulation models to investigate alternative sheep farming systems. Wright and Baars (1976) also used this method to study bull beef production.

However, very little work has been published in New Zealand with respect to the design of hill country farming systems. McCall (1985), analysed the effect of varying lambing date and stocking rate, along with the influence of pre- and post-lambing nutrition on farm profitability. Walker (1984) analysed the effect of wintering hoggets for supply to an export hogget market, and Journeaux et al (1987) compared the profitability of alternative bull beef options on summer wet and summer dry Wairarapa hill country.

This work has been based on a generalised farm type, rather than specific case farms. It is well known, however, that there are substantial variations in physical and financial performance of farms within classes, regions, and districts (Fitzharris and Wright, 1984; Parker and Townsley, 1986). This means that while broad recommendations can be made with respect to methods of improving hill country farming, they may in fact have little relevance to an individual property. The author, who has had a close association over the past five years with the development of Massey University's hill country sheep farm, Tuapaka, was particularly interested in developing a comprehensive model of an individual farm. This would provide valuable information for the further development of the farming system, and help to identify components which required more understanding and hence improve the effectiveness of the on-farm research effort.

[1] In the context of this study a production system is defined as the biological system that produces outputs (products) from inputs on a farm property.

[2] The farming system encompasses both the production system and the management system.

[3] The management system is defined as the system used on the property to design, implement and control the production system.

The design of pastoral based systems using simulation models in New Zealand has involved models of varying complexity ranging from simple feed budget models to complex biological models. One major question that must be asked is; "What advantage do the complex biological models have over the less sophisticated (simple) feed budget models in terms of designing alternative hill country systems?" This study addresses this question.

Simulation can be defined as a technique "that involves setting up a model of a real situation, and then performing experiments on the model" (Naylor et al, 1966). However, Wright (1970) pointed out that this definition allows all research involving models to be classified as simulation models. To prevent confusion later in the text, the author has differentiated between models, in terms of their complexity. The comprehensive biological models have been referred to as simulation models while the basic feed supply - demand model is referred to either as a "simple feed budget" or as "the simple feed budgeting approach/technique".

1.2 The Physical Resources and Management of Tuapaka.

1.2.1 Physical Resources.

The Tuapaka hill unit is located in the Manawatu district of the North Island, New Zealand. It lies to the southeast of the Manawatu river on the flanks of the Tararua ranges, 13 km from Palmerston North (Figure 1.1).

The farm comprises 365 HA (334 HA effective), which rise steeply from 80 m above sea level (asl) at the front of the property to an altitude of 140 m asl, and then more gently from this point to 340 m asl at the back boundary (Figure 1.2).

The property faces northwest and is deeply bisected by a number of primary and secondary gullies that rise in the vicinity of the back boundary. These gullies are steep sided and drain into the Manawatu river. The topography of the hill block can be divided into 261 HA of easy to moderately steep hill country of which 50% is discable, and 104 HA is steep to very steep hill country.

The soils can be subdivided into three main groups (McLaughlin, 1983). The front hills are steep to very steep, and comprise Tuapaka hill soils, Halcombe steepland soils, and Makara steep and very steep soils. These soils are generally of low to very low natural fertility, having been formed under Black Beech forest, and are derived from sandstone, loess, conglomerate, and greywacke.

The mid-hills are generally of easier contour, partly yellow grey earth and partly yellow brown earth with intergrades. These soils are of medium fertility, tend to be wet in winter, and comprise Halcombe hill soils, a rolling phase of the Shannon silt loam, and some Makara steepland soils. These soils were formed under dicotylous podocarp forests and were derived from sandstone, conglomerate, and loess with some greywacke.

Figure 1.1 Location Map (Source: McLaughlin, 1983)

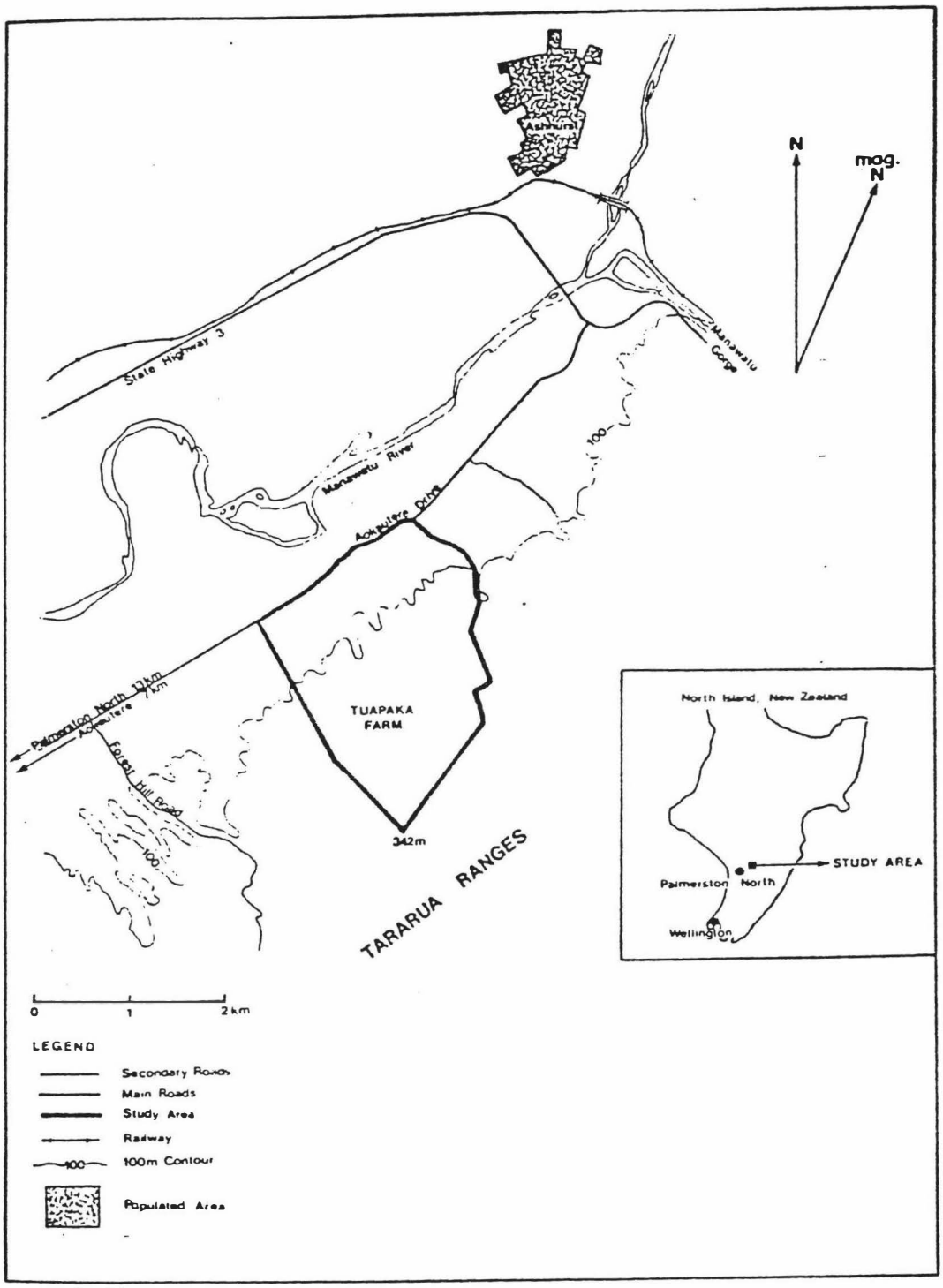
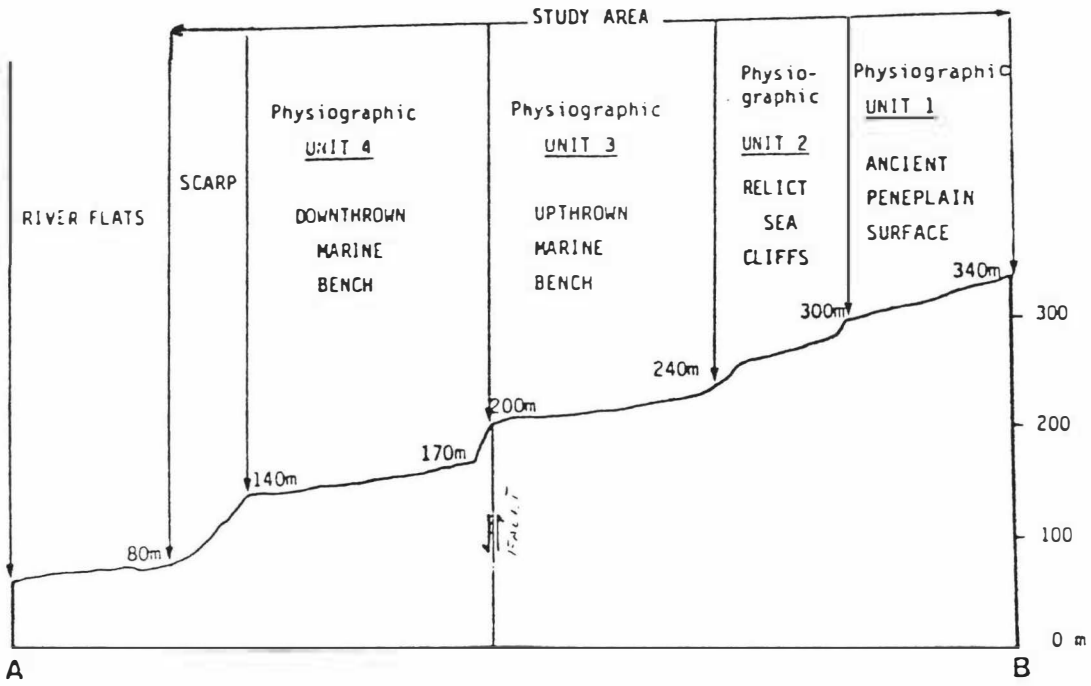


Figure 1.2 Idealized section across Tuapaka Farm, showing Physiographic Units. (Source: McLaughlin, 1983)



The back hills are made up of mainly yellow brown earths, and comprise of Ramiha silt loam, Korokoro silt loam, and in the northeast corner, Makara steepland soils. These soils are free draining, but leached and of low natural fertility, although once superphosphate has been applied these soils are the most productive on the hill block. The contour is generally easy with less gully dissection.

The climate at Tuapaka changes with altitude. Wind run and precipitation increase with altitude, whereas, soil temperatures decline. The average rainfall at the front of the property is estimated at around 1140 mm, rising to 1270 mm at the back boundary (Cowie, 1978). On-farm rainfall data has been collected since 1976 (Table 1.1). Over this period the average precipitation for Tuapaka has been 1132 mm/annum, with a range of 931 - 1321 mm/annum. The driest month is February, and the wettest months June, July, and October. Of special note is the extreme variability in any one month.

Table 1.1 A Summary of Average Monthly Rainfall Data (mm) For Tuapaka From 1976-1985.

Month	Average Rainfall	Minimum	Maximum
January	60	0	109
February	54	11	97
March	83	18	188
April	73	32	140
May	93	40	137
June	105	46	243
July	105	39	180
August	96	41	159
September	100	0	165
October	104	68	154
November	91	56	163
December	100	23	174
Total	1132		

The wind run at Tuapaka is extremely high. The strong northwest and westerly winds are channeled up the deep gullies of Tuapaka, increasing their velocity (Cowie, 1978). This tends to have a significant drying effect on the shallower hill soils over the spring, summer and autumn period.

Tuapaka was developed out of scrub and bush remnants through a process of burning and oversowing from 1938 into the early 1950's. The hill pastures were sown from a bush burn mix that contained a high proportion of browntop (Agrostis tenuis Sibth.) seed. Once the initial clearing was completed, later pasture development included the oversowing of selected paddocks with white clover (Trifolium repens), intensive subdivision during the 1960's, the aerial application of DDT super phosphate from 1965 - 1970 to control grassgrub, and the cultivation and establishment of improved species (ryegrass (Lolium perenne L.), white clover, red clover (Trifolium pratense L.) and cocksfoot (Dactylis glomerata L.)) on 32 HA of the back hills (Ramiha silt loam) in 1974 and 1975.

The pastures on Tuapaka can be subdivided into four main classes. The first consists of pastures that are ryegrass/white clover dominant with a reasonable proportion of browntop and Yorkshire fog (Holcus lanatus L.), which are found on the more fertile sites,covered by the Ramiha silt loam. Class two consists of a low fertility sward dominated by browntop, with crested dog's tail (Cynosurus cristatus L.), sweet vernal (Anthoxanthum odoratum L.) and rat's-tail (Vulpia myuros L.) making up the remainder of the sward's grasses. Clover content is low, with sub-clover (Trifolium subterraneum L.) the predominant legume. These pastures are found on the low fertility sites, predominantly the Tuapaka hill soils. Class three denotes a sward that is predominantly rat's-tail and browntop, with some Yorkshire fog on the higher fertility sites. These pastures are found on the very steep front scarp and the steeper gullies, where the soils are of low fertility, and are prone to drying out over the summer. Class four pastures are found over most of the middle of the farm, where there are medium fertility soils less prone to drought. These pastures contain predominantly ryegrass and Yorkshire fog.

With the exception of class one, the clover content of the swards is low and the clovers tend to be small leafed hill country ecotypes. Sub-clover is found on the drier slopes, and Lotus major (Lotus coniculatus L.) on the wetter south facing slopes.

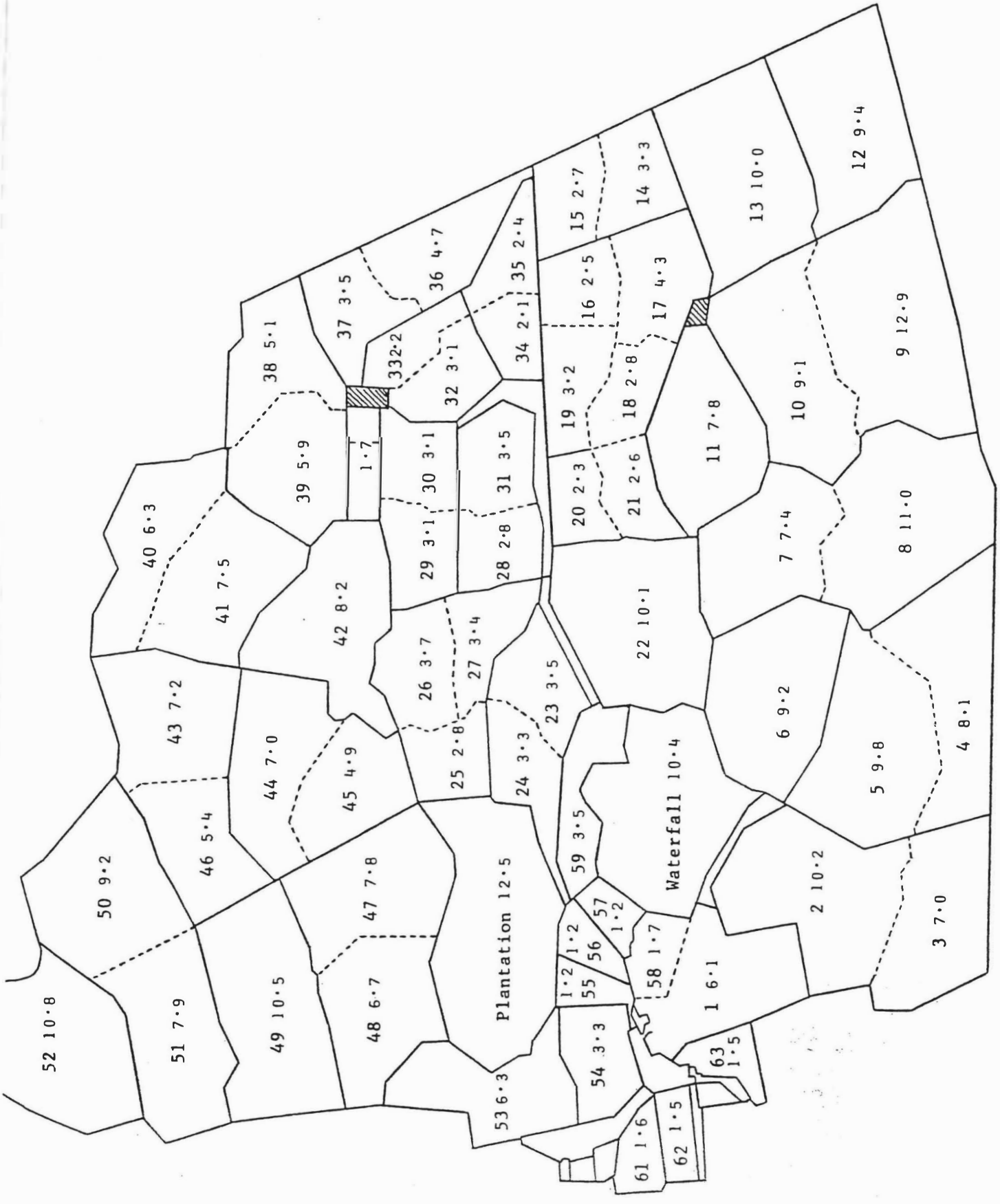
Trials by Korte (unpublished) over the period 1977 - 1979 found that the resident hill pasture produced 6,600 kg DM/HA/annum compared to 9,200 - 10,300 kg DM/HA/annum on a newly sown sward. Data collected since 1983 suggests that the resident hill sward produces 7,500 kg DM/HA/annum over the entire hill block.

The hill unit is subdivided into 53 main paddocks with conventional and electric fences (Figure 1.3). Trough water is reticulated to 95% of paddocks on the farm. The farm is well accessed, with three major gravelled tracks and a central lane. The farm has comprehensive stock handling facilities, including scales for both sheep and cattle weighing, and the usual range of farm machinery.

The property is run by a manager, with the aid of a head shepherd.They are also responsible for running the bull beef unit on the flats. Shearing is done by contractors, and casual labour is hired for fencing, shelter planting, weed spraying, and some maintenance work.

The farm has had a reasonable topdressing history. Between 1976 and 1983 the farm received on average, 300 kg/HA of superphosphate per annum. Lime was applied to the Shannon block (paddocks 1 - 8) at a rate of 2.5 t/HA. Since 1983 the farm has received the equivalent of 200 kg/HA of superphosphate per annum, and lime has been applied to one sixth of the farm at a rate of 2.5 t/HA each year. Olsen P levels range from 9 to 38, with an average of 15 across the property. Soil pH levels are between 5.4 and 6.2 .

Figure 1.3 Tuapaka Sheep Unit.
Effective Area 334ha.



Prior to 1982 the farm was achieving production levels of around 4.3 kg wool per sheep stock unit (S.S.U.), and 100% lambing for the Perendale flock. The Angus herd was averaging around 86% calving. Up until this time the property was run as one farm. In 1982, Tuapaka was split into two separate enterprises. The 111 HA of flats were fenced off to form a bull beef unit, and the 365 HA hill block was set up as an independent hill country sheep unit. The Perendale flock was replaced by Romneys over the ensuing four years. Research work was phased out and the farms were run on fully commercial lines. Comparisons of post-1982 performance with previous years is therefore difficult. In 1982 the author was given the responsibility of designing and implementing an all-sheep system for the Tuapaka hill unit.

1.2.2 The Tuapaka Hill Farming System.

The problems facing Massey University's Tuapaka hill country farm are typical of those confronting hill country farmers in the lower North Island of New Zealand. The major difficulty is that of matching feed demand with feed supply. The reasons for this are:

1) Low winter pasture growth rates which limit the number of capital stock that can be carried, and hence the potential physical production that can be achieved.

2) The late spring flush which limits the availability of feed over the critical early lactation period.

3) The inability of the relatively low winter stocking rate to effectively control pasture growth during late spring and early summer. This reduces both pasture quality and subsequent pasture growth rates.

4) Low summer pasture quality and highly variable autumn pasture growth rates which limit animal production over the summer/autumn period.

These factors are largely responsible for the relatively low levels of performance achieved on much of New Zealand's hill country (During et al, 1980; Rattray, 1982; Taylor, 1982; Sheath et al, 1984). The design of an all-sheep policy for implementation in 1983 attempted to overcome these problems. This system consisted of 2700 ewes, 800 ewe hoggets, and 80 rams and others to be wintered on the 334 HA (effective) hill block at a stocking rate of 10.0 S.U./HA, with lambing in early September and weaning in early January after the late spring flush. Target mating liveweights of 55 kg for two-tooths and mixed age ewes were set. Shearing months were; ewes, November and March; lambs, January; hoggets, October; and two-tooths, February.

Ewes were rotationally grazed (60 day grazing interval) post-weaning, cleaning up paddocks ahead of the lambs. Over flushing/tupping the ewes were on a faster rotation (20 - 30 days). This was increased after the first cycle of mating to an 80 day round to build up feed for lambing. The rotation was shortened to 40 days in the last three weeks of pregnancy before set stocking just prior to lambing. The ewes remained set stocked until weaning.

Post weaning the lambs were shuffle grazed over several paddocks at low stocking rates, approximately three weeks ahead of the ewes. Lambs were sold as feed dictated, with all lamb sales generally completed by the end of February. The replacement ewe lambs were shuffle grazed until the end of May, before being mobbed up and rotated around a separate hogget block (60 days) for the winter. In August the rotation was sped up to a 30 day round. In September the hogget area was reduced by one third and the hoggets were placed on a 20 day rotation. Following shearing in October, the hoggets (now classed as two tooths) were set stocked until early January. A 40 day rotation was then commenced, with the two tooths taking second priority to the lambs. The two tooths join the mixed age ewes at the start of flushing in early March.

The author had responsibility for the planning and control of the all-sheep policy. This included grazing management, stock selling policies, and other decisions that related to feed management such as the application of urea.

An information system was set-up to monitor data that was perceived to be useful for managing the system. This data included -

Stock liveweights
Pasture cover
Pasture growth rates
Pasture composition
Wool weights
Stock losses
Lambing percentage
Climatic data
Soil fertility data

A technician assisted with the collection of this data. Pasture and climatic data was collected on a fortnightly basis. Liveweight data was collected monthly, and animal production data as it occurred. Over time a data base was built-up that could be used to analyse alternative systems, as well as for day to day management purposes.

1.2.3 The Need For a Revised Farming System.

Evaluation of the data collected at Tuapaka from the time that the all-sheep policy was implemented, reinforced the impression that the control of the spring flush is central to achieving high levels of productivity from hill country. The problem was to design a system that could achieve this.

From a knowledge of the pattern of feed requirements, and also from observation of other hill country properties, it was hypothesised that the feed demand profile of a low stocking rate, highly fecund flock (130% lambing) would better match the feed supply, than a lower performance flock (100% lambing) run at a higher stocking rate (described in the previous section).

The basis for this hypothesis was that the winter requirements for a twin rearing ewe were only 18% higher than that for a single rearing ewe, but 44% higher during the spring (lactation) (Milligan, 1981). To prove this hypothesis an analysis that compared the present system with a highly fecund flock run at a lower stocking rate was required. The analysis would need to take into account not only the physical output from each system, but also the financial returns. This is described in detail in the next Chapter.

1.2.4 Objectives of the Study.

The objectives of this study are twofold:

1) To test the hypothesis that a high performance flock has a feed requirement pattern that better matches the pattern of pasture growth at Tuapaka than a low performance flock, and that the high performance flock will also be more profitable.

2) To investigate different methods of designing farm systems using modelling. Quantifying the effectiveness of simple versus complex approaches was of particular interest.

1.3 Thesis Outline.

In Chapter Two the basic assumptions for the high and low performance flocks are outlined. The Chapter includes a description of the construction of the simple feed budget and financial models used to compare the two flocks. Results from these models are presented and discussed, and limitations of the feed budgeting technique are identified.

These limitations are discussed in Chapter Three. McCall's (1984) hill country grazing model is also described and problems in using this model in its current form are discussed.

The construction of several simulation sub-models based on McCall's model for the comparison of the feed budgeting technique with the more complex simulation models is described in Chapter Four.

In Chapter Five results from two of these sub-models are presented. The wool simulation model is used to generate wool production for the range of stock classes in the high and low performance flocks. These simulated levels of wool production are then compared with those assumed for the simple feed budgeting approach in Chapter Two. In the second part of Chapter Five the model that simulates a mob of single rearing ewes on pasture over the period of lactation is used to analyse the effect of stocking rate and pasture cover at lambing on the performance of the system and this is compared to output from the simple feed budget analysis.

In Chapter Six the methodology used in this study is evaluated, the conclusions drawn from the study are discussed, and areas for further research are identified.

Chapter Two

Feed Budget Analysis.

2.0 Chapter Outline.

In this chapter the construction of the feed budget model is outlined. First, the pasture and animal components of the model are described. The levels of physical production and costs and prices used in the financial model are then outlined. In the final section the results obtained from the model are presented and discussed, and the overall conclusions drawn from this analysis are summarised.

2.1 Introduction.

Feed budgeting has traditionally been used to design pastoral farming systems and compare alternative farming systems. A wide range of different farming problems have been studied using this approach. For example, recent work using feed budgeting techniques has included analysis of sheep systems (Walker, 1984; Hall, 1986), bull beef (Journeaux, 1986), goats (Gray et al, 1986), deer (Greensill, 1984), and dairy cattle (Lockhart,1986). The basis of feed budgeting is to match feed supply with feed demand through time (Frengley, 1974).

In pastoral situations feed supply is based primarily on pasture growth. Forage crops, conserved feed such as hay and silage, and nitrogen boosted pasture growth are secondary sources. Other sources of feed under New Zealand conditions may also include grain and feed concentrates. Feed demand is a function of the number of animals present at any one time, and the feed requirements of those animals. The latter are dependent on the animals age, liveweight, physiological status, and rate of liveweight gain (Ullyatt et al, 1980).

The third component of the feed budget is pasture cover. Pasture cover is a measure of the amount of feed on a farm at a point in time and in simple terms reflects the balance between feed supply and feed demand. Thus, if feed supply exceeds feed demand, pasture cover increases. The converse applies for declining pasture cover.

Feed budgeting in the context of this study involves the derivation of a feed supply profile through time (from pasture growth rate data), and the design of alternative sheep systems which generate matching feed demand profiles. The compatibility of a particular sheep system with the pattern of pasture production is determined by comparing the feed supply and feed demand profiles.

It was decided to use spreadsheet technology (rather than the more traditional programming methods) for the construction of a feed budgeting model to analyse alternative sheep systems. The spreadsheet offered a number of advantages over fixed programs. A spreadsheet is more flexible, easy to use, can be made problem specific and is easily altered. In addition, spreadsheet programming can be mastered in a matter of hours using a tutorial program. This was an important consideration, because the author had no previous computer programming experience - the adoption of this technology overcame this constraint and avoided the need to work through an intermediary computer programmer. The MULTIPLAN spreadsheet program (255 rows by 63 columns) developed by Microsoft Corporation was used in the study.

2.2 Tuapaka Feed Supply.

The topography of the Tuapaka hill unit precludes the conservation of hay or silage and the feeding out of supplementary feeds. As such the main source of feed is pasture grown *in situ*. Nitrogen boosted pasture growth provides a secondary source. However, for the purpose of this study nitrogen usage has been excluded because at current prices (1986) for sheep products, nitrogen is generally not economic on hill country (Journeaux, 1987).

Pasture growth rates at Tuapaka were collected consistently from 1983. Average monthly pasture growth rates derived from these data for the period 1983 to 1985, are presented in Table 2.1. These formed the basis of the feed supply component of the model.

Table 2.1 Average Monthly Pasture Growth Rates for the Tuapaka Hill Unit.

Month	Pasture Growth Rate kg DM/HA/DAY
January	20
February	16
March	22
April	16
May	12
June	8
July	10
August	13
September	17
October	28
November	43
December	31

2.2.1 Pasture Quality.

Feed budgets generally use kilograms of dry matter (kg DM) as the units of feed supply. Animal requirements were defined in the feed tables presented by Ullyatt et al (1980) in units of energy i.e. megajoules of metabolisable energy (MJME). Energy (MJME) will therefore be used as the primary unit in calculations, but will be converted to standard units of dry matter by dividing by the pasture quality (MJME/kg DM) in any given period when presenting results.

In his study of alternative hogget fattening policies Walker (1984) derived a set of pasture quality values for hill country pastures (Table 2.2) based on data published by Ullyatt et al(1980). These are used to calculate the metabolisable energy content of pasture grown on a monthly basis throughout the year.

Table 2.2 Average Monthly Pasture Quality Values for Hill Country. (Source: Walker, 1984)

Month	Pasture Quality MJME/kg/DM
January	10.3
February	9.3
March	10.0
April	10.8
May	10.8
June	11.0
July	11.2
August	11.2
September	11.3
October	11.0
November	11.0
December	11.0

2.3 Feed Demand.

Walker (1984), after reviewing the numerous sets of feed tables that are available, decided to use those published by Ullyatt et al (1980). The same tables were considered to be satisfactory for this study.

2.3.1 Ewe Feed Requirements.

The derivation of the feed requirements for the two flocks under study required information on the fecundity of the flock. To estimate the feed requirements of the total flock, feed requirements had to be derived for each ewe category during pregnancy and lactation. There are four basic categories into which a ewe could fall; barren, single bearing, twin bearing,and triplet bearing. However the number of categories multiply further once these ewes have lambed into barren, single bearing ewes rearing 0 or 1 lamb, twin bearing ewes rearing 0,1, or 2 lambs, and triplet bearing ewes rearing 0,1,2, or 3 lambs.

Blair (1985) determined the proportion of barren, single bearing, twin bearing and triplet bearing ewes that would be expected to occur in flocks over a range of performance levels, and provided information on the proportion of ewes that would rear 0,1,2,and 3 lambs. This data was used to construct the fertility composition of the flocks studied (Table 2.3).

Table 2.3 The Pregnancy and Lactation Status of Ewes Within Flocks Achieving 100% Lambing and 132% Lambing. (Source: Blair, 1985)

	Flock Performance	
Pregnancy Status	100% Lambing (% Ewes)	132% Lambing (% Ewes)
Barren	7	7
Single Bearing	56	18
Twin Bearing	37	55
Triplet Bearing	0	19
Rearing Rank		
1/0	8	3
1/1	44	14
2/0	3	5
2/1	8	11
2/2	24	37
3/0	0	2
3/1	0	3
3/2	0	6
3/3	0	6

Three basic liveweight profiles were developed to represent, a single rearing ewe, a twin rearing ewe, and a triplet rearing ewe (Table 2.4). The single rearing ewe was assumed to have a basal pre-flushing liveweight of 50 kg. The twin and triplet rearing ewes were assumed to have a pre-flushing liveweight of 60 kg and 65 kg, respectively.

Data from Ullyatt et al (1980) described the feed requirements of the 50 kg single and 60 kg twin rearing ewes, but not for triplet rearing ewe feed requirements. A liveweight profile was therefore synthesised for a 65 kg triplet rearing ewe and feed requirements were extrapolated from the data provided by Ullyatt et al (1980).

Table 2.4 The Liveweight Profiles for Single, Twin and Triplet Rearing Ewes (kg).**

Date	Single Rearing Ewe (kg)	Twin Rearing Ewe (kg)	Triplet Rearing Ewe (kg)
1st January	49.6	59.6	64.6
10th January	50.0	60.0	65.0
31st January	50.0	60.0	65.0
28th February	50.0	60.0	65.0
10th March	50.0	60.0	65.0
31st March	52.0	62.0	67.0
30th April	55.0	65.0	70.0
31st May	55.0	65.0	70.0
30th June	55.0	65.0	70.0
31st July	55.0	65.5	70.5
31st August	58.5	74.2	80.0
1st September	50.0	60.0	65.0
22nd September	50.0	60.0	65.0
30th September	50.5	60.5	65.5
31st October	51.7	61.7	66.7
10th November	52.0	62.0	67.0
11th November	47.5	57.5	62.5
30th November	48.4	58.4	63.4
31st December	49.6	59.6	64.6

** These values include the weight of wool grown between shearings on 11th November.

A 4.5 and 5.0 kg birthweight for twin and single lambs respectively was assumed. The birthweight of triplet lambs was taken as 3.0 kg. Ullyatt et al's data assumed that both single and twin lambs achieved liveweight gains of 200 gm/DAY from birth to weaning.

The ewes were flushed over the period 10th March to 30th April. Mating commenced on the 5th April. This gave a 1st September lambing date. The ewes were shorn on the 10th November and weaned at the end of December. Half monthly feed requirements were selected to allow the ewes to maintain body weight (less fleeceweight changes, and the weight of conceptus over pregnancy) at about the level set as the pre-flushing basal liveweight.

A further set of feed requirements was derived for ewes that lost lambs after parturition i.e. a twin bearing ewe that rears a single lamb (Table 2.5).

By combining this information, it was now possible using Blair's (1985) data for the proportion of ewes bearing 0,1,2, or 3 lambs and the proportion of ewes rearing 0,1,2, or 3 lambs (Table 2.3) to synthesise average half monthly ewe feed requirements for both the 100% lambing and the 132% lambing flocks.

This data assumed that all the ewes lambed on 1st September, and in order to account for a normal lambing, data derived by Walker (1984) (Table 2.6) was used to spread the ewe flock feed requirements so that it better represented reality.

Table 2.5 The Average Feed Requirements for Ewes of Different Bearing Rank/Rearing Rank (MJME/EWE/DAY)

Half Monthly Period	Bearing Rank/Rearing Rank					
	1/1	2/1	2/2	3/1	3/2	3/3
Jan 1	12.7	14.7	14.7	15.5	15.5	15.5
Jan 2	10.3	11.9	11.9	12.6	12.6	12.6
Feb 1	10.3	11.9	11.9	12.6	12.6	12.6
Feb 2	10.3	11.9	11.9	12.6	12.6	12.6
Mar 1	12.3	14.2	14.2	15.1	15.1	15.1
Mar 2	16.6	19.0	19.0	20.0	20.0	20.0
Apr 1	17.0	19.3	19.3	20.3	20.3	20.3
Apr 2	17.5	19.6	19.6	20.6	20.6	20.6
May 1	11.1	12.6	12.6	13.3	13.3	13.3
May 2	11.1	12.6	12.6	13.3	13.3	13.3
Jun 1	11.1	12.6	12.6	13.3	13.3	13.3
Jun 2	11.1	12.6	12.6	13.3	13.3	13.3
Jul 1	11.1	12.8	12.8	14.4	14.4	14.4.
Jul 2	11.4	13.8	13.8	16.5	16.5	16.5
Aug 1	13.0	17.1	17.1	19.0	19.0	19.0
Aug 2	16.0	21.5	21.5	23.3	23.3	23.3
Sep 1	19.4	20.7	27.7	21.0	27.7	32.1
Sep 2	20.5	21.6	29.6	21.9	29.6	34.1
Oct 1	23.9	25.6	43.2	26.0	34.3	39.0
Oct 2	24.8	26.6	35.8	27.0	35.8	41.0
Nov 1	25.6	27.5	37.0	27.9	37.0	42.8
Nov 2	26.3	28.3	38.2	28.7	38.3	43.8
Dec 1	27.0	28.9	39.5	29.3	39.5	45.8
Dec 2	27.8	29.7	40.6	29.6	40.5	47.4

Table 2.6 The Lambing Spread for a Hill Country Ewe Flock. (Source: Walker, 1984)

Week of Lambing	Percentage of Ewes Lambing
1	22.0
2	40.0
3	18.0
4	6.0
5	4.0
6	4.0
7	6.0

2.3.2 Replacement Ewe Hogget Feed Requirements.

The derivation of feed requirements for the replacement ewe hoggets was based on the assumption that the 100% flock replacements would reach a basal pre-flushing two tooth liveweight of 50 kg, while those of the 132% flock would reach 60 kg at the same age (Table 2.7). The liveweight gain profiles were based on those given by the Ministry of Agriculture and Fisheries (M.A.F.) (1983).

Table 2.7 The Liveweight Profiles of Replacement Ewe Lambs for the 100% and 132% Flocks.**

Date	100% Flock Replacement (kg)	132% Flock Replacement (kg)
1st January	24.0	22.4
15th January	25.0	23.9
16th January	24.0	23.1
31st January	25.0	24.7
28th February	26.9	27.7
31st March	28.9	31.3
30th April	30.8	34.8
31st May	32.9	38.5
30th June	33.8	39.5
31st July	34.7	40.5
31st August	36.9	43.0
30th September	39.9	46.5
1st October	37.1	43.2
31st October	41.4	48.7
30th November	45.6	54.0
31st December	50.0	59.5
31st January	51.1	60.7
28th February	52.0	62.5
1st March	50.0	60.0

**Shearing dates: Lambs - 15th January
Hoggets - 30th September
Two tooths - 28th February

Table 2.8 The Lamb Liveweight Composition of the 100% and the 132% Flock at Weaning (kg). **

100% Flock					
Mid Lambing Date mean age (days)	7/9 (115)	22/9 (100)	7/10 (85)	21/10 (71)	
Lamb birth rank/ rearing rank					Mean Weaning Weight kg
2/2	25.2 (14.9)	22.5 (5.8)	19.8 (1.9)	17.3 (1.4)	23.7
2/1	27.5 (5.0)	24.5 (1.9)	21.5 (0.6)	18.7 (0.5)	25.8
1/1	28.0 (27.3)	25.0(10.6)	22.0 (3.5)	19.2 (2.6)	26.3
				Flock Mean	25.0

132% Flock					
Mid Lambing Date mean age (days)	7/9 (115)	22/9 (100)	7/10 (85)	21/10 (71)	
Lamb birth rank/ rearing rank					Mean Weaning Weight kg
3/3	20.3 (3.7)	18.0 (1.4)	15.8 (0.5)	13.7 (0.4)	18.9
3/2	23.7 (3.7)	21.0 (1.4)	18.3 (0.5)	15.8 (0.4)	22.4
3/1	26.0 (1.8)	23.0 (0.7)	20.0 (0.3)	17.2 (0.2)	24.1
2/2	25.2 (22.9)	22.5 (8.9)	19.8 (2.9)	17.3 (2.3)	23.7
2/1	27.5 (6.8)	24.5 (2.6)	21.5 (0.9)	18.7 (0.7)	25.8
1/1	28.0 (8.7)	25.0 (3.4)	22.0 (1.1)	19.2 (0.8)	26.3
				Flock Mean	23.4

**Note: The bracketed figures are the percentage of lambs in that category.

Average lamb weaning weights for each flock were based on the proportion of single, twin and triplet lambs in the flock, their rearing rank and hence their rate of liveweight gain to weaning, and the spread of lambing (Table 2.8). Ram lambs were assumed to wean 2.0 kg heavier than ewe lambs (Rendell,pers comm). To simplify the analysis, average liveweights were used rather than a distribution of liveweights about the mean as in Garrick et al (1986).

The daily energy requirements for the replacement stock (MJME/DAY) - derived from Townsley's (1986) equation - are summarised in Table 2.9.

Table 2.9 The Average Feed Requirements for the Replacement Stock from the 100% and 132% Lambing Flocks.

Half Monthly Period	100% Flock Replacement (MJME/HD/DAY)	132% Flock Replacement (MJME/HD/DAY)
1st January	9.2	10.1
2nd January	9.4	10.6
1st February	9.6	11.0
2nd February	9.9	11.4
1st March	10.1	12.6
2nd March	10.4	13.2
1st April	10.6	13.8
2nd April	10.9	14.3
1st May	11.2	14.9
2nd May	11.4	15.5
1st June	9.8	11.1
2nd June	9.9	11.2
1st July	10.0	11.3
2nd July	10.1	11.4
1st August	12.4	14.5
2nd August	12.7	14.8
1st September	14.7	17.6
2nd September	15.2	18.2
1st October	17.1	21.6
2nd October	17.9	22.7
1st November	18.6	23.9
2nd November	19.4	25.1
1st December	20.2	26.3
2nd December	21.2	27.6
1st January	13.9	18.1
2nd January	14.1	18.4
1st February	14.2	18.6
2nd February	14.3	18.9

2.3.3. Sale Lamb Feed Requirements.

Lambs surplus to requirements for replacement stock were retained on the farm, provided the feed supply allowed, until mid-June and mid-July for ewe and ram lambs respectively, and then slaughtered. Ram lambs were grown at 100 gm/DAY and the ewe lambs at 90 gm/DAY from weaning until slaughter. The liveweight of these lambs at weaning was the same as those shown in Table 2.8 . Average liveweights, rather than a distribution of liveweights about the mean and daily energy requirements (MJME/DAY) based on Townsley's equation (1986) were used as for flock replacements (Table 2.10). Ewe lambs were slaughtered earlier at lighter weights to avoid carcasses grading overfat (Kirton et al, 1984).

Table 2.10 The Average Feed Requirements for Non-replacement Lambs from the 100% and 132% Lambing Flocks.

Half Monthly Period	100% Flock Lambs (MJME/HD/DAY)		132% Flock Lambs (MJME/HD/DAY)	
	Ewe	Ram	Ewe	Ram
1st January	10.2	11.0	10.0	11.0
2nd January	10.6	11.5	10.4	11.4
1st February	11.0	11.9	10.5	11.6
2nd February	11.4	12.3	10.8	12.0
1st March	11.7	12.7	11.2	12.4
2nd March	12.1	13.2	11.6	12.9
1st April	12.5	13.7	12.0	13.3
2nd April	12.9	14.1	12.3	13.8
1st May	13.3	14.6	12.7	14.2
2nd May	13.7	15.1	13.1	14.7
1st June	14.1	15.5	13.5	15.2
2nd June	14.5	16.0	13.9	15.7
1st July		16.5		16.2

2.4 Stock Numbers.

Information on stock numbers throughout the year were required to calculate the feed demand (number of animals * feed requirements) for the property at any one point in time. The ensuing information describes stock losses, stock sales, stock purchases and replacement rates.

2.4.1 Stock Losses.

Stock losses were divided into three categories; ewes, replacement stock and sale lambs. Ewe losses are assumed to be 6% of ewes wintered (Blair,1985) for both flocks. However, for the 100% flock 4% of ewes wintered are lost pre-partum and 2% post-partum compared to the 132% flock where 5% are lost pre-partum and 1% post-partum.It was assumed that one third of pre-partum ewe losses occurred 2-4 weeks prior to lambing and two thirds in the final two weeks prior to lambing. Post-partum losses were assumed to occur in the first month of lactation, with two thirds of the losses occurring in the first two weeks.

Lamb losses for both replacement ewe lambs and sale lambs were at the rate of 0.8% per month. Over the period July through to December replacement stock losses were assumed at 0.25% per month. A further 0.5% were lost up until two tooth mating.

2.4.2 Replacement Rate.

A minimum replacement rate was assumed for each system in order to allow for a high ratio of ewes to ewe hoggets. The reason for this is that it allows a higher level of feed demand to be achieved (through the large change in ewe feed requirements following lambing) during the spring period thereby providing better spring pasture control. The number of ewe hoggets wintered were therefore just sufficient to replace ewe losses and the sale of cull of ewes. Thus, the 100% flock required a 24% replacement rate compared to 23% for the 132% flock. The number of ewe hoggets wintered also accounted for the 2% hogget death rate up until two tooth mating.

2.4.3. Stock Sales and Purchases.

The only capital stock sold were cull ewes. The culls from the 100% flock consisted of 7% barren ewes and 11% wet dry ewes, compared to 7% barren and 10% wet dry ewes in the 132% flock. It was assumed that all barren ewes were sold at the start of July after pregnancy diagnosis. One third of the wet dry ewes were sold by the end of September, and the remainder were sold at weaning (December 31st).Lamb sales were dependent on the feed situation as described in Section 2.3.3.

The sheep system was designed to be self-sustaining, with no stock except rams bought onto the property. The rams are not included in the feed budget analysis to simplify calculations, and because their feed requirements are similar for both flocks.

2.4.4 Stock Number Calculations.

Rather than changing the numbers in individual animal classes, the model was set-up so that the mid-winter (June) stocking rate (S.U./HA) could be entered as a single figure. Using this mid-winter stocking rate, the model calculated the respective number of ewes, and replacement stock. From this, the subsequent number of ewes and replacement stock present in each period throughout the year were calculated according to the assumptions described in Section 2.4 .

Lamb numbers at weaning were calculated from ewe numbers wintered multiplied by the lambing percentage. This was then split into replacement lambs, (based on the mid-winter ewe hogget numbers plus an allowance for deaths up until the end of June) and sale lambs (the remaining lambs). These groups were split equally into ewe and ram lambs. Lamb losses, calculated by the model, were deducted from lamb numbers half monthly.

Lamb sales were set by entering the desired number of ewe and ram lambs on hand in any half monthly period. The number of lambs sold, was taken as the difference between the lambs that should have been on hand in that period (based on lamb numbers in the previous period less losses) and the actual number of lambs on hand as entered by the operator.

2.5 Analysis of Profitability.

Although feed budget analysis is useful for analysing the technical feasibility of a pastoral system, the true worth of an option must be measured in economic terms. To carry out an economic analysis of alternative systems, some assumptions need to be made about the physical output from the system, the prices received for those outputs and the costs involved in generating those outputs. These assumptions are described in this section.

It was decided to use gross margin analysis to compare the profitability of the two flocks because they are similar except in the levels of performance achieved. The gross margin of an enterprise can be calculated by the formula -

GROSS MARGIN = GROSS REVENUE - VARIABLE COSTS Eqn. 2.1

For the comparison of the two flocks, gross revenue includes income from wool, lamb, and cull ewe sales. The variable costs of the enterprise are those costs that vary with the level of production and disappear if the enterprise is discontinued. The analysis does not take into account fixed costs, which are costs that are incurred irrespective of the type of enterprise adopted (Barnard and Nix, 1979). The variable costs in the gross margin analysis then, are animal health, shearing, cartage, and the purchase of ram replacements.

2.5.1 Income Assumptions.

Wool Production and Income.

There is very little data that relates wool production to feed intake. Estimates of wool production for the various stock classes are therefore reasonably subjective. Lambs shorn in January were assumed to clip 1.0 kg in the 100% flock compared with 0.8 kg for the 132% flock. The 0.2 kg differential allowed for the higher proportion of multiple reared lambs in the 132% flock. Sale lambs were assumed to be woolly if they were to be sold before mid-February, but lambs sold after mid-February were shorn in January and produced the same clip as the replacement ewe lambs.

The pelt wool from the sale lambs was not incorporated in the calculation of the wool clip, but was included into the value of the lamb carcass. The pelt wool on the lambs was estimated from work by Hawker (1981) that provided wool growth rates for lambs from January through to September (Table 2.11). It was assumed that a lamb had a woolpull of 0.25 kg post-shearing and that this increased as a function of the wool growth rate over time.

Table 2.11 The Average Monthly Wool Growth Rates for the Sale Lambs. (Source: Hawker, 1981)

Month	Average Daily Wool Growth Rates (gm/DAY)
January	15.0
February	14.9
March	13.3
April	12.9
May	12.1
June	9.6
July	7.0

The fleeceweights for the ewe hoggets shorn in early October were assumed to be 2.8 kg and 3.3 kg respectively for the 100% and the 132% flocks. This was also based on Hawker's (1981) data. The 0.5 kg difference was maintained at two tooth shearing in early March, when the 132% flock two tooths clipped 2.5 kg compared with 2.0 kg from the 100% flock two tooths.

Ewes shorn in early November clipped 4.5 kg in both flocks. Although the 132% flock ewes reared a higher proportion of multiple lambs (which would reduce ewe fleeceweight) they were fed at a higher level throughout the year in order to compensate for this factor. The ewes each clipped 0.2 kg of crutchings in July.

The prices used in the calculation of wool income were obtained from Massey University's Keeble Sheep Farm for the 1985/1986 clip (Morris, pers comm). It was assumed that 20% of the clip would be classed as oddments. A summary of the wool clip of each flock, with the price of the different wool classes is given in Table 2.12 . Total wool production was determined by multiplying the sheep numbers present at each shearing by the assumed yields. Wool income was then calculated by multiplying the prices shown in Table 2.12.

Table 2.12 A Summary of the Wool Clip and Prices for the 100% and 132% Lambing Flocks (kg).

Wool Clip	Price (c/kg)	100% Flock	132% Flock
Ewe	330	4.5	4.5
Lamb	350	1.0	0.8
Hogget	350	2.8	3.3
Two tooth	330	2.0	2.5
Crutching	200	0.2	0.2
Oddments	200	20 % of the above clip	

Lamb Meat Production and Income.

Lamb meat production was dependent on lamb liveweight at slaughter. As previously mentioned (Section 2.3.3), sale lambs were assumed to grow at 90 gm/DAY and 100 gm/DAY respectively for ewe and ram lambs from weaning to slaughter. The relationships derived by Kirton et al (1984) were used to calculate the killing-out percentage of lambs slaughtered at different ages and to grade each carcass. The fat depth over the twelfth rib (G.R. fat depth) was calculated from relationships derived by Shadbolt et al (1985) .

Table 2.13 provides a summary of the liveweight profiles, carcass weights and G.R. fat depth measurements for the respective lambs of the two flocks. The table also includes the lamb grade for each carcass weight/fat depth combination based on the New Zealand Meat Board Lamb Grading System (1985).

The lamb grading system is based on carcass weight and G.R. fat depth. The gross price paid per kilogram for the different grades, summarised in Table 2.13, is based on the meat schedule dated 28th April 1986. A premium is paid for the Alpha grade, lean carcasses, and lean heavy weight carcasses. Carcasses with high levels of fat cover are heavily discounted.

Table 2.13 also shows the changes in carcass weight and fat depth, and the corresponding meat grades for the ewe and ram lambs in the study. This demonstrates that as ewe lamb carcasses achieve weights above 14.8 kg they move into the TM grade which is heavily discounted due to fat cover. A similar situation exists for ram lambs at carcass weights above 16.5 kg where they move into the PX grade. Killing charges are deducted from the gross returns on a per head basis. This penalises the lighter carcasses as the costs are spread over less kilograms of carcass. Figure 2.1 shows the effect of carcass weight, grading, and killing charges on the net value of a lamb carcass. This demonstrates the large effect the grading system can have on returns from lamb sales.

Table 2.13 A Summary of the Liveweight, Carcass Weight, G.R. Fat Depth, Grading, and Schedule of the 100% and 132% Lambing Flocks' Sale Lambs.

100% Flock														
Half Monthly Period	Weaning	Jan 1	Jan 2	Feb 1	Feb 2	Mar 1	Mar 2	Apr 1	Apr 2	May 1	May 2	Jun 1	Jun 2	Jul 1
Ewe Lamb:														
Liveweight	24.0	25.4	26.8	27.1	28.3	29.7	31.1	32.5	33.8	35.2	36.6	37.9	39.3	
Carcass Wt. (kg)	9.6	10.2	10.9	11.0	11.6	12.2	12.9	13.6	14.2	14.8	15.5	16.1	16.8	
G.R. Fat Depth (mm)	4	5	6	6	7	8	9	10	11	13	14	15	16	
Grading	YL	YL	YL	YL	PL	PL	PM	PM	PM	TM	TM	TH	TH	
Schedule Value (c/kg)	134	134	134	134	122	122	133	133	133	91	91	75	75	
Ram Lamb:														
Liveweight	26.0	27.5	29.1	29.5	30.9	32.4	34.0	35.5	37.0	38.5	40.1	41.6	43.1	44.6
Carcass Wt. (kg)	10.3	11.0	11.7	11.9	12.6	13.3	14.0	14.8	15.5	16.2	16.9	17.6	18.3	19.1
G.R. Fat Depth (mm)	2	3	4	4	5	6	6	7	8	9	9	10	11	12
Grading	YL	YL	YL	YL	YM	YM	YM	YM	PM	YX	YX	PX	PX	PX
Schedule Value (c/kg)	134	134	134	134	143	143	143	143	133	138	138	102	102	102

132% Flock

Half Monthly Period	Weaning	Jan 1	Jan 2	Feb 1	Feb 2	Mar 1	Mar 2	Apr 1	Apr 2	May 1	May 2	Jun 1	Jun 2	Jul 1
Ewe Lamb:														
Liveweight	22.4	23.6	25.0	25.5	26.7	28.1	29.5	30.9	32.2	33.6	35.0	36.3	37.7	
Carcass Wt. (kg)	8.8	9.4	10.0	10.3	10.8	11.5	12.2	12.8	13.4	14.1	14.8	15.4	16.0	
G.R. Fat Depth (mm)	2	3	4	5	6	7	8	9	10	11	12	13	15	
Grading	ALPHA	YL	YL	YL	YL	PL	PL	PM	PM	PM	PM	TM	TM	
Schedule Value (c/kg)	180	141	141	141	141	117	117	139	139	139	139	70	70	
Ram Lamb:														
Liveweight	24.4	25.7	27.3	27.9	29.3	30.8	32.4	33.9	35.4	36.9	38.5	40.0	41.5	43.0
Carcass Wt. (kg)	9.5	10.1	10.9	11.2	11.8	12.5	13.3	14.0	14.7	15.4	16.2	16.9	17.6	18.3
G.R. Fat Depth (mm)	2	2	3	3	4	5	6	6	7	8	9	9	10	11
Grading	YL	YL	YL	YL	YL	YL	YM	YM	YM	PM	YX	YX	PX	PX
Schedule Value (c/kg)	134	134	134	134	134	134	143	143	143	133	138	138	102	102

Figure 2.1 The Effect of Carcass Weight and Grading on the Net Value of Ewe and Ram Lamb Carcasses.

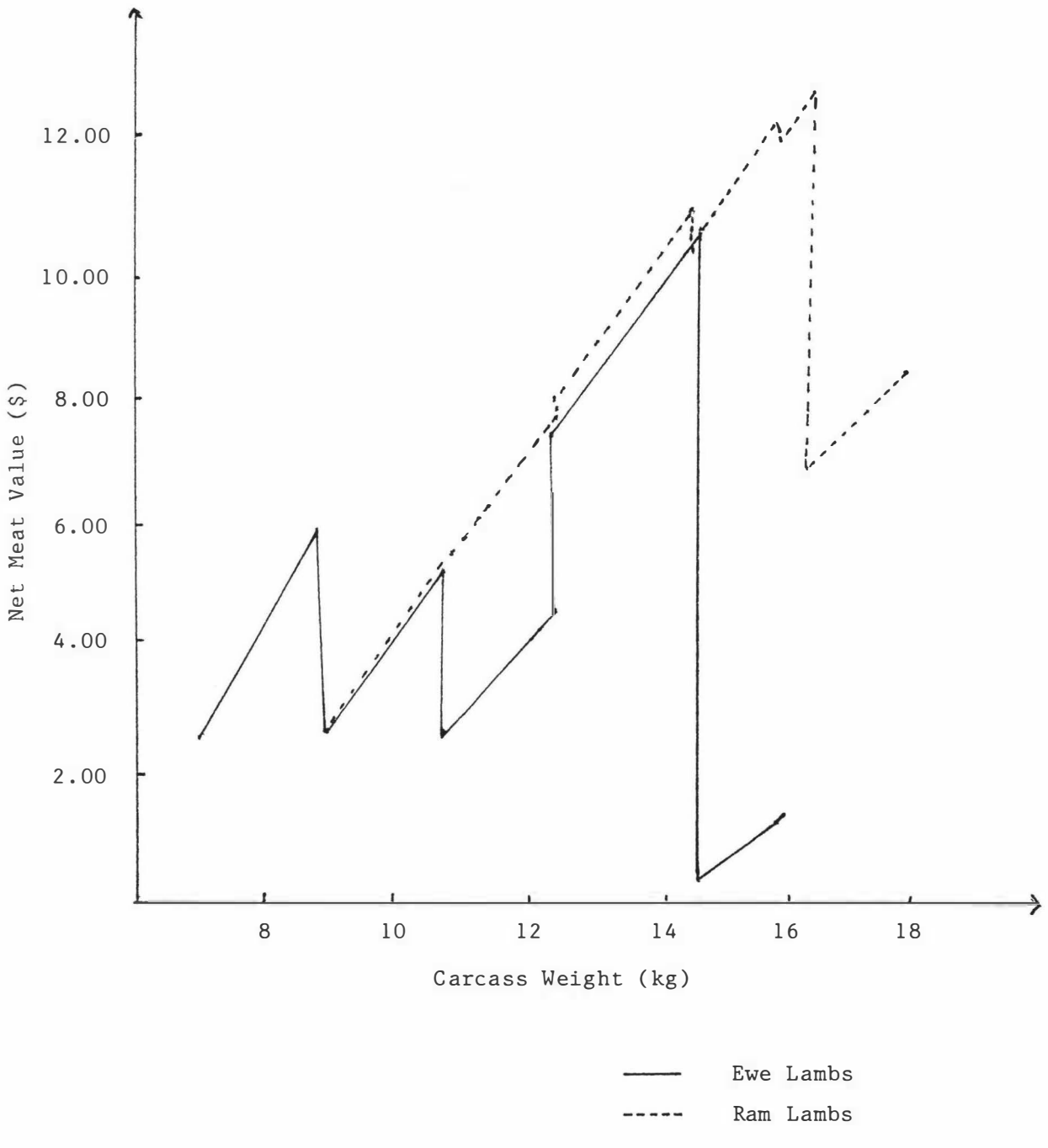


Table 2.14 A Summary of the Value of Lamb Carcasses from the 100% and 132% Lambing Flocks.

100% Flock														
Half Monthly Period	Weaning	Jan 1	Jan 2	Feb 1	Feb 2	Mar 1	Mar 2	Apr 1	Apr 2	May 1	May 2	Jun 1	Jun 2	Jul 1
Ewe lamb	$9.42	$11.16	$13.33	$10.04	$10.37	$11.86	$14.78	$16.24	$17.63	$12.69	$13.86	$12.26	$13.17	
Ram Lamb	$10.37	$12.17	$14.47	$11.24	$14.22	$15.92	$17.69	$19.28	$19.32	$21.50	$23.10	$18.15	$19.29	$20.34
132% Flock														
Ewe Lamb	$11.77	$9.82	$11.06	$9.75	$11.51	$10.36	$11.83	$16.00	$17.29	$18.77	$20.25	$10.92	$11.80	
Ram Lamb	$8.67	$10.18	$11.49	$10.23	$12.08	$13.71	$16.61	$18.20	$19.65	$19.68	$22.06	$23.45	$18.52	$19.46

Lamb returns are therefore a function of lamb carcass weight, the grading of the carcass and the pelt value (wool-pull). The latter is dependent on whether or not the lamb was shorn and the date at which it was killed. Killing charges and levies - based on the lamb schedule effective as at the 28th April 1986 - amounted to $9.96/head, irrespective of carcass weight. The value of ewe and ram lamb carcasses on a half monthly basis for the 100% and 132% flocks are summarised in Table 2.14. Total lamb returns were simply calculated by multiplying these values by the number of lambs sold in each half monthly period.

Cull Ewe Returns.

Cull ewes were sold in the first half of July, October and January. It was assumed that the culls sold in July and October would receive a $4.00 premium over those sold in January, because of market demand and that the January ewes would be in poorer condition (Table 2.15). A $2.00 premium has been allowed for the 132% flock ewes over the 100% flock ewes due to their higher liveweight. Total ewe returns were calculated by multiplying these values by the number of ewes sold.

Table 2.15 Cull Ewe Prices.

Sale Date	Flock	
	100%	132%
July	$12.00	$14.00
October	$12.00	$14.00
January	$ 8.00	$10.00

2.5.2 Cost Assumptions.

Animal Health Costs.

Animal health costs were broken down into three categories;dip, drench, and vaccine. The Lincoln College Farm Budget Manual (1983) and the M.A.F. Farm Costs and Prices Technical Paper (1985) were used to calculate the component costs of animal health expenditure. It was assumed that all mixed age ewes were vaccinated once prior to lambing and two tooth ewes were vaccinated twice, pre-tup and pre-lamb. All stock, and lambs sold at weaning, were dipped. Drenching costs which are dependent on liveweight are summarised in Table 2.16 . The ewes and two tooths were drenched twice pre-tup and at docking. The lambs and ewe hoggets were drenched at 21 day intervals up until the end of May, and then monthly until the end of December.

Table 2.16 A Summary of the Animal Health Costs.

Component	Cost/Head (c/HD)
Dip	6.2
Vaccine	16.0
Drench L.W.	
20kg	8.4
21-30kg	12.5
31-40kg	16.7
40kg	20.9

Shearing Costs.

Shearing costs are at the full contract price of $127/100. Stock numbers shorn are based on the number of animals in each class in the month of shearing. Only lambs sold before February were not shorn.

Ewes were crutched in late July at a cost of $55/100. An allowance of $9.50 per bale is made to cover wool packs, twine,emery paper, stencil ink and other associated costs. The weight of a standard wool bale is assumed to be 150 kg.

Cartage Costs.

Cartage costs were obtained from the M.A.F. Costs and Prices Technical Paper (1985) . Lambs cost $54/100 and cull ewes cost $70/100 to cart to the works. The cartage cost for wool was $4.14/bale.

Ram Purchase Costs.

A ram purchase price of $200/head net was used for both flocks. Sufficient rams to give a ram : ewe ratio of 1:100 were retained.

2.6. General Form of the Model.

The model can be considered to be made up of two sub-models. The first is a feed budget model used to analyse the number of stock that can be run on the Tuapaka hill unit (given the assumptions outlined in Sections 2.1 to 2.5). The second is a financial model that combines the stock numbers from the feed budget analysis with the assumptions made for physical production levels, and multiplies these by the respective costs and prices, discussed in Section 2.5. From this the gross margin of the system under analysis can be determined.

A small additional segment to the model was developed to assist in reaching an optimal solution. This calculated the marginal return (cents/kg DM) on feed consumed from retaining a lamb for an extra period, and the dry matter consumed for that period. With the aid of this program, an optimal solution could be reached after 4-5 iterations.

The spreadsheet allows the financial component to be linked directly with the feed budget component to generate a single large model. The model was constructed so that once the stocking rate was entered for a given level of performance, the only variable that could be changed was the pattern of lamb sales. The author used the pattern of lamb sales in two ways. First, to ensure that the final pasture cover achieved for an option equalled the initial pasture cover of 1800 kg DM/HA on January 1st, and secondly to optimise the gross margin for a given stocking rate and level of performance.

2.7 The Feed Budget Model.

2.7.1 Feed Supply.

The feed budget model requires average daily pasture growth rates (kg DM/HA/DAY) and pasture quality (MJME/kg DM) to be entered on a half monthly basis. Daily pasture growth rates are multiplied by the respective half monthly pasture quality level to calculate the total amount of energy available on a per hectare basis (MJME/HA) for animal consumption. Because it was assumed that an all grass system would be operated, no allowance was made for the conservation of hay or silage, or its subsequent feeding out.

2.7.2 Feed Demand.

The daily animal feed requirements (MJME/HD/DAY) are entered on a half monthly basis for each stock class, as outlined in Section 2.3 . To account for the effect of lambing spread on feed demand, a multiplier function was incorporated into the model, based on the proportion of ewes lambing in different weeks (Table 2.6). The multiplier function calculates daily ewe intakes for a given spread of lambing, from September 1st.

The feed requirements for the replacement stock and sale lambs were as given in Section 2.3 . Feed demand was calculated as daily animal feed requirements per hectare (kg DM/HA/DAY).

2.7.3. Model Calculations.

For each stock class the model calculates the daily feed requirements on a per hectare basis using the following equation -

$$\text{FEED DEMAND(MJME/HA/DAY)} = \frac{\text{STOCK NUMBERS} * \text{ANIMAL INTAKE (MJME/HD/DAY)}}{\text{AREA (HA)}}$$

...Eqn 2.2

The difference between feed demand and feed supply is calculated for each half monthly period as follows:

DIFFERENCE (MJME/HA/DAY) = FEED SUPPLY (MJME/HA/DAY) - FEED DEMAND (MJME/HA/DAY)

...Eqn 2.3

The difference is then converted to kilograms dry matter by dividing by the respective half monthly pasture quality factors as shown below:

$$\text{DIFFERENCE (kg DM/HA/DAY)} = \frac{\text{DIFFERENCE (MJME/HA/DAY)}}{\text{PASTURE QUALITY (MJME/kg DM)}}$$

...Eqn 2.4

To calculate the average pasture cover, the difference (Eqn 2.4) is multiplied by the number of days in the half monthly period. This value indicates whether pasture cover has increased or decreased over that period.

CHANGE IN PASTURE COVER (kg DM/HA) = DIFFERENCE (kg DM/HA/DAY) * NUMBER OF DAYS

...Eqn 2.5

To calculate the level of pasture cover at the end of each period, the value obtained from Eqn 2.5 is added to the level of pasture cover at the start of the period .

The model starts on January 1st with an initial pasture cover of 1800 kg DM/HA. If the farming system is sustainable in the long term, the final pasture cover level on December 31st should also equal 1800 kg DM/HA. The primary means of adjusting pasture cover, after entering the stocking rate for either the 100% or 132% lambing flock, was by altering the pattern of lamb sales. No constraints were placed on the within year levels of pasture cover generated by the model.

2.8 Financial Model.

Most of the calculations performed by the financial model have been described previously in Section 2.5. Once the basic cost and price assumptions have been entered into the financial model, no further data is necessary because the financial model uses data generated by the feed budget model as input.

The model calculates total wool production and total wool income and from this determines the "WOOL INCOME" indices on a per stock unit basis. Cull ewe returns and lamb sale data is used to calculate the "SHEEP INCOME" indices per stock unit. Sheep income and wool income are then added to generate "TOTAL SHEEP INCOME" . The latter is also calculated on a per hectare basis. (Refer to Table 2.27, for examples of the above indices).

A number of other indices are generated from the lamb sale data. These include average lamb price, average carcass weight, average price per kilogram of carcass meat, and carcass meat per hectare. Similarly for wool, the physical wool production indices, wool per stock unit and wool per hectare are derived.

2.8.1. Farm Cost Calculations.

The farm cost calculations (animal health, shearing, cartage and ram replacement) were based on the assumptions outlined in Section 2.5.2 . Animal health costs were entered into the model and the model calculated the number of stock on hand for each operation based on the half monthly stock numbers from the feed budget model. This data was then used to calculate the total animal health expenditure and per stock unit and per hectare indices.

Shearing costs were calculated in a similar manner with the stock numbers for each operation extracted from the half monthly stock numbers in the feed budget model. Crutching and shearing costs on a per head basis were entered manually. The model also calculated the total number of bales of wool produced, non-labour related shearing costs and the cost of wool transportation.

Stock cartage costs for each class were entered and the total cost was found by summing these values times the number of animals sold. The transport costs of the wool and stock were added together to provide total transportation costs.

Ram costs were based on; the purchase price (this value was entered manually), the number of rams required for the number of ewes wintered and the annual replacement rate.

The model totalled the different expenditures and then calculated the per stock unit and per hectare indices for expenditure. Per stock unit indices for the different classes of expenditure were also calculated.

The difference between income and expenditure was used to calculate the gross margin of the system on a per hectare and a per stock unit basis. These outputs provide the basis for analysing the financial consequences of the alternative systems.

2.9 Discussion of Results.

2.9.1. Introduction.

Initial experiments with the model were performed to find the maximum stocking rate (within 0.5 S.U./HA) that could be run given the average pasture growth rates for the Tuapaka hill country unit. This was achieved by running the highest stocking rate possible, that allowed the final pasture cover (December 31st) to equal the initial pasture cover (January 1st) where all lamb sales occurred at or shortly after weaning. The results indicated that for a September 1st lambing, maximum stocking rates of 12.5 S.U./HA and 11.0 S.U./HA could be run at 100% and 132% lambing, respectively.

Subsequently, the 132% flock model was run at stocking rates of 11.0 S.U./HA, 10.0 S.U./HA, and 9.0 S.U./HA, and the 100% flock model at 12.5 S.U./HA, 11.5 S.U./HA, and 10.5 S.U./HA. By comparing the financial return for each of these stocking rates, the "optimum" stocking rate for each performance level could be identified and the associated gross margin determined. As mentioned previously, the pattern of lamb sales was manipulated for each stocking rate first, to ensure that the final pasture cover equalled the initial pasture cover and that a realistic pattern of change in pasture cover was achieved during the year, and secondly to obtain the maximum gross margin for that stocking rate.

Table 2.17 Average Monthly Pasture Growth Rates, Animal Requirements, Pasture Surplus/Deficit and Pasture Cover Levels for the 100% Flock Stocked at 10.5 S.U./HA on the Tuapaka Hill Unit.

Month	Pasture Growthrate (kg/DM/HA/DAY)	Animal Intake (kg DM/HA/DAY)	Surplus/Deficit (kg DM/HA/MNTH)	Pasture Cover (kg DM/HA)
January	20.0	20.4	-11	1789
February	16.0	22.0	-167	1622
March	22.0	24.1	-65	1557
April	16.0	25.1	-272	1285
May	12.0	17.8	-179	1106
June	8.0	17.3	-278	828
July	10.0	11.0	-30	798
August	13.0	12.8	7	805
September	17.0	16.6	13	818
October	28.0	20.9	220	1038
November	43.0	23.6	584	1622
December	31.0	25.3	178	1800

Table 2.18 Average Monthly Pasture Growth Rates, Animal Requirements, Pasture Surplus/Deficit and Pasture Cover Levels for the 100% Flock Stocked at 11.5 S.U./HA on the Tuapaka Hill Unit.

Month	Pasture Growthrate (kg/DM/HA/DAY)	Animal Intake (kg DM/HA/DAY)	Surplus/Deficit (kg DM/HA/MNTH)	Pasture Cover (kg DM/HA)
January	20.0	22.3	-71	1729
February	16.0	21.4	-150	1579
March	22.0	23.7	-54	1525
April	16.0	22.8	-204	1321
May	12.0	13.2	-36	1285
June	8.0	12.6	-136	1149
July	10.0	12.0	-62	1087
August	13.0	14.0	-31	1056
September	17.0	18.1	-34	1022
October	28.0	22.9	158	1180
November	43.0	25.8	517	1697
December	31.0	27.7	103	1800

Table 2.19 Average Monthly Pasture Growth Rates, Animal Requirements, Pasture Surplus/Deficit and Pasture Cover Levels for the 100% Flock Stocked at 12.5 S.U./HA on the Tuapaka Hill Unit.

Month	Pasture Growthrate (kg/DM/HA/DAY)	Animal Intake (kg DM/HA/DAY)	Surplus/Deficit (kg DM/HA/MNTH)	Pasture Cover (kg DM/HA)
January	20.0	21.00	-31	1769
February	16.0	16.40	-12	1757
March	22.0	19.1	89	1846
April	16.0	20.65	-136	1710
May	12.0	14.3	-71	1639
June	8.0	13.7	-169	1470
July	10.0	13.1	-94	1376
August	13.0	15.2	-69	1307
September	17.0	10.7	-81	1226
October	28.0	24.9	96	1322
November	43.0	28.0	450	1772
December	31.0	30.1	28	1800

Table 2.20 Average Monthly Pasture Growth Rates, Animal Requirements, Pasture Surplus/Deficit and Pasture Cover Levels for the 132% Flock Stocked at 9.0 S.U./HA on the Tuapaka Hill Unit.

Month	Pasture Growthrate (kg DM/HA/DAY)	Animal Intake (kg DM/HA/DAY)	Surplus/Deficit (kg DM/HA/MNTH)	Pasture Cover (kg DM/HA)
January	20.0	20.9	-25	1775
February	16.0	22.8	-188	1587
March	22.0	24.1	-68	1519
April	16.0	24.0	-270	1249
May	12.0	20.8	-271	978
June	8.0	13.8	-173	805
July	10.0	10.4	-13	792
August	13.0	12.4	20	812
September	17.0	16.2	24	836
October	28.0	20.8	222	1058
November	43.0	23.7	578	1636
December	31.0	25.7	164	1800

Table 2.21 Average Monthly Pasture Growth Rates, Animal Requirements, Pasture Surplus/Deficit and Pasture Cover Levels for the 132% Flock Stocked at 10 S.U./HA on the Tuapaka Hill Unit.

Month	Pasture Growthrate (kg/DM/HA/DAY)	Animal Intake (kg DM/HA/DAY)	Surplus/Deficit (kg DM/HA/MNTH)	Pasture Cover (kg DM/HA)
January	20.0	20.3	-7	1793
February	16.0	22.0	-167	1626
March	22.0	23.6	-52	1574
April	16.0	24.7	-258	1316
May	12.0	12.9	-28	1288
June	8.0	11.7	-111	1177
July	10.0	11.6	-48	1129
August	13.0	13.7	-23	1106
September	17.0	18.0	-30	1076
October	28.0	23.2	150	1226
November	43.0	26.4	499	1725
December	31.0	28.6	75	1800

Table 2.22 Average Monthly Pasture Growth Rates, Animal Requirements, Pasture Surplus/Deficit and Pasture Cover Levels for the 132% Flock Stocked at 11 S.U./HA on the Tuapaka Hill Unit.

Month	Pasture Growthrate (kg/DM/HA/DAY)	Animal Intake (kg DM/HA/DAY)	Surplus/Deficit (kg DM/HA/MNTH)	Pasture Cover (kg DM/HA)
January	20.0	17.3	85	1885
February	16.0	18.4	-69	1816
March	22.0	20.3	50	1866
April	16.0	19.7	-110	1756
May	12.0	14.0	-61	1695
June	8.0	12.9	-146	1549
July	10.0	12.7	-84	1465
August	13.0	15.1	-66	1399
September	17.0	19.8	-83	1316
October	28.0	25.5	78	1394
November	43.0	29.9	419	1813
December	31.0	31.4	-13	1800

2.9.2. Feed Budget Results.

Examination of the feed budget results in Tables 2.17 - 2.22 indicates that the high performance flock provides a slightly better fit of feed requirements with feed supply, (reflected in the monthly surplus/deficit data and the pattern of monthly pasture cover) and suggests that a 32% increase in lambing percentage requires a drop in stocking rate of approximately 1.5 S.U./HA. In effect, this is a 14 - 17% decrease in stock numbers. If stocking rate is adjusted to incorporate this, only a small difference between the annual pattern of pasture cover for the two levels of performance exists. On this basis there is little advantage in running a lower stocking rate high performance flock on Tuapaka if the sole criteria for selecting a farming system was that of matching feed supply and feed demand.

This difference is smaller than expected, but can be attributed to a number of factors. The original hypothesis was based on a comparison of the feed requirements of a single rearing ewe with a twin rearing ewe. This in effect is equivalent to comparing a 100% lambing flock with a 200% lambing flock. However, the actual difference in lambing percentage between the two flocks in the analysis was only 32%.

The feed budget analysis was used for a flock rather than individual animals. The latter considers only the feed requirements of single and twin rearing ewes. In fact a ewe flock comprises a number of different bearing and rearing rank ewes as shown in Table 2.3. Although multiple rearing ewes consume a higher proportion of their total feed (relative to their winter requirements) over the period of lactation than single rearing ewes (Table 2.23), this advantage is reversed if the multiple bearing ewes lose one or more lambs (Table 2.24).

While the difference in flock performance was only 32% lambing, the real difference between the number of ewes bearing single, twin and triplet lambs was 38%, 18% and 19% respectively (Table 2.3). This affected the proportion of ewes that failed to rear lambs present at birth (Table 2.25). Thus, in the 100% flock; 19% of ewes failed to rear lambs present at birth, compared with 30% in the 132% flock. Failure to rear a lamb after carrying that lamb for the period of gestation, creates a large winter feed cost relative to the spring feed requirements of a ewe. Because the 132% flock lost a higher percentage of lambs, the advantage (in terms of their higher feed consumption over the period of lactation relative to the winter period) of the higher proportion of multiple bearing ewes in the flock, was reduced.

Table 2.23 A Comparison of the Feed Requirements of Single, Twin and Triplet Rearing Ewes.

Half Monthly Period	Single Rearing Ewe		Twin Rearing Ewe			Triplet Rearing Ewe		
	MJME/HD/DAY	MJME/Period	MJME/HD/DAY	MJME/Period	% Diff. *	MJME/HD/DAY	MJME/Period	% Diff. *
Jan 1	12.7	191	14.7	221	16	15.5	233	22
Jan 2	10.3	165	11.9	190	16	12.6	202	22
Feb 1	10.3	144	11.9	167	16	12.6	176	22
Feb 2	10.3	144	11.9	167	16	12.6	176	22
Mar 1	12.3	185	14.2	213	15	15.1	227	23
Mar 2	16.6	266	19.0	304	14	20.0	320	20
Apr 1	17.0	255	19.3	290	14	20.3	305	19
Apr 2	17.5	263	19.6	294	12	20.6	309	18
May 1	11.1	167	12.6	189	14	13.3	200	20
May 2	11.1	178	12.6	202	14	13.3	213	20
Jun 1	11.1	167	12.6	189	14	13.3	200	20
Jun 2	11.1	167	12.6	189	14	13.3	200	20
Jul 1	11.1	167	12.8	192	15	14.4	216	30
Jul 2	11.4	182	13.8	221	21	16.5	264	45
Aug 1	13.0	195	17.1	257	32	19.0	285	46
Aug 2	16.0	256	21.5	344	34	23.3	373	46
Sep 1	19.4	291	27.7	416	43	32.1	482	65
Sep 2	20.5	308	29.6	444	44	34.1	512	66
Oct 1	23.9	359	33.2	498	39	39.0	585	63
Oct 2	24.8	397	35.8	573	44	41.0	656	65
Nov 1	25.6	384	37.0	555	45	42.8	642	67
Nov 2	26.3	395	38.2	573	45	43.8	657	67
Dec 1	27.0	405	39.5	593	46	45.8	687	70
Dec 2	27.8	445	40.6	650	46	47.4	758	71
		6,469		8,607	33		9,456	46

*Compared to a single rearing ewe.

Table 2.24 A Comparison of the Feed Requirements of Single Rearing Ewe, With a Twin Bearing/Single Rearing Ewe and a Triplet Bearing/Single Rearing Ewe.

Half Monthly Period	Single Rearing Ewe		Twin Rearing Ewe			Triplet Rearing Ewe		
	MJME/HD/DAY	MJME/Period	MJME/HD/DAY	MJME/Period	% Diff.	MJME/HD/DAY	MJME/Period	% Diff.
Jan 1	12.7	191	14.7	221	16	15.5	233	22
Jan 2	10.3	165	11.9	190	16	12.6	202	22
Feb 1	10.3	144	11.9	167	16	12.6	176	22
Feb 2	10.3	144	11.9	167	16	12.6	176	22
Mar 1	12.3	185	14.2	213	15	15.1	227	23
Mar 2	16.6	266	19.0	304	14	20.0	320	20
Apr 1	17.0	255	19.3	290	14	20.3	305	19
Apr 2	17.5	263	19.6	294	12	20.6	309	18
May 1	11.1	167	12.6	189	14	13.3	200	20
May 2	11.1	178	12.6	202	14	13.3	213	20
Jun 1	11.1	167	12.6	189	14	13.3	200	20
Jun 2	11.1	167	12.6	189	14	13.3	200	20
Jul 1	11.1	167	12.8	192	15	14.4	216	30
Jul 2	11.4	182	13.8	221	21	16.5	264	45
Aug 1	13.0	195	17.1	257	32	19.0	285	46
Aug 2	16.0	256	21.5	344	34	23.3	373	46
Sep 1	19.8	297	21.2	318	7	21.0	315	6
Sep 2	21.4	321	22.8	342	7	22.9	344	7
Oct 1	25.1	377	26.9	404	7	27.2	408	8
Oct 2	26.3	421	28.1	450	7	28.5	456	8
Nov 1	27.3	410	29.2	438	7	29.6	444	8
Nov 2	28.1	422	30.0	450	7	30.5	458	9
Dec 1	28.7	431	30.6	459	7	31.2	468	9
Dec 2	29.1	466	31.1	498	7	31.8	509	9
		6,231		6,984	12		7,297	17

Table 2.25 A Comparison of the Proportion of Ewes that Fail to Rear the Number of Lambs Present at Birth for the 100% and 132% Lambing Flocks. (Source: Blair, 1985)

	Proportion of the Flock						
Bearing Rank	1	2	3	2	3	3	Total
Rearing Rank	0	0	0	1	1	2	
100% Flock	8%	3%	-	8%	-	-	19%
132% Flock	3%	5%	2%	11%	3%	6%	30%

There were also differences in the feed requirements of replacements for the two flocks. The high performance replacements, grown out to 60 kg by two tooth mating, consume 25% more feed per head than their low performance flock counterparts (Table 2.26). The peak difference in feed requirements for these two groups occurs through autumn and spring, and the minimum after weaning and in mid-winter. The 18 - 21% higher mid-winter stocking rate for the 50 kg replacement reduces the 25% per head difference in feed intake to 3 - 5% on a per hectare basis.

Table 2.26 A Comparison of Half Monthly Feed Requirements of Replacement Stock for the 100% and 132% Lambing Flocks.

Half Monthly Period	60kg Hogget		50kg Hogget		% Difference
	MJME/HD/DAY	MJME/Period	MJME/HD/DAY	MJME/Period	
Jan 1	10.1	152	9.2	138	10
Jan 2	10.6	170	9.4	150	13
Feb 1	11.0	154	9.6	134	15
Feb 2	11.4	160	9.9	139	15
Mar 1	12.6	189	10.1	152	25
Mar 2	13.2	211	10.4	166	27
Apr 1	13.8	207	10.6	159	30
Apr 2	14.3	215	10.9	164	31
May 1	14.9	224	11.2	168	33
May 2	15.5	248	11.4	182	36
Jun 1	11.1	167	9.8	147	13
Jun 2	11.2	168	9.9	149	13
Jul 1	11.3	170	10.0	150	13
Jul 2	11.4	182	10.1	162	13
Aug 1	14.5	218	12.4	186	17
Aug 2	14.8	237	12.7	203	17
Sep 1	17.6	264	14.7	221	20
Sep 2	18.2	273	15.2	228	20
Oct 1	21.6	324	17.1	257	26
Oct 2	22.7	363	17.9	286	27
Nov 1	23.9	359	18.6	279	28
Nov 2	25.1	377	19.4	291	29
Dec 1	26.3	395	20.2	303	30
Dec 2	27.6	442	21.2	339	30
Jan 1	18.1	272	13.9	209	30
Jan 2	18.4	294	14.1	226	30
Feb 1	18.6	260	14.2	199	31
Feb 2	18.9	265	14.3	200	32
		6,955		5,585	25

Although the between flock feed demand patterns were similar, there was considerable difference in the within flock pattern of feed demand due to the effect of stocking rate. For the high stocking rate options to be self sustaining, lambs were slaughtered at, or soon after weaning. This allowed feed to be taken into the winter to buffer the winter/early spring deficit. The low stocking rate option's pattern of feed demand generated a large spring surplus. The low stocking rate options therefore retained lambs into late winter to reduce pasture cover. The medium stocking rate systems fell mid-way between the two extremes.

In practice, a proportion of the feed carried through the summer would have senesced and decayed, as well as declining in quality. More detailed models, such as McCall's (1984) have taken this into account. The simple feed budget model with a cumulative pasture cover function and with no adjustment for loss of pasture other than through intake may therefore over-estimate autumn and winter feed supplies.

The validity of the low stocking rate analysis is questionable in the light of current knowledge, because it results in low pasture cover levels (below 1000 kg DM/HA) for 4 - 5 months of the year (Tables 2.17 & 2.20), including the period of early lactation. Bircham (1984) and Hodgson and Maxwell (1984) suggest that both pasture growth rates and animal intakes are reduced over the lactation period if pasture cover is allowed to fall below 1000 kg DM/HA. This feed budgeting analysis takes no account of the interaction between pasture cover, pasture growth rate and animal intake, since pasture growth rates and animal intakes are fixed. The levels of animal performance set for the low stocking rate options are unlikely to be attained, and as a result the physical and financial output from the low stocking rate option for the 132% lambing flock and the 100% lambing flock will be over-estimated.

The initial construction of the feed budgeting model required the derivation of a set of feed requirements, based on predetermined levels of animal performance. The analysis of a system's ability to cope with variations in pasture growth rates by altering the levels of animal intakes requires the derivation of a new set of performance levels associated with these intakes. However, published feed requirements for pregnant and lactating ewes are rigidly defined in the feed tables and information on the effect on performance of feeding ewes higher or lower levels of nutrition than specified in the feed tables is incomplete. The effect of varying ewe nutrition on ewe and lamb performance through the periods of pregnancy and lactation is therefore not easily addressed within the feed budget framework used. In contrast, liveweight and liveweight gain data can be more readily derived from tables for immature and dry stock, as shown by Townsley (1986).

Finally, the feed budget analysis is based on average pasture growth rates and takes no account of the different sheep systems' ability to cope with variations in pasture supply.

2.10. Financial Results.

2.10.1 Between Flock Profitability Comparison.

The gross margins per stock unit and per hectare are summarised in Table 2.27 for the two flocks across three stocking rates. The high performance flock achieves a higher gross margin per stock unit and per hectare than the low performance flock, despite a difference of 1.5 S.U./HA in stocking rate. The difference in profitability between the two flocks ranges from $6/HA (2.6%) up to $38/HA (16.5%). This represents an increase in total farm profitability of between $2,004 and $12,692.

Table 2.27 The Gross Margin Indices for the 100% and 132% Flocks.

	Stocking Rate (S.U./HA)	Wool Income	Sheep Income	Total Income	Variable Costs	Gross Margin
$/S.U.						
100% Flock	10.5	$15.89	$12.41	$28.30	$6.40	$21.90
	11.5	$15.25	$11.99	$27.24	$5.75	$21.49
	12.5	$13.88	$ 9.42	$23.30	$4.88	$18.42
132% Flock	9.0	$16.53	$20.12	$36.65	$6.85	$29.80
	10.0	$15.77	$16.40	$32.17	$6.02	$26.15
	11.0	$14.70	$11.89	$26.59	$5.12	$21.47
$/HA						
100% Flock	10.5	167	130	297	67	230
	11.5	175	138	313	66	247
	12.5	174	118	291	61	230
132% Flock	9.0	149	181	330	62	268
	10.0	158	164	322	60	262
	11.0	162	131	292	56	236

The 132% flock has a slightly higher (4.0 - 5.9%) wool income per stock unit than the low performance flock, because wool production is greater due to higher hogget and two tooth wool yields, and more lambs are shorn (Table 2.28). However, on a per hectare basis the low performance flock produces more wool (Table 2.28).

Table 2.28 Wool Production for the 100% and 132% Flocks.

	Stocking Rate (S.U./HA)	Wool Production Indices	
		kg/S.U.	kg/HA
100% Flock	10.5	5.2	55
	11.5	5.0	58
	12.5	4.6	58
132% Flock	9.0	5.4	49
	10.0	5.2	52
	11.0	4.8	53

Wool makes up 45 - 60% of total sheep income (Table 2.29). A small error in the estimation of the wool clip for individual stock classes could therefore have a large impact on the profitability of the two flocks. The average wool price used in the analysis was $3.04/kg compared to current (1986/87) prices of $3.50 to $3.80/kg. Such an increase in wool price almost removes the profit advantage of the high performance flock.

Table 2.29 The Components of Sheep Income for the 100% and 132% Flocks.

100% Flock Stocking Rate			
Component	12.5 S.U./HA	11.5 S.U./HA	10.5 S.U./HA
Wool Income	$56,567 (59.6)	$57,163 (56.0)	$54,388 (56.2)
Lamb sales	$31,886 (33.6)	$38,978 (38.2)	$37,005 (38.2)
Ewe sales	$ 6,490 (6.8)	$ 5,971 (5.8)	$ 5,452 (5.6)
Total Income	$94,943	$102,112	$96,845
132% Flock Stocking Rate			
Component	11.0 S.U./HA	10.0 S.U./HA	9.0 S.U./HA
Wool Income	$52,724 (55.3)	$51,424 (49.1)	$48,480 (45.0)
Lamb sales	$36,149 (37.9)	$47,532 (45.3)	$53,688 (50.0)
Ewe sales	$ 6,507 (6.8)	$ 5,915 (5.6)	$ 5,324 (5.0)
Total Income	$95,370	$104,871	$107,492

**Note: The figure in brackets represent the percentage of total income.

The major difference in profitability between the two flocks is attributed to sheep income (Table 2.27). On a per stock unit basis the high performance flock produces $2.47 to $7.71/S.U. (26.2 - 62.1%) above the low performance flock. These large differences ensure that the high performance flock has the highest sheep income per hectare, despite the 1.5 S.U./HA difference in stocking rate (Table 2.27).

The major source of sheep income is lamb sales, with ewe sales only contributing 9% to 17% of sheep income (Table 2.30). The financial returns from lamb sales are summarised in Table 2.31. Despite lower carcass weights (Table 2.32), the high performance flock achieved higher prices per kilogram than the low performance flock, except at the highest stocking rate option (Table 2.31; also refer to Table 2.13). Unlike wool income, changes in the lamb schedule do not affect the profit margin between the two flocks to a large degree. A 20 cents per kilogram change in the lamb schedule causes a per hectare change in the marginal profitability between the two flocks by $2.60 to $3.04 per hectare.

Table 2.30 The Components of Total Sheep Income for the 100% and 132% Flock.

100% Flock Stocking Rate			
Component	12.5 S.U./HA	11.5 S.U./HA	10.5 S.U./HA
Lamb sales	$31,886 (83.1)	$38,978 (86.7)	$37,005 (87.2)
Ewe sales	$ 6,490 (16.9)	$ 5,971 (13.3)	$ 5,452 (12.8)
Total Income	$38,379	$44,949	$42,457
132% Flock Stocking Rate			
Component	11.0 S.U./HA	10.0 S.U./HA	9.0 S.U./HA
Lamb sales	$36,149 (84.7)	$47,532 (88.9)	$53,688 (81.0)
Ewe sales	$ 6,507 (15.3)	$ 5,915 (11.1)	$ 5,324 (9.0)
Total Income	$42,656	$53,447	$59,012

** Note the figures in brackets represent the percentage of total income.

Table 2.31 A Breakdown of the Components of Lamb Meat Income for the 100% and 132% Flocks.

100% Flock				
Stocking Rate (S.U./HA)	Average Lamb Price ($/HD)	Price/kg ($/kg)	Return/HA ($/HA)	Returns/Ewe ($/Ewe)
10.5	18.78	$1.10	114	$12.66
11.5	17.34	$1.28	120	$12.18
12.5	12.60	$1.16	98	$ 9.17
132% Flock				
9.0	21.66	$1.38	165	$21.30
10.0	16.57	$1.34	146	$16.98
11.0	11.10	$1.13	111	$11.74

Table 2.32 Lamb Meat Production Indices for the 100% and 132% Flocks.

	Lamb Meat Production Indices			
	Stocking Rate (S.U./HA)	Average Carcass Weight (kg)	kg/S.U.	kg/HA
100% Flock	10.5	17.00	9.8	103
	11.5	13.60	8.2	94
	12.5	10.90	6.8	85
132% Flock				
	9.0	15.67	13.2	119
	10.0	12.39	10.9	109
	11.0	9.82	8.9	98

The low stocking rate/low performance flock produces heavily discounted carcasses due to the model structure, which requires that all feed produced be consumed. This means that at lower stocking rates, lambs are retained until surplus feed is used up, whereas in reality a farmer would attempt to sell the lambs for the best price, and divert the surplus feed to improving the liveweight of capital stock. Thus, the low stocking rate option for the low performance flock could be considered unrealistic and it should be excluded from the comparison of the two flocks.

Differences in costs between the two systems were between 4.9% and 7.0% on a per stock unit basis(8.0% - 8.2% on a per hectare basis (Table 2.27)). Essentially the high performance flock has higher per stock unit costs due to the higher number of lambs per ewe that must be shorn and drenched. However, the low performance flock has higher per hectare costs due to the effect of stocking rate. This trend is interesting to note, considering that lower stocking rate, higher performance systems have been advocated as a means of reducing costs.

2.10.2 Within Flock Profitability Comparison.

If the low stocking rate, low performance option is ignored because of the model's limitations, the between flock differences in profitability are only of the order of 6%, compared to 7% to 13.6% for within flock differences. This suggests that at either level of performance larger gains in profitability ($5,678 - $10,688) can be made by running a low stocking rate system.

The low stocking rate options produce more wool per stock unit (Table 2.28) because lambs are retained longer, and consequently more lambs are shorn. Thus, there is a curvilinear increase in wool production per hectare as stocking rate increases rather than the expected straight line response. This is reflected in differences between the wool income indices of $8 - $9/HA between the low and medium stocking rate options while those between the medium and high stocking rate options are minor (Table 2.27).

Similarly, profitability increases with decreasing stocking rate because of higher lamb returns. The low stocking rate system allows lambs to be retained for longer, and hence reach heavier carcass weights. This provides a number of advantages. First, the per head killing charge is spread over more kilograms of carcass. Secondly a heavy, lean carcass for which the largest premiums are paid can be produced (Table 2.33). Combined, these factors provide not only the highest return per kilogram and per carcass, but also the highest return per hectare (Table 2.31). Lamb returns are therefore 49% higher for the low stocking rate option.

Table 2.33 The Proportion of Lambs in the Different Grades for the Two Flocks at Three Stocking Rates.

100% Flock			
Carcass Grade	10.5 S.U./HA	11.5 S.U./HA	12.5 S.U./HA
ALPHA			
YL		32.9%	100%
PL			
YM		45.9%	
PM	32.6%	21.2%	
YX	0.8%		
PX	66.6%		
Average price/kg	$1.10	$1.28	$1.16
132% Flock			
Carcass Grade	9.0 S.U./HA	10.0 S.U./HA	11.0 S.U./HA
ALPHA	6.6%	39.6%	38.4%
YL			46.1%
PL			
YM		58.8%	15.5%
PM	32.0%		
YX	61.4%	1.6%	
PX			
TM			
Average Price/kg	$1.38	$1.34	$1.13

The cost structure increases as stocking rate decreases, both on a per stock unit and a per hectare basis. This is due to an increase in lamb drenching, and lamb shearing costs.

Although this analysis shows that in the case of the high performance flock, the low stocking rate option is the most profitable, the feasibility of this option was questioned in Section 2.9.2 due to the low levels of pasture cover that the system generated.

2.11 Conclusions.

The objectives of this part of the study were -

1) To determine the validity of the hypothesis that the feed requirements of a high performance flock better matched the feed supply of Massey University's Tuapaka hill country unit, than a low performance flock run at a higher stocking rate.

2) To compare the profitability of a high performance flock with that of a low performance flock run at a higher stocking rate.

A model, incorporating feed budget and gross margin sub-models was constructed to simulate a 100% and 132% lambing flocks run at different stocking rates. The conclusions that can be drawn from the output of this model are:

1) A low stocking rate high performance flock offers little advantage over a low performance flock run at a higher stocking rate in terms of matching feed demand with feed supply.

2) A high performance flock is marginally (3% - 8%) more profitable than a low performance flock run at a higher stocking rate. This small difference could be erased by changes in the relative prices of wool and lamb, the two major components of profitability.

3) A low stocking rate option at either level of performance, is more profitable than a high stocking rate system, provided lambs are sold prior to entering a grade that is heavily discounted because of excessive fat cover.

4) The validity of some parts of the analysis is questionable due to limitations imposed by the feed budgeting approach. For example, the feed budgeting technique fails to take into account the effect of pasture cover on pasture growth rates and animal intake. This may cause the analysis to over-estimate the production obtained from the low stocking rate options, where pasture cover remained below a critical level of 1000 kg DM/HA for a period of four to five months.

5) The feed requirement tables provide no information on the expected levels of wool production for different stock classes given some level of intake, or on the effect of different levels of intake over the periods of gestation and lactation on animal performance.

Chapter Three

The Limitations of the Feed Budgeting Technique.

3.0 Introduction.

In the previous Chapter a number of weaknesses of the feed budgeting approach used were outlined. Essentially these centred on :

1) The inability of the model to take into account the interaction between pasture cover, pasture growth rates and animal performance.

2) The effect of seasonal variation in pasture growth rates on levels of animal performance.

Construction of the feed budget model in Chapter Two also highlighted the inadequacy of published feed requirements tables for New Zealand hill country farming. In particular information is lacking with respect to :

1) Ewe liveweight changes over lactation when one, two or three lambs are reared, and the effect of lamb growth rates at other than 200 gm/DAY.

2) The effect of ewe liveweight loss on lamb and wool production.

3) The pregnancy requirements for a ewe which does not maintain conceptus-free body weight and produce either a 5.0 kg single lamb, or a set of 4.5 kg twin lambs.

4) The relationship between feed intake and wool production for different stock classes.

This lack of data makes it difficult to model animal/pasture relationships for flocks of different performance levels on hill country. However, a number of sophisticated models have been developed in an attempt to overcome the problems described above (e.g. Wright, 1970; Bircham, 1984; McCall, 1984). A fundamental question, however, is whether these more detailed modelling approaches, generate answers which are more realistic and which have as a consequence, greater research and practical application. The advantages of simple feed budgets, such as those which can be constructed on spreadsheets, are low cost, greater user-friendliness, lesser data requirements and easier adaptability. In contrast, a larger simulation model, which attempts to incorporate all (or a large proportion) of the relationships (interactions) of a farm production system are more expensive to construct, generally need to be programmed and tend to be inflexible at the farm level. The purpose of this chapter is to investigate the differences between a detailed hill country simulation model and the simple spreadsheet feed budget model described in Chapter Two. The initial sections of the chapter include a literature review of animal intake, pasture quality, pasture growth rates and pasture cover, and the interactions between these.

3.1 The Relationship Between Pasture Cover and Pasture Growth Rate.

Average pasture growth rates (which were fixed irrespective of the level of pasture cover), were used for the analysis in Chapter Two, despite differences in levels of pasture cover of 300 - 500 kg DM/HA at certain times of the year.

Early work by Brougham (1955), however, indicated that ryegrass followed a sigmoidal growth curve with respect to pasture cover. Later work by Hunt (1971) and Leafe et al (1974) confirmed this, but it was not until much later work by Bircham (1981) and Hodgson and Maxwell (1984) that some attempt was made to quantify the effect of pasture cover on pasture growth rate.

Bircham (1984) developed a pasture model for a sward under continuous grazing over the period lambing to weaning. Bircham considered that pasture growth rates were the product of the potential (environmentally possible) growth rate and a dimensionless multiplier that describes the relationship between pasture cover and pasture growth rate. The model reduces pasture growth rates at pasture cover levels below 1000 kg DM/HA and above 2000 kg DM/HA.

Hodgson and Maxwell (1984) found that under continuous stocking for spring swards, pasture growth rates increased with increasing pasture cover up to 1000 kg DM/HA. However, pasture senescence increased linearly with increasing pasture cover so that net herbage production reached a maximum between 1000 - 1500 kg DM/HA.

The work by Bircham (1984) and Hodgson and Maxwell (1984) suggests that pasture growth rates are relatively constant over the range 1000 - 2000 kg DM/HA. Below 1000 kg DM/HA pasture growth rates are reduced due to below optimum leaf area, and above 2000 kg DM/HA pasture growth rates are reduced due to high levels of pasture senescence. This suggests that for some parts of the feed budget analysis in Chapter Two, where pasture cover levels fall below 1000 kg DM/HA, the results may not be valid.

3.1.1 The Effect of Pasture Cover on Animal Intake.

A number of workers (During et al, 1980; Rattray et al, 1980; Milligan, 1981) have related animal intake to post-grazing residual dry matter levels (kg DM/HA). Others have related animal intake to pasture allowance (kg DM/HEAD/DAY) (Jagusch et al, 1979; Rattray, 1980; Rattray et al, 1980). In both cases animal intake increases curvilinearly with either increasing residual dry matter levels or increasing allowance.

Bircham (1984), and Hodgson and Maxwell (1984), have since related animal intake to pasture cover under continuous grazing conditions. Bircham found that ewe and lamb intake increased with increasing pasture cover up to levels of 2000 kg DM/HA. However, to achieve pasture covers of 2000 kg DM/HA under set stocking, low stocking rates were required. Hodgson and Maxwell (1984) calculated that to maximise total animal production, ewes and lambs should be set stocked on swards that were maintained at between 1000 - 1500 kg DM/HA.

Animal intake is also dependent on pasture quality. Jagusch et al (1979) found that lamb intakes increased with increasing herbage quality. This has been associated with shorter rumen retention times of dry matter (Ullyatt, 1971). Pasture quality has traditionally been described in terms of organic matter digestibility (OMD) (Minson, 1982). However changes in OMD are largely a response to dead herbage, but animal response is unrelated to the dead content of pasture and more closely related to green dry matter than total herbage mass or allowance (Rattray and Clark, 1984).

Butler (1986) found strong evidence that differences in animal performance when grazing reproductive pastures was due primarily to the quantity of leaf lamina in the sward, and secondly to the relative quantities and distribution of lamina and stubble. He concluded that pasture quality was largely determined by the quantity of leaf mass or allowance, i.e. "leaf quantity is pasture quality", probably modified under certain conditions by the presence of reproductive stubble.

In conclusion animal intake is dependent on both pasture quality and pasture cover. The feed budgeting method described in Chapter Two took no account of these factors. Ewe and lamb intakes appear to be reduced at pasture cover levels below 1000 kg DM/HA under set stocking. Some options studied achieved pasture cover levels below this level during early lactation, and as a result animal performance is likely to be lower than predicted. Similarly pasture quality was determined prior to analysis, and no account was taken of the factors that can influence quality.

3.1.2 The Factors That Effect Pasture Quality.

Pasture quality can be defined in units of metabolisable energy per unit of dry matter (MJME/kg DM), or in terms of digestibility, where digestibility is defined as the total amount of nutrients per unit of feed intake available to the animal (as a percentage of total intake) (Poppi, 1983). Pasture quality is dependent on the levels of green and dead herbage in the sward. Rattray (1977) found that pasture quality followed a seasonal pattern, peaking in early spring and then declining over late spring/summer to a low in February, before increasing again. Sward digestibility has been related to the proportion of dead herbage in the sward (Leafe et al, 1974; Rattray, 1978; Korte, 1981). For example, the digestibility of dead matter was measured at 36% compared to 80% for green material by Rattray (1978).

Leaf death is directly related to the amount of herbage present (Hunt, 1970). In a re-evaluation of Hunts' data, Korte (1981) showed that herbage died at a rate of 0.8% of the amount of green herbage present in the sward on a daily basis (kg DM/HA/DAY), regardless of stage of growth or shading. However, several workers have found that leaf death increases with increasing moisture stress and temperature (Leafe et al, 1977; Chu, 1979; Bowan et al, 1982).

Pasture growth rates over the spring period increase initially because of an increase in leaf and tiller numbers, and secondly due to the active growth of stems that are in the reproductive state (Radcliffe, 1974). This rapid growth of reproductive tillers causes intense competition for nutrients and water and many younger vegetative tillers die (Langer et al, 1964). In addition, new tillering is severely inhibited by growth substances produced by the reproductive tillers (Jewiss, 1972).

These two factors combine to cause a major decline in green leaf production, if the reproductive tillers are not removed (Korte et al, 1982). Furthermore, this stem material is largely rejected by animals (Korte et al, 1982) and subsequently dies. The early removal of the influorescence through grazing can therefore reduce the impact of the reproductive growth phase and the subsequent accumulation of dead matter (Korte, 1981).

The pasture quality of feed consumed by the grazing animal tends to be higher than the pasture quality of the sward because of the grazing animals ability to selectively graze. Grazing animals exhibit selection through the choice of grazing site, then of bite within that site (Milne et al, 1982). They consistently select more leaf than stem, and more green than dead material, compared to the sward from which it is harvested (Guy, 1979; Genty, 1983).

In contrast, Hodgson (1966) noted that the upper most leaves were most frequently grazed. He also considered that deliberate choice is not involved except in swards of low digestibility, and that the composition of the animals diet is similar to the composition of the grazing horizon at the top of the sward. Hodgson (1981) found that by measuring the digestibility of the sward at different heights there was a curvilinear increase in digestibility with increasing height. This reflects the spatial distribution of leaf, stem, and dead material. Grazing sheep are very reluctant to penetrate the horizons of the sward containing psuedostems (the stems together with leaf sheaths) even when herbage intake is severely limited as a consequence (Bathram, 1980).

No account of the dead/green content of the sward, the influence of pasture cover on dead matter levels and the resulting level of pasture quality, or the selectivity of grazing animals, was taken in the spreadsheet model.

3.2 Simulation Modelling.

A number of omissions in the spreadsheet feed budget have been identified in the previous sections. It is difficult to gauge the magnitude of these. Conceptually at least, they could be estimated using a model which does include the biological relationships described in Section 3.1 - 3.1.2, to analyse identical problems to those analysed by the spreadsheet feed budget model and then comparing the outputs.

A number of pasture - animal simulation models have been developed in recent years (Bircham,1984; McCall, 1984; White et al, 1986). However only one of these models (McCall, 1984), is specific to North Island hill country.

McCall (1984) developed a complex simulation model with the specific objectives of:

1) Identifying technological constraints to increased production from North Island hill country grazing systems by

   (a) integrating relevant knowledge in the form of a mathematical model, and (b) manipulating that model.

2) Evaluating the systems approach, and modelling as a tool, in aiding research management.

To achieve these objectives McCall attempted to integrate soil, animal, and pasture components in a model of a North Island hill country grazing system. It was built at a farm level and allowed the simulation of grazing management on a paddock basis, and animals on a flock basis. The model addresses the issues raised in the introduction to this chapter, and as such could be used to investigate the limitations of the simpler spreadsheet feed budgeting approach. However, there are a number of difficulties in using the model for this purpose, (discussed in the next section).

3.3 Discussion of the Applicability of McCall's Model.

The issue that is of prime importance is the validity of the simulation model. McCall concluded that "the model is valid in the sense that it appears to show the required realism (determined subjectively) for the purpose of evaluating alternative grazing strategies on North Island hill country".

However, McCall notes in a number of sections that some of the mathematical relationships derived are subjective due to limitations imposed by the data that was available. This identified areas where further research was required to allow a better understanding of component relationships. These included; the description of pasture growth as a function of environment, pasture senescence, the factors that affect animal intake, and the quality of the feed consumed by the grazing animal. However, until such time as these areas have been adequately defined and quantified, McCall's model remains the most comprehensive description of hill country grazing systems available.

There are several practical problems in using McCall's model. The soil - pasture component of the model is set-up to simulate the effect of pasture cover on pasture growth rate by using daily climatic data. This data has not been collected at Tuapaka, but climatic data from the nearest meteorological station could be modified to simulate the location, aspect, and altitude for the Tuapaka site. This problem could also be overcome if pasture growth rates (the same as used in the spreadsheet model) could be entered directly into the model. This is one of the future objectives for further development of the model (McCall, pers. comm.).

Pasture growth in McCall's model is related to green pasture cover, not total pasture cover. This division is essential in modelling sward dynamics. It is difficult to relate this to the simple feed budgeting approach, where the green and dead components of the sward are not differentiated.

The model also relies on the ratio of green and dead herbage for the calculation of the ME content of the sward and the ME content of the diet of the grazing animal. To accommodate the inclusion of the dead component in the model, McCall modelled the removal of dead matter through decay and earthworm activity. These activities are also a function of daily climatic data.

McCall's model can relate animal intake to pasture cover, and pasture quality, although these are related to the green and dead components of the sward rather than total pasture cover. The animal component of the model can therefore address the issues raised in Section 3.2.1. It can also produce output in terms of wool, liveweight gain (or loss), the products of pregnancy, ewe milk yield and subsequent lamb growth rates, for a given level of intake. All these variables can be changed simply by altering the level of nutrition.

The model was designed to study a whole farm situation, and operate at a paddock by paddock management level. The model has 40 "paddocks", around which the operator can "manage" a number of mobs of sheep. This creates a number of problems if the output from the simple spreadsheet feed budget is to be compared to the output from the simulation model. First, the simple feed budget takes no account of on-farm management in terms of feeding mobs of sheep in paddocks at different levels of pasture cover. It would be a major exercise to create a year round management plan for the simulation model that mimicked the simple feed budget. Secondly, the analysis of wool production requires the feed intakes used in the simple feed budget analysis to be entered directly into the simulation model. The simulation model does not have the capacity to accept directly entered animal intake data because animal intake is a function of the grazing management imposed on the "model flock" on a paddock by paddock basis.

In summary, the operation of the model does not allow it to be readily adapted to a specific farm situation, such as Tuapaka. In addition, the model is not "user-friendly". For example, a number of runs have to be made to set up the start conditions for a study. This makes it difficult to analyse particular periods of the year, or specific stock classes. The output from the model, produced on a daily basis, is also difficult to interpret.

3.4 Summary.

The feed budgeting approach has a number of limitations, which the literature review indicates, could have a significant bearing on the validity of analysis performed in Chapter Two. The analysis of the impact of these limitations is complicated by the lack of data, but could be estimated by comparing the results of the simple spreadsheet feed budget with those of a more sophisticated simulation model. McCall (1984) developed such a model for North Island hill country grazing systems. However, in its current form it is unsuited to carry out the required analysis.

It was concluded that a user-friendly spreadsheet model could be built using the mathematical relationships defined by McCall, specifically for the purpose of estimating the effectiveness of the simple feed budgeting analysis used in Chapter Two.

Chapter Four

Construction of Simulation Models.

4.0 Introduction.

In this chapter the construction of spreadsheet models, to study in greater detail two areas of the original feed budget analysis - wool production and the interaction between pasture cover, pasture growth rate and animal intake is described. In the previous chapter it was shown that these aspects were most likely to reduce the accuracy of the results generated by the simple feed budgeting method adopted in Chapter Two.

It was decided to construct the models using spreadsheet technology for the same reasons as those outlined in Section 2.1. In addition, the spreadsheet program run on a personal computer, overcame the two major disadvantages of McCall's model - that it was not user-friendly and that access was limited through the use of a mainframe computer. The development of models on a personal computer would allow them to be used widely for extension, teaching and on commercial properties.

Microsoft's Multiplan spreadsheet program (250 lines deep by 60 columns wide) was used. This was too small to accommodate McCall's model in its entirety. This problem was overcome by building smaller sub-models to describe particular aspects of the sheep farming system. In some cases these sub-models could be linked together so that information generated by one could be used as input for the other.

4.1 The Animal Sub-models.

McCall's model used input data, and produced output data on a daily basis. One aim in developing the new models was to simplify both input and output procedures. Animal intake (MJME/HEAD/DAY) would be entered and produced on a monthly or half monthly basis.

4.1.1 The Replacement Stock Model.

The replacement stock model, simulated an immature dry female sheep over the period of weaning to two tooth shearing (late February). This model was one of the least complex to build, and provided a base from which to build later animal sub-models. The structure is laid out in Table 4.1 . The inputs required to run the model, included: the liveweight of the ewe lamb at weaning, the fleece weight of the ewe lamb at weaning, the shearing dates for lambs, hoggets and two tooths, the mean birth date for the ewe lambs, the average green pasture cover for each month from January until February the following year, the monthly pasture quality values (MJME/kg DM) for the year and the average daily intake (MJME/HEAD/DAY) for each month from January until February the following year.

Table 4.1

The Replacement Stock Model.

ANIMAL INPUT DATA ========== 100% FLOCK EWE HOGGET REPLACEMENT GROWTH PROFILE ==========

Initial Liveweight	24
Initial Fleeceweight	0.25
Fleece free L.W.	23.75
Month of lamb shearing	6
Month of hogget shearing	10
Month of 2tooth shearing	6
Mean lambing date (days)	258

MONTH	JAN	FEB	NOV	DEC	JAN	FEB
ESTIMATED GREEN COVER	1000	1000	1100	1050	1000	1000
PASTURE QUALITY	10.3	9.3	11	11	10.3	9.3
Lamb intake (kgDM/hd/d)	1.07	1.24	1.73	1.88	1.20	1.20
Potential Intake	1.11	0.97	1.98	1.79	1.55	1.23
INPUT " INTAKE MJME/HD/DAY	11	11.5	19	20.65	13.95	14.25
IMEI (MJME/hd/d)	11.0	11.5	19.0	20.7	12.4	11.2
NEW (KJME/hd/d)	424	347	371	427	470	338
MEI (MJME/hd/d)	10.6	11.2	18.6	20.2	11.9	10.8
Intake Calculations						
L.W. effect.	30.0	30.0	48.2	52.7	55.6	56.2
Age effect.	30.0	30.0	50.0	50.0	50.0	50.0
>50 kg effect.	30.0	30.0	48.2	50.0	50.0	50.0
Max Intake %L.W.	5.5	5.5	3.8	3.6	3.6	3.6
Actual intake % LW.	4.5	3.6	3.7	3.6	3.2	2.5
>50 kg effect	1.00	1.00	1.00	0.94	0.88	0.87
Potential Intake	1.11	0.97	1.80	1.79	1.55	1.23
Shearing Effect 1st month	1.00	1.00	1.00	1.00	1.00	1.00
Shearing Effect 2nd month	1.00	1.00	1.10	1.00	1.00	1.00
TRUE POTENTIAL INTAKE	1.11	0.97	1.98	1.79	1.55	1.23
Accessability Factor	1.173	1.173	1.114	1.136	1.173	1.173
Lamb Age (years)	0.3	0.4	1.5	1.5	1.6	1.7
KM	0.71	0.70	0.73	0.73	0.71	0.70
FHP1	3.3	3.3	4.3	4.6	4.8	4.8
FHP2	5.1	5.1	6.6	7.1	7.4	7.4
MEM	7.1	7.3	9.1	9.8	10.3	10.6
Maintenance Requirements	8.3	8.5	10.2	11.1	12.1	12.5
Wool Requirements	0.4	0.3	0.4	0.4	0.5	0.3
Energy for gain	1.0	1.1	4.0	4.4	1.1	0.1
Wool growthrate (gm/d)	25	21	22	25	28	20
Bodyweight gain (gm/d)	64	64	149	149	37	4
Final Liveweight	26.8	29.1	51.9	57.3	59.3	59.9
Fleece free L.W.	25.7	27.5	50.4	55.0	56.1	56.3
Final Fleeceweight	1.0	1.6	1.5	2.2	3.1	3.7
Actual Liveweight gain (gm/d)	89	84	171	174	65	24
Shorn Fleece (kg)	0.0	0.0	0.0	0.0	0.0	0.0

OUTPUT SUMMARY ==========

INITIAL LIVEWEIGHT	24.0
INITIAL FLEECE WEIGHT	0.25

MONTH	JAN	FEB	NOV	DEC	JAN	FEB
LAMB INTAKE (kgDM/day)	1.07	1.24	1.73	1.88	1.20	1.20
LAMB INTAKE (MJME/day)	11.0	11.5	19.0	20.7	14.0	14.3
FINAL LAMB LIVEWEIGHT	26.8	29.1	51.9	57.3	59.3	59.9
LIVEWEIGHT GAIN (gm/day)	89	84	171	174	65	24
FINAL FLEECEWEIGHT	1.03	1.61	1.46	2.25	3.12	3.68
WOOL GROWTHRATE (gm/day)	25	21	22	25	28	18
SHORN FLEECEWEIGHT	0.0	0.0	0.0	0.0	0.0	0.0

The model contains a number of component calculations. Part of the model calculates the potential intake for the sheep in any given month based on age,liveweight, shearing date, pasture cover, and pasture quality. This was included in the model so that it could be linked to a pasture sub-model at a future date to allow the effect of pasture cover and pasture quality on animal intake to be analysed.

The second part of the model calculates the liveweight gain and wool production achieved for the level of nutrition specified. Animal intake is denoted as TMEI (MJME/HEAD/DAY). Wool growth rate is dependent on TMEI. Energy for wool growth is partitioned from TMEI ahead of the other metabolic processes. Residual TMEI is available for maintenance and liveweight gain. Maintenance requirements (MEM) are based on; age, liveweight, and pasture components such as pasture quality, and accessibility (which in turn is based on green pasture cover).

Shearing occurs on the first day of the month denoted. The amount of fleece assumed to be left on the animal is 0.25 kg. Calculations for any one period are incorporated in the column that is headed with the periods name. The dependent variables are entered at the top of the column, and the calculations that are based on these variables, follow an ordered sequence down the column.

Output is summarised on a monthly basis at the bottom of the spreadsheet (Table 4.1) and includes: a summary of daily animal intake in terms of both MJME and dry matter, the final liveweight at the end of each month, the average monthly liveweight gain (g/DAY), the final fleece weight at the end of each month, the average monthly wool growth rates (g/DAY), the shorn fleece weight for each shearing and the actual average monthly body weight gain ((g/DAY) (liveweight gain - wool growth rate)).

A full run takes approximately 30 minutes on a 640-K I.B.M. personal computer. The model is iterative, as a number of functions are dependent on the average fleece-free liveweight of the animal during a monthly period.

4.1.2 The Sale Lamb Model.

The sale lamb model is based on a smaller version of the replacement stock model (Table 4.1). It is identical, except that it only models lamb growth from weaning until mid-July (the last period in which sale lambs were retained on the property (Section 2.5.1)).

4.1.3 The Dry Ewe Model.

This model simulates a dry ewe over the period of weaning to mating (Table 4.2). The model was constructed so that it could be used to investigate a range of weaning and mating date combinations from October through to June. To allow for this flexibility, it could commence on any specified weaning date, and stop once the desired mating date had been reached. This was achieved by entering the weaning date and mating date as a day number in the year, e.g. January 1st equals 1, December 31st equals 365.

Table 4.2

The Dry Ewe Model.

WEANING TO POST-TUPPING TWIN EWE LIVEWEIGHT PROFILE

D.I.GRAY

DAY RAM PUT OUT (Jan 1st=1)	95
WEANING DATE (Oct 1st=274)	365
*note: 10 day periods/month	
EWE LW WEANING	59.6
EWE FLEECE WEIGHT weaning	1.4
FLEECE-FREE LW weaning	58.2

MONTH	FEBRUARY			MARCH			APRIL		
PERIOD	1	2	3	1	2	3	1	2	3
FINAL DAY OF PERIOD	41	51	59	69	79	90	100	110	120
WEANING DAY	0	0	0	0	0	0	0	0	0
WEANING DAY	0	0	0	0	0	0	0	0	0
WEANING DAY	0	0	0	0	0	0	0	0	0
MATING DAY	0	0	0	0	0	0	1	1	1
MATING DAY	0	0	0	0	0	0	0	1	1
MATING DAY	0	0	0	0	0	0	1	0	0
DAYS POST-WEANING	0	0	0	0	0	0	0	0	0
DAYS POST-WEANING	42	52	60	70	80	91	101	111	121
DAYS POST-WEANING	42	52	60	70	80	91	101	111	121
DAYS POST-MATING	0	0	0	0	0	0	5	15	25
LIVEWEIGHT ESTIMATOR									
1st CYCLE LW1	0.0	0.0	0.0	0.0	0.0	0.0	56.2	0.0	0.0
2nd CYCLE LW1	0.0	0.0	0.0	0.0	0.0	0.0	56.2	0.0	0.0
3rd CYCLE LW1	0.0	0.0	0.0	0.0	0.0	0.0	59.1	0.0	0.0
4th CYCLE LW1	0.0	0.0	0.0	0.0	0.0	0.0	62.3	0.0	0.0
1st CYCLE LW2	0.0	0.0	0.0	0.0	0.0	0.0	59.9	0.0	0.0
2nd CYCLE LW2	0.0	0.0	0.0	0.0	0.0	0.0	63.2	0.0	0.0
3rd CYCLE LW2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4th CYCLE LW2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PASTURE COVER	800	800	800	1000	1000	1000	900	900	900
PASTURE QUALITY	9.3	9.3	9.3	10	10	10	10.8	10.8	10.8
EWE INTAKE	1.28	1.28	1.28	1.42	1.66	1.90	1.79	1.80	1.81
IMEI	11.9	11.9	11.9	14.2	16.6	19.0	19.3	19.4	19.5
KM	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
EWE AGE (flock average)	3.4	3.5	3.5	3.5	3.5	3.6	3.6	3.6	3.7
FHP	8.0	7.9	7.9	7.9	7.9	8.1	8.3	8.4	8.6
AMNDNT	1.25	1.25	1.25	1.17	1.17	1.17	1.22	1.22	1.22
MEM	14.2	14.1	14.0	13.0	13.1	13.4	14.0	14.3	14.5
NEW	260	251	244	274	304	329	320	307	295
WOOL GROWTHRATE (gm/day)	15	15	15	16	18	20	19	18	18
MEI	11.6	11.7	11.7	13.9	16.3	18.7	19.0	19.1	19.3
ER	-1.8	-1.7	-1.7	0.9	3.2	5.3	5.0	4.9	4.7
ER2	-1.8	-1.7	-1.7	0.9	3.2	5.3	5.0	4.9	4.7
EVG	31.5	31.2	31.0	30.9	31.3	32.0	32.9	33.7	34.4
EVG2	31.5	31.2	31.0	30.9	31.3	32.0	32.9	33.7	34.4
EBWG (gm/day)	-58	-55	-54	30	102	166	153	145	138

OUTPUT SUMMARY

MONTH	FEBRUARY			MARCH			APRIL		
PERIOD	1	2	3	1	2	3	1	2	3
INITIAL LW	59.4	58.9	58.5	58.2	58.6	59.9	62.1	63.9	65.6
INITIAL FLEECEWEIGHT	2.0	2.1	2.3	2.4	2.6	2.7	2.9	3.1	3.3
INITIAL FLEECE-FREE LW	57.4	56.8	56.2	55.8	56.1	57.2	59.1	60.7	62.3
LIVEWEIGHT GAIN	-61	-59	-57	32	108	176	162	154	146
WOOL GROWTHRATE	15	15	15	16	18	20	19	18	18
FINAL LW	58.9	58.5	58.2	58.6	59.9	62.1	63.9	65.6	67.2
FINAL FLEECE WEIGHT	2.1	2.3	2.4	2.6	2.7	2.9	3.1	3.3	3.5
FINAL FLEECE-FREE LW	56.8	56.2	55.8	56.1	57.2	59.1	60.7	62.3	63.7

The input required to operate the model included; weaning date, mating date, liveweight at weaning, fleece weight at weaning, green pasture cover levels, pasture quality (MJME/kg DM), and daily ewe intake, either as kg DM or MJME.

The dry ewe model structure was identical to the replacement flock model for calculating liveweight gain (or loss). The output - summarised at one third of a month intervals - included; initial liveweight and fleece weight at the start of a period, liveweight gain, wool growth rate, final liveweight and fleece weight at the end of a period. A full run took approximately 15 minutes.

4.1.4 The Pregnant Ewe Models.

The pregnant ewe models were set up to simulate a twin and a single bearing ewe over the period of gestation. Unlike the previous models, these models are complex, because as well as portraying ewe liveweight gain (or loss) and wool growth, they also model the products of pregnancy. Separate models were developed for twin and single bearing ewes to allow model output to be compared with published feed tables.

The model structure is shown in Table 4.3 . It is similar to the replacement flock model. The inputs required to run the model include; ewe liveweight at mating, ewe fleece weight at mating, mating day (i.e. January 1st = 1), average monthly green pasture cover levels, monthly pasture quality, and daily ewe intake on a monthly or half monthly basis (either as dry matter or MJME).

The output, summarised on a monthly basis includes average daily intake, initial ewe liveweight and fleece weight, liveweight gain, wool growth rate, final ewe liveweight and fleece weight, initial conceptus liveweight, conceptus liveweight gain, final conceptus liveweight, final foetal liveweight, conceptus free ewe liveweight, and conceptus free ewe liveweight gain which is termed "true liveweight gain". In the case of the twin bearing ewe model, the output included total and individual foetal liveweight.

Simulation of gestation can start at any time between early February and late May. The summary output is based on a time period of one sixth of a month. Subsequent experience would suggest that a time period of up to one month would have had no effect on the accuracy of the results obtained from the model. This would reduce the size, and running time of the model by one third.

"If" statements were used to start and stop the model according to mating date and to specify the day of gestation. This was because foetal growth, based on a standard growth curve scaled to 1 kilogram, was dependent on the day of gestation. The growth of the conceptus was also dependent on the level of nutrition. If the ewe was underfed, the rate of foetal growth was reduced by holding the foetus back in time on the standard growth curve.

Table 4.3

The Pregnant Ewe Model.

THE TWIN EWE PREGNANCY MODEL.

	INPUT
Ewe L.W. mating.	62.1
Fleece weight.	2.9
Fleece-free L.W.	59.2

SUMMARY OUTPUT

MONTH	FEB	MAR	APR	MAY	JUN	JUL	AUG
GREEN COVER (kgDM/ha)	1200	1200	900	800	800	800	900
Ewe numbers. (TWINS)							
Intake/day (kgDM/hd/d)	0.0	0.0	1.9	1.3	1.3	1.3	1.9
Pasture Quality (MJME/kgDM)	10.0	10.0	10.0	10.0	10.0	10.0	10.0
TMEI	0.0	0.0	19.5	12.6	12.6	13.3	18.9
Initial Ewe LW	0.0	0.0	62.1	64.2	64.6	64.6	66.4
Actual LWG	0	0	69	13	0	59	270
Initial Fleeceweight	0.0	0.0	2.9	3.4	3.8	4.0	4.2
Wool Growthrate	0	0	18	10	8	7	11
Initial Conceptus LW	0.0	0.0	0.0	0.1	1.8	3.5	6.7
Growth Period of month (days)	0	0	30	31	30	31	25
Final Ewe LW	0.0	62.1	64.2	64.6	64.6	66.4	73.2
Final Fleeceweight	0.0	2.9	3.4	3.8	4.0	4.2	4.5
Conceptus LW	0.0	0.0	0.1	1.8	3.5	6.7	12.3
Conceptus LWG	0	0	4	55	54	105	225
Combined Feotal LW	0.0	0.0	0.0	0.2	1.3	4.4	8.6
INDIVIDUAL FEOTAL LW	0.0	0.0	0.0	0.1	0.6	2.2	4.3
Conceptus-free Ewe LW	0.0	62.1	64.1	62.7	61.1	59.7	60.8
ConceptusFleece-free Ewe LW	0.0	59.2	60.6	59.0	57.1	55.5	56.4
TRUE EWE LWG	0	0	47	-52	-62	-52	34

WF2	0.0	0.1	0.2	5.8	7.6	8.6
WPLAC3	0.0	0.4	0.8	1.0	1.0	1.0
WFLUD3	0.3	0.5	0.9	1.6	2.1	2.7
CONT	0.4	1.0	1.8	8.3	10.7	12.3
WUTER	0.4	0.5	0.5	1.0	1.1	1.1
Change in Wuter/period	0.1	0.1	0.1	0.1	0.1	0.1
WMAM	0.0	0.0	0.0	1.2	1.5	1.7
Change in Wmam/period	0.0	0.0	0.0	0.3	0.4	0.2
FEKG	-3.2	-1.9	-0.5	4.2	4.3	4.4
FEKG2	1.0	1.0	1.0	4.2	4.3	4.4
PLKG if t<70,1.67	1.7	1.7	1.7	3.3	3.2	3.2
PLKG2	1.7	1.7	1.7	3.3	3.2	3.2
FLKG if t<70,.22	0.2	0.2	0.2	0.4	0.4	0.4
UEKG	0.2	0.3	0.6	2.0	2.1	2.2
UWSUTH	0.1	0.1	0.2	0.6	0.6	0.7
UEKG2	1.8	2.3	2.6	3.3	3.3	3.3
UEKG3	1.8	2.3	2.6	3.3	3.3	3.3
MAKG 100<=t<126	0.0	0.0	0.0	10.6	9.4	8.8
MAKG t>125	0.0	0.0	0.0	11.0	11.0	11.0
PEBALF	0.0	0.1	0.2	24.1	32.8	37.6
PEBALP	0.1	0.6	1.3	3.2	3.3	3.4
PEBALL	0.1	0.1	0.2	0.7	0.9	1.1
PEBALU	0.8	1.1	1.4	3.3	3.6	3.8
PEBALM	0.0	0.0	0.0	12.7	16.6	18.9
ENERGY REQUIRED/day						
Feotus	0.0018	0.0046	0.0104	0.6780	0.8729	0.9565
Placenta	0.0054	0.0549	0.0651	0.0147	0.0128	0.0089
Fluids	0.0038	0.0057	0.0064	0.0093	0.0221	0.0421
Uterus	0.0435	0.0327	0.0288	0.0251	0.0319	0.0367
Mammary	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sum ERQD (ERP)	0.1	0.1	0.1	0.7	0.9	1.0
NEPG	0.0	0.0	0.0	0.5	0.9	1.8
RATIO	0.03	0.05	0.09	0.93	0.93	0.92
EFEOT	0.0	0.0	0.0	0.4	0.8	1.6
EFEOT/FER	0.00	0.00	0.00	0.62	0.96	1.68
EFEOT/FER2	0.84	0.84	0.84	0.84	0.96	1.68
EFEOT/FER3	0.84	0.84	0.84	0.84	0.96	1.68
T-RATIO	0.84	0.84	0.84	0.84	0.96	1.68
T-RATIO 2	0.84	0.84	0.84	0.84	0.96	1.00
T-RATIO 3	0.84	0.84	0.84	0.84	0.96	1.00
MEPG	0.2	0.4	0.4	2.9	3.8	4.2
CONK	0.2	0.4	0.7	2.1	2.5	2.8
CONM	0.2	0.3	0.5	1.7	2.0	2.3
ConHP	0.3	0.6	0.9	3.9	4.9	5.4
PME	0.4	0.7	1.0	4.6	5.8	6.4
MEPX	-2.2	-2.1	-2.0	3.5	5.6	9.3
ER1	-1.8	-2.0	-2.1	0.0	0.0	0.0
DIFF	0.0	0.0	0.0	-1.1	-0.2	2.9
ER2	0.0	0.0	0.0	-0.8	-0.1	0.0
MEF	0.0	0.0	0.0	0.0	0.0	2.9
ER3	0.0	0.0	0.0	0.0	0.0	0.7
TRUE ER	-1.8	-2.0	-2.1	-0.8	-0.1	0.7

Month	MAY			AUGUST		
Period of the month	P1	P2	P3	P1	P2	P3
Last day of period (days of yr.)	130	140	151	222	232	243
Day of pregnancy (T)	40	50	61	132	142	153
DAY OF PREGNANCY	40	50	61	132	142	147
TRUE day T	40	50	61	132	142	147
RATIO EFFECT	1.00	1.00	1.00	0.84	0.96	1.00
EFFECT on T due to feed	40	50	61	129	138	143
ACTUAL T	40	50	61	129	138	143
INTAKE/MONTH		39.1			47.2	
INTAKE/day (kgDM/ho/d)	1.3	1.3	1.3	1.7	1.9	2.2
TMEI/day (MJME)	12.6	12.6	12.6	17.1	19.3	21.5
AWE	12.2	11.9	11.6	12.5	13.5	15.1
NEW	181.9	168.0	155.8	159.8	179.6	207.5
MEI	12.4	12.4	12.4	16.9	19.1	21.3
PME	0.4	0.7	1.0	4.6	5.8	6.4
MEP	-2.2	-2.1	-2.0	3.5	5.6	9.3
MEM	14.6	14.5	14.4	13.4	13.5	12.0
Mean Flock Age (yrs)	4.7	4.7	4.8	4.9	5.0	5.0
KM	0.71	0.71	0.71	0.71	0.71	0.71
FHP1	8.3	8.3	8.2	7.8	7.8	7.9
Accessability Factor	1.25	1.25	1.25	1.22	1.22	1.08
FHP2	10.4	10.3	10.2	9.5	9.6	8.5
Maintenance Requirements	14.6	14.5	14.4	13.4	13.5	12.0
Wool Requirements	0.2	0.2	0.2	0.2	0.2	0.2
Energy for gain	-1.8	-2.0	-2.1	-0.8	-0.1	0.7
Wool growthrate (gm/d)	11	10	9	10	11	12
EVG	36.9	36.6	36.4	34.1	34.1	34.4
TRUE EVG	35.0	35.0	35.0	34.1	34.1	34.4
Bodyweight gain (gm/d)	-49.3	-54.9	-58.4	-24.1	-3.6	20.8
Liveweight gain (gm/d)	-52.2	-58.2	-61.9	-25.6	-3.8	22.0
Gain/period (kg)	-0.52	-0.58	-0.68	-0.26	-0.04	0.11
Wuter+Wmam gain/period	0.05	0.05	0.06	0.34	0.44	0.25
Total Gain/period	-0.47	-0.53	-0.62	0.08	0.41	0.37
Time Factor	0	0	0	0	0	0
initial Liveweight	0	0	0	0	0	0
Initial Fleeceweight	0	0	0	0	0	0
initial Fleece-free liveweight	0	0	0	0	0	0
Actual Measured LWG (gm/d)	-14	20	31	178	291	410
Final liveweight	64.0	64.2	64.6	68.2	71.1	73.2
Final fleece weight	3.6	3.7	3.8	4.3	4.4	4.5
Final Fleece free L.W.	60.5	60.6	60.8	63.9	66.7	68.7
Initial conceptus-fleecefree LW	60.6	60.1	59.6	55.5	55.6	56.0
Final Conceptus-fleecefree LW	60.1	59.6	59.0	55.6	56.0	56.4
Conceptus	0.35	0.98	1.85	8.31	10.71	12.33
ACTUAL T	40	50	61	129	138	143
PFWT1	4.7	4.7	4.7	4.7	4.7	4.7
PFWT	4.7	4.7	4.7	4.7	4.7	4.7
WF	0.0	0.0	0.0	0.6	0.8	0.9
WPLAC	0.0	0.1	0.3	0.5	0.5	0.5
WFLUD	0.1	0.2	0.3	0.9	1.1	1.4
ROBWF	0.0	0.0	0.1	3.2	4.0	4.4
WPLAC2	0.0	0.0	0.1	0.1	0.1	0.1
WFLUD2	0.0	0.1	0.1	0.2	0.2	0.3

The model construction was similar to the replacement flock model except that it now included functions that partitioned energy to the products of pregnancy. Total ME intake (TMEI), was partitioned off for the requirements of pregnancy first, for wool growth second and maintenance and liveweight gain last. Where TMEI was insufficient to meet the requirements for maintenance, the ewe catabolised body tissue, resulting in a loss of liveweight. The energy available for pregnancy was partitioned to the components of the conceptus i.e. foetal growth, placental growth, fluid production and mammary gland development.

Output was summarised at the top of the model structure.The time required to complete a full run of the model was approximately one hour.

4.1.5 The Lactation Model.

The lactation model (Table 4.4) was designed to simulate a twin rearing ewe or a single rearing ewe over the period of lactation and allowed output to be compared with published feed tables. The lactation model was constructed so that ewe and lamb intakes could also be entered directly. The lactation model could also be linked to the pasture sub-model and ewe and lamb intakes would then be determined by pasture cover and pasture quality.

The model is similar to the pregnancy model in structure. The required input includes; ewe liveweight at lambing, ewe fleece weight at lambing, lambing date, lamb birth weight, average monthly green pasture cover and pasture quality levels, ewe shearing date, ewe stocking rate, and ewe and lamb daily herbage intake, either in terms of dry matter or MJME.

Output from the lactation model is summarised on a half monthly basis, because changes in ewe and lamb liveweight were not adequately described using a time scale of one month. Output includes; ewe liveweight, ewe fleece weight, ewe liveweight gain (or loss), ewe wool growth rate, ewe wool clip at shearing, lamb liveweight, lamb fleece weight, lamb liveweight gain, lamb wool growth rate, ewe and lamb intakes, ewe milk yield, and the proportion of milk and herbage ME intake in the lambs' diet.

The structure of the model is similar to that described for the previous models. Time periods are one sixth of a month. This short period was used primarily for setting up the intake/pasture component relationship because it was felt that a short time interval should be used to minimise the changes in pasture cover between periods. Further work is required to quantify the impact of different time periods on model output. However, the use of longer time periods, as for the pregnancy model, will greatly reduce model size and running time.

The day of lactation is a major determinant of ewe milk production (similar to the way in which day of gestation drives the pregnancy model).

Table 4.4

The Lactating Ewe Model.

TWIN EWE LACTATION MODEL

D.I.GRAY

INPUT	
EWE LW	60.9
EWE FLEECEWEIGHT	4.5
FLEECEFREE L.W.	56.4
LAMB BIRTHWEIGHT	4.3
Mid Lambing Day (Aug 1st = 213)	246
EWE SHEARING MONTH (Jan=1)	11
TWIN S.R. (EWES/HA)	10.0

MONTH	SEPT	OCT	NOV	DEC
GREEN COVER (KGDM/HA)	1050	1200	1500	1400
QUALITY (MJME/KGDM)	11.3	11	11	11

OUTPUT SUMMARY

MONTH	SEPT	SEPT	OCT	OCT	NOV	NOV	DEC	DEC
PERIOD	1	2	1	2	1	2	1	2
EWE INTAKE AS DETERMINED BY								
AVERAGE PASTURE COVER (GUIDE)	1.58	1.96	2.22	2.01	2.25	2.15	1.84	1.66
AVERAGE INTAKE/DAY (INPUT)	2.5	2.4	2.3	2.1	2.0	1.8	1.8	1.7
INITIAL LW	60.9	58.3	56.7	56.9	57.6	54.4	56.0	57.9
INITIAL FLEECEWEIGHT	4.5	4.5	4.7	4.8	5.0	0.5	0.8	1.1
INITIAL FLEECE-FREE LW	56.4	53.7	52.0	52.1	52.6	53.9	55.3	56.8
	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
DAYS/PERIOD	13.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LIVEWEIGHT GAIN (gm/d)	-204	-115	4	36	87	91	104	94
WOOL GROWTHRATE (gm/d)	6	8	12	14	17	18	20	21
MEASURED LWG	-198	-108	15	49	103	109	124	114
SHORN FLEECE	0.0		0.0		4.8		0.0	
FINAL LW	58.3	56.7	56.9	57.6	54.4	56.0	57.9	59.6
FINAL FLEECEWEIGHT	4.5	4.7	4.8	5.0	0.5	0.8	1.1	1.4
FINAL FLEECE-FREE LW	53.7	52.0	52.1	52.6	53.9	55.3	56.8	58.2
SHORN FLEECEWEIGHT	0.0		0.0		4.8		0.0	
MILK YIELD/DAY	3.1	2.6	1.9	1.3	0.9	0.6	0.4	0.3
INITIAL LAMB LW	4.3	9.3	12.3	15.1	17.7	19.8	22.0	24.1
INITIAL LAMB FLEECEWEIGHT	0.25	0.35	0.47	0.61	0.77	0.94	1.13	1.34
INITIAL FLEECE-FREE LAMB LW	4.04	8.92	11.86	14.49	16.91	18.85	20.87	22.77
LIVEWEIGHT GAIN (gm/d)	384	203	185	172	141	147	140	151
WOOL GROWTHRATE (gm/d)	8	8	9	11	11	13	14	15
MEASURED LW GAIN (gm/d)	392	211	194	182	153	160	154	166
FINAL LAMB LW	9.3	12.3	15.1	17.7	19.8	22.0	24.1	26.4
FINAL LAMB FLEECE WEIGHT	0.35	0.47	0.61	0.77	0.94	1.13	1.34	1.57
FINAL FLEECE-FREE LAMB LW	8.9	11.9	14.5	16.9	18.9	20.9	22.8	24.8
MILK INTAKE/DAY	1.54	1.31	0.96	0.67	0.45	0.30	0.20	0.13
MILK MEI/DAY	7.06	5.99	4.39	3.05	2.06	1.36	0.89	0.58
PERCENTAGE OF TOTAL ENERGY	100	80	51	32	21	13	8	5
HERBAGE INTAKE/DAY	0.00	0.13	0.39	0.59	0.70	0.83	0.91	1.01
HERBAGE MEI/DAY	0.00	1.50	4.25	6.48	7.65	9.10	9.96	11.10
PERCENTAGE OF TOTAL ENERGY	0	20	49	68	79	87	92	95
TOTAL ENERGY INTAKE/DAY	7.06	7.49	8.64	9.53	9.71	10.46	10.85	11.68
EWE & LAMBS DM INTAKE/DAY	2.45	2.62	3.11	3.25	3.36	3.47	3.59	3.69

MONTH	SEPT	SEPT	SEPT	DEC	DEC	DEC
LACTATION PERIOD	1	2	3	4	5	6
FINAL DAY OF PERIOD	248	253	258	353	358	363
DAY OF LACTATION	1	1	1	1	1	1
DAY OF LACTATION	1	0	0	0	0	0
	3	0	0	0	0	0
TRUE DAY OF LACTATION	3	8	13	108	113	118
TRUE INTAKE/PERIOD	7.4	12.3	12.3	8.4	8.4	8.4
INPUT INTAKE/EWE/DAY	2.5	2.5	2.5	1.7	1.7	1.7
TMEI	27.7	27.7	27.7	18.4	18.4	18.4
AWE	4.8	4.5	5.3	16.2	16.5	16.8
NEW	85	83	95	339	350	359
WOOL GROWTHRATE (gm/d)	5	5	6	20	21	21
MEI	27.6	27.6	27.6	18.1	18.1	18.0
EWE AGE (flock)	4.0	4.0	4.0	4.3	4.3	4.3
INITIAL EWE LW	60.9	0.0	0.0	0.0	0.0	0.0
STARTING FLEECEWEIGHT	4.5	0.0	0.0	0.0	0.0	0.0
INITIAL EWE FLEECEWEIGHT	4.5	4.5	4.5	1.1	1.2	1.3
EBWG (gm/d)	-169.0	-174.6	-156.7	84.9	88.4	91.6
LIVEWEIGHTGAIN (gm/d)	-179.1	-185.0	-166.1	90.0	93.7	97.1
INITIAL FLEECE-FREE LW	56.4	55.5	54.6	56.8	57.3	57.7
FINAL FLEECE-FREE LW	55.5	54.6	53.7	57.3	57.7	58.2
FINAL FLEECEWEIGHT	4.5	4.5	4.5	1.2	1.3	1.4
SHORN FLEECEWEIGHT	0.0					
SHEARING DAY SETUP	0	0	0	0	0	0
SHEARING DAY SETUP	0	0	0	51	56	61
TRUE SHEARING DAY	0	0	0	0	0	0
FINAL LIVEWEIGHT	60.0	59.1	58.3	58.4	59.0	59.6
KM	0.7	0.7	0.7	0.7	0.7	0.7
FMPI	7.9	7.8	7.7	8.0	8.0	8.1
ACCESSABILITL FACTOR	1.1	1.1	1.1	1.0	1.0	1.0
MEM	12.3	12.1	12.0	11.4	11.4	11.5
MEPI	15.3	15.5	15.6	6.7	6.6	6.5
ER	-5.8	-5.9	-5.3	3.0	3.1	3.2
EVG	35	34	34	35	35	35
EVG2	34.6	34.1	33.6	34.8	35.0	35.0
MILK PRODUCTION Twins						
AT	1.0	1.0	1.0	1.0	1.0	1.0
ATI	3.8	3.8	3.8	3.8	3.8	3.8
WL (week of lactation)	1.3	2.0	2.7	16.3	17.0	17.7
MYEILD	3.1	3.2	3.1	0.3	0.3	0.2
PMEL	23.0	23.5	22.6	2.2	1.9	1.6
EMB	18.7	18.8	18.9	9.8	9.7	9.7
EMB	18.7	18.8	18.9	9.8	9.7	9.7
EWB3	4.4	4.7	3.7	-7.6	-7.9	-8.1
LLWT	45.0	45.0	45.0	45.0	45.0	45.0
LLWL	1.3	2.0	2.7	6.0	6.0	6.0
B (buffering ability)	0.0	0.0	0.0	0.0	0.0	0.0
B2	0.0	0.0	0.0	0.0	0.0	0.0
B3	0.0	0.0	0.0	0.0	0.0	0.0
EMB4	4.4	4.7	3.7	0.0	0.0	0.0
MILKFC	1.0	1.0	1.0	1.0	1.0	1.0
MINIMUM MILKFC	1.0	1.0	1.0	0.0	0.0	0.0
MINIMUM MILKFC	1.0	1.0	1.0	1.0	1.0	1.0
MINIMUM MILKFC days 1-14	1.0	1.0	1.0	0.0	0.0	0.0
MINIMUM MILKFC	1.0	1.0	1.0	0.0	0.0	0.0
MINIMUM MILKFC	1.0	1.0	1.0	1.0	1.0	1.0
MINIMUM MILKFC	0.0	0.0	0.0	1.0	1.0	1.0
MINIMUM MILKFC days 15-35	0.0	0.0	0.0	0.0	0.0	0.0
TRUE MILKFC	1.0	1.0	1.0	1.0	1.0	1.0
POTENTIAL MILKYEILD	3.1	3.2	3.1	0.3	0.3	0.2
ACTUAL MILKYEILD1	3.1	3.1	3.0	0.3	0.3	0.2
4 WEEK LOCATOR	0.0	0.0	0.0	1.0	1.0	1.0
4 WEEK LOCATOR	1.0	1.0	1.0	0.0	0.0	0.0
LOCATOR	1	1	1	1	1	1
LOCATOR2	1	1	1	1	1	1
4 WEEK LOCATOR	5.00	5.00	5.00	5.00	5.00	5.00
YEILD1	3.1	3.1	3.0	0.3	0.3	0.2
YEILD2	3.1	3.1	3.0	0.3	0.3	0.2
YIELD2	0.0	0.0	0.0	0.0	0.0	0.0
YEILD3	0.0	0.0	0.0	0.3	0.3	0.2
TRUE MILKYEILD	3.10	3.14	3.03	0.29	0.25	0.22
TOTAL/PERIOD	9.29	15.68	15.17	1.46	1.26	1.09
NEL	22.9	23.2	22.4	2.2	1.9	1.6
NEL	14.9	15.1	14.6	1.4	1.2	1.0
MYEILD	3.1	3.1	3.0	0.3	0.3	0.2
NEL2	22.9	23.2	22.4	2.2	1.9	1.6
NEL2	14.9	15.1	14.6	1.4	1.2	1.0
MPL	8.0	8.1	7.8	0.8	0.7	0.6
MEI	27.6	27.6	27.6	18.1	18.1	18.0
MEM	12.3	12.1	12.0	11.4	11.4	11.5
MEPI	15.3	15.5	15.6	6.7	6.6	6.5
DIFF	-4.9	-5.0	-4.4	3.0	3.1	3.2
MEF	0.0	0.0	0.0	4.5	4.8	4.9
ERI	-5.8	-5.9	-5.3	3.0	3.1	3.2
ER2	0.0	0.0	0.0	0.0	0.0	0.0
TRUE ER	-5.8	-5.9	-5.3	3.0	3.1	3.2

INTAKE FUNCTIONS

STOCKINGRATE/PERIOD	10.0	10.0	10.0	10.0	10.0	10.0
LSIMIK	1.10	1.31	1.48	1.08	1.07	1.06
SRS	2.50	2.50	2.50	2.50	2.50	2.50
PTWIN	2	2	2	2	2	2
SHFAC	-1.63	-1.63	-1.63	-1.63	-1.63	-1.63
SHFFAC	0.00	0.00	0.00	0.00	0.00	0.00
SHFAC	0.00	0.00	0.00	0.00	0.00	0.00
MEAN AIR TEMP	9.0	9.0	9.0	9.0	9.0	9.0
MEAN AIR TEMP	10.0	10.0	10.0	10.0	10.0	10.0
MEAN AIR TEMP 3	10.0	10.0	10.0	10.0	10.0	10.0
SHFAC	0.00	0.00	0.00	0.00	0.00	0.00
TRUE SHFAC	1.00	1.00	1.00	1.00	1.00	1.00
INTKFC	1.10	1.31	1.48	1.08	1.07	1.06
FLEECE-FREE EWE LW	50.0	50.0	50.0	50.0	50.0	50.0
VOLMAX	3.60	3.60	3.60	3.60	3.60	3.60
SLOPE	0.63	0.63	0.63	0.63	0.63	0.63
INTERCEPT	-3.37	-3.37	-3.37	-3.37	-3.37	-3.37
VOLIT	3.79	3.79	3.79	3.60	3.60	3.60
VOLIT2	3.60	3.60	3.60	3.60	3.60	3.60
WW	6.38	5.48	4.56	6.82	7.27	7.73
BCOND	0.87	0.88	0.90	0.86	0.85	0.84
VOLIT3	3.12	3.19	3.26	3.08	3.05	3.01
VOLIT4	0.03	0.04	0.05	0.03	0.03	0.03
POTINT EWE	1.94	2.32	2.63	1.89	1.86	1.84
LAMVOL	0.0	0.0	0.0	2.4	2.5	2.6
VOLAM	5.3	5.3	5.3	5.1	5.1	5.1
OFAC	1.0	1.0	1.0	0.9	0.9	0.9
LAMVOL2	0.00	0.00	0.00	2.22	2.31	2.39
POTGRN	1.9	2.3	2.6	4.1	4.2	4.2
SRIR	0.0	0.0	0.0	0.0	0.0	0.0
PREG	1050	1050	1050	1400	1400	1400
TRESG	1050	1050	1050	1400	1400	1400
IS	1.3	1.6	1.8	3.7	3.7	3.8
IS2	3.2	3.9	4.4	9.2	9.3	9.4
TRESG	1046.8	1046.1	1045.6	1390.8	1390.7	1390.6
OSI	3.2	3.9	4.4	9.2	9.3	9.4
MULTVI	0.7	0.7	0.7	0.9	0.9	0.9
AVERAGE EWE INTAKE	1.30	1.56	1.76	1.69	1.66	1.64
EWE INTAKE/PERIOD			1.58			1.66

LAMB INTAKE & GROWTH

LAMB BIRTHWEIGHT	4.3	4.3	4.3	4.3	4.3	4.3
FLEECE-FREE LW	4.0	4.0	4.0	4.0	4.0	4.0
INITIAL FLEECEWEIGHT	0.3	0.3	0.3	0.3	0.3	0.3
INITIAL LAMB LW	4.29	6.35	8.02	24.10	24.90	25.65
INITIAL LAMB FLEECEWEIGHT	0.25	0.28	0.32	1.34	1.41	1.49
INITIAL LAMB FLEECE-FREE LW	4.04	6.07	7.70	22.77	23.49	24.16
BODYWEIGHT GAIN (gm/d)	405	327	244	145	135	126
LW GAIN (gm/d)	430	346	259	154	143	134
WOOL GROWTHRATE (gm/d)	7	7	7	15	15	15
FINAL LW	6.4	8.0	9.3	24.9	25.7	26.4
FINAL FLEECEWEIGHT	0.3	0.3	0.4	1.4	1.5	1.6
FINAL FLEECE-FREE LW	6.1	7.7	8.9	23.5	24.2	24.8
MDMI	0.3	0.3	0.3	0.0	0.0	0.0
PERMK	70.9	47.8	36.5	1.2	1.0	0.8
DAY OF LACTATION	3	8	13	108	113	118
SLOPE	-0.15	-0.43	-1.22	-1.80	-1.80	-1.80
INTERCEPT	5.50	16.50	39.00	55.00	55.00	55.00
PHDMI	0.0	0.0	0.0	52.9	53.2	53.5
PHDMI2	0.0	0.0	0.0	1.2	1.3	1.3
HDMI	0.0	0.0	0.0	1.1	1.2	1.2
HDMI2	0.00	0.00	0.00	1.01	1.01	1.01
DM INTAKE/PERIOD			0.00			1.01
MMEI				11.10	11.10	11.10
MMEI	7.1	7.2	6.9	0.7	0.6	0.5
IMEI	7.1	7.2	6.9	11.8	11.7	11.6
PHMEI	0.0	0.0	0.0	0.9	1.0	1.0
IMEI	7.1	7.2	6.9	11.8	11.7	11.6
NEW (wool)	114	118	117	255	257	259
LAMB AGE (years)	0.01	0.02	0.04	0.30	0.31	0.32
MEI	7.0	7.0	6.8	11.5	11.4	11.3
FMP	2.0	2.7	3.1	5.2	5.3	5.4
MEM	2.7	3.7	4.3	7.2	7.3	7.4
ADMNT	1.0	1.0	1.0	1.0	1.0	1.0
ADMNT2	1.0	1.0	1.0	1.0	1.0	1.0
MEM2	2.7	3.7	4.3	7.2	7.3	7.4
ER	3.2	2.6	2.0	2.1	2.0	1.9
EVG	8.0	8.0	8.0	14.7	15.0	15.4

Ewe herbage ME intake (TMEI) is partitioned into wool growth, milk production and liveweight gain (or loss). If insufficient energy is available for maintenance, ewe liveweight is catabolised to meet the energy deficit. If ewe ME intake is insufficient to meet both the production processes and maintenance requirements, milk yield is reduced. The size of the reduction is dependent on the stage of lactation, the energy deficit and the liveweight of the ewe.

In the case of the lamb, TMEI is a combination of herbage ME and milk ME intake. This is partitioned off first to wool production, secondly to maintenance, and finally to liveweight gain. It is assumed that all the milk produced by the ewe is consumed by the lamb and that in the case of twin lambs, milk is shared equally.

A large part of the model is taken up with formulae for estimating ewe and lamb intake under continuous grazing. Ewe and lamb intake is dependent on stocking rate, ewe and lamb liveweight, lamb age, shearing date, mean air temperature post-shearing, green pasture cover, and pasture quality. This component of the model is only functional when it is linked to the pasture sub-model.

The model, due to its size, requires 1.5 hours to run on its own, and three hours if it is linked to the pasture sub-model.

4.1.6 A Comparison of Simulation Generated Wool Production With Actual Levels of Wool Production.

To obtain some feel for the validity of the animal models, the model of the replacement dry sheep was used to simulate the liveweight profile of ewe hoggets from Massey University's Tuapaka hill country unit and Riverside farm.

The initial liveweight for the ewe lamb on January 1st was entered into the model. The ME intake of the ewe hogget was manipulated to generate the actual monthly liveweight profile of the ewe hogget from January, until the end of September (Table 4.5). The model simulated the wool production for the period January to the end of September when the hoggets were shorn. This was then compared to the actual levels of production achieved on the two farms (Table 4.5).

The model over-estimated wool production for the Perendale breed and where animals had a major animal health problem. For example, in 1986 when the Tuapaka ewe hoggets had a viral pneumonia problem - reflected in the poor liveweight gains - the model over-estimated wool production by 0.9 kg/HEAD. Similarly in 1985, the Riverside ewe hoggets had scabby mouth in April, and lost liveweight. In this case the model over-estimated summer wool production by 1.75 kg. However, for the period May to September the model predicted 2.6 kg of wool production, and the actual clip was 2.8 kg. This preliminary validation suggests that the model simulates wool production with reasonable accuracy for Romney ewe hoggets that do not suffer from serious animal health problems.

Table 4.5 A Comparison of Simulation Generated Wool Production and Actual Wool Production on Massey University's Tuapaka Hill Unit and Riverside Farm.

Liveweight Profile (kg)					
	Tuapaka			Riverside	
Breed Year Month	Perendale 1982/83	Romney 1984/85	Romney 1985/86	Romney 1982/83	Romney 1984/85
January	27.7	24.8	25.2	28.5	26.5
February	30.0	28.3	26.8	29.5	29.0
March	31.5	30.1	27.8	30.0	30.5
April	32.5	30.3	28.7	30.0	28.5
May	33.8	32.7	29.8	34.0	32.0
June	34.9	33.1	30.8	36.5	34.0
July	36.7	34.9	31.5	37.0	38.0
August	40.3	38.1	32.8	38.5	40.0
September	45.9	41.6	33.2	40.5	43.0
Fleeceweight:					
Actual	3.9	3.0	2.0*	2.9	2.8*
Simulated	3.6	3.3	2.9	2.8	4.5
			May-Sep:		
(Perendales)		(2.2)	Actual		2.8
			Predicted		2.6

*Animal Health Problems

4.2 The Pasture Model.

The main objectives of building a pasture model were -

1) To demonstrate the effect of pasture cover on pasture growth rates.

2) To demonstrate the effect of pasture cover on pasture quality.

3) To demonstrate the effect of pasture cover on ewe and lamb intake and subsequent performance by linking the pasture model to the lactation model.

The output of the more detailed pasture simulation model could then be compared with that from the initial feed budgeting approach. A number of difficulties were confronted in using McCall's pasture model relationships. First, the model required the input of a range of climatic data on a daily basis. The personal computer did not have the storage capacity to handle this amount of data. Secondly, to generate an identical set of average monthly growth rates to that used in the initial feed budget (Table 2.1) using daily climatic data would be extremely difficult, even if the storage problem could be overcome.

The alternative was to generate a set of potential monthly pasture growth rates based on average monthly climatic data available at Tuapaka. These could then be linked to McCall's functions that described the effect of pasture cover on pasture growth rate and pasture quality. To use these functions both green pasture growth rates and net dead matter accumulation rates had to be generated.

4.2.1 The Tuapaka Pasture Growth Model.

The Generation of Potential Pasture Growth Rates: The initial requirement for the construction of a pasture model specific to the Tuapaka hill country unit was to correlate pasture growth rates with climatic data to allow the generation of potential pasture growth rates that could then be linked into McCall's pasture functions. The author had collected pasture growth rate data on a fortnightly basis for the last four years. This measure included both green pasture growth and dead matter components as shown in Equations 4.1 and 4.2.

$$P.G.R. = G.P.G.R. + NDMA \qquad \text{Eqn...4.1}$$

$$NDMA = P.S.R. - DM.D.R.R. \qquad \text{Eqn...4.2}$$

P.G.R.	= Pasture growth rate	(kg DM/HA/DAY)
G.P.G.R.	= Green pasture growth rate	(kg DM/HA/DAY)
NDMA	= Net dead matter accumulation rate	(kg DM/HA/DAY)
P.S.R.	= Pasture senescence rate	(kg DM/HA/DAY)
DM.D.R.R.	= Dead matter decay and removal rate	(kg DM/HA/DAY)

The Tuapaka average monthly pasture growth rates were obtained from a range of green pasture cover levels. These were converted to potential pasture growth rates (i.e. when green pasture cover was non-limiting) by scaling according to the average level of green pasture cover at the time of measurement using McCall's green pasture cover functions. (These simulated the effect of different levels of green pasture cover on pasture growth rate).

Effect of Climatic Variables on Pasture Growth Rates at Tuapaka: During the same period that pasture growth rates were collected soil temperature data (10 cm depth) and soil moisture data (75 mm depth) had been recorded on a fortnightly basis. Rainfall data has been recorded automatically on a daily basis, and sunshine hours are recorded on a daily basis at the D.S.I.R. weather station 20 km south of Tuapaka during the same period. Multiple regression analysis, using soil moisture, soil temperature, rainfall and sunshine hours as the independent variables and potential pasture growth rate as the dependent variable, was carried out on the data set (Table 4.6). Pasture growth rates were thus related to the climatic variables in each of the four seasons throughout the year (autumn, winter, spring, summer).

Table 4.6: Multiple Regression Analysis of Pasture Growth Rates and Climatic Data.

Months	Jan-Feb	May & June	Jul-Sept	Oct-Dec
Predictor Variables				
Soil Temperature *	1.414	3.586	2.188	8.096
Soil Moisture +	1.269	-0.396	0.138	8.819
Rainfall #	-0.008	0.0710	-0.008	0.968
Sunshine Hours x	-1.080	-0.00334	0.038	0.590
Intercept	-19.5	-15.7	13.1	-521.2
r^2	0.93	0.99	0.940	0.997
S.D.	2.87	1.10	1.30	0.69

* Monthly average (10cm, 3.00pm, ^{o}C)
+ Monthly average (7.5cm % moisture)
# Monthly total (mm)
x Monthly total (hours)

The results indicate that potential pasture growth rates are highly correlated ($r^2 \geq 0.93$) with the four climatic variables and show that these variables which were included in McCall's pasture growth functions, could be used with confidence to predict pasture growth rates.

The Dead Matter Component of the Sward: In McCall's model, dead matter accumulated as a result of pasture senescence, which in turn was related to green pasture cover and soil moisture content. The removal of dead herbage was a function of earthworm activity and microbial decay.

The data collected at Tuapaka for the dead matter component of the sward was too crude to differentiate between senescence, decay, and earthworm activity. For this reason, net dead matter accumulation rates only, were used in the pasture model.

McCall's model suggested that the dead matter content of the sward would increase through the spring due to the death and senescence of reproductive tillers, and that this would be accentuated by low soil moisture levels in late spring and summer. Through the autumn period dead matter levels would not fall appreciably until the autumn rains, when microbial decay and earthworm activity reduced dead matter levels through the late autumn and winter months. The data collected at Tuapaka followed this trend.

Two regression equations that related net dead herbage accumulation rate to average green pasture cover and to soil moisture content were derived from the Tuapaka data for the period September to March (Figure 4.1). Data collected at Tuapaka for the period April to June showed that the rate of dead matter removal was an average of 1.0% of the initial mass of dead matter (kg DM/HA) at the start of each month. This figure was used for the period April to August. Within year changes in the dead matter component of the Tuapaka pasture model were therefore described by three equations.

Pasture Quality: The pasture model uses the relationships derived by McCall to calculate the quality of the pasture sward and of the diet consumed by the grazing animal. Potential monthly sward digestibility is based on Ullyatt's data (1978) for a browntop dominant sward. Green digestibility is inversely related to green pasture cover. Average sward digestibility is calculated from the ratio of dead:green, with the digestibility of dead herbage assumed to be 33% .

The digestibility of diet is related to average sward digestibility. The gross energy content of the sward was assumed to be 18.4 MJME/kg DM and the conversion efficiency of digestible energy to metabolisable energy was assumed to be 81% . Using these relationships the model can calculate the ME content of the herbage consumed by the grazing animal.

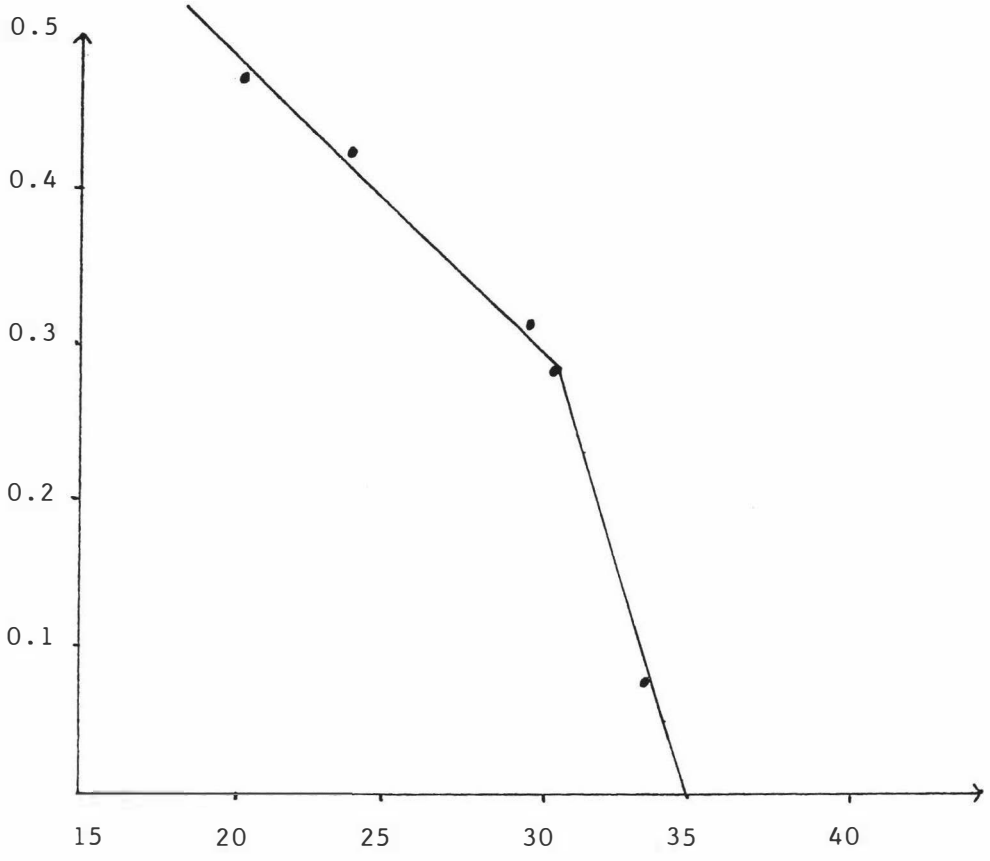
The Pasture Model Structure: The pasture sub-model format is based on that used to develop monthly feed budget models (Table 4.7). Input includes farm area, green pasture cover and dead pasture cover (at 1st January), average daily animal intake for each month, and monthly climatic data. From this, the model calculates the rate of green pasture growth, based on the actual pasture growth rate, and the rate of dead matter accumulation or removal (Equation 4.3).

$$G.P.G.R. = A.P.G.R. - DM.A.R. + DM.R.R. \quad \text{Eqn...4.3}$$

G.P.G.R.	= Green pasture growth rate	(kg DM/HA/DAY)
A.P.G.R.	= Actual pasture growth rate	(kg DM/HA/DAY)
DM.A.R.	= Dead matter accumulation rate	(kg DM/HA/DAY)
DM.R.R.	= Dead matter removal rate	(kg DM/HA/DAY)

The green pasture growth rates are then transferred into the summary sheet at the top of the model.

Figure 4.1 The Rate of Net Dead Herbage Accumulation as a Percentage of Average Green Cover Versus Soil Moisture Percentage at Tuapaka for the Period September to March.



Functions

Soil Moisture $< 31\%$ $Y = 0.8668 - 0.01883X$

Soil Moisture $\geq 31\%$ $Y = 2.528 - 0.0725X$

Table 4.7

The Tuapaka Pasture Growth Model.

Tuapaka Pasture Growth Model
==========
D.L.GRAY

Run Name 132% Lambing 9.0 s.u./ha
Farm Area 326

Initial Cover (kgDM/ha) 1800
Green Cover 1400
Dead Cover 400

Months	Jan	Feb	Oct	Nov	Dec
Green Growthrate (kgDM/ha/d)	14	11	17	23	15
Animal Intake (kgDM/ha/d)	20.4	21.3	19.9	23.1	26.2
Supplements	0	0	0	0	0
Pasture Quality (MJME/kgDM)	10.5	10.0	11.5	11.3	10.8
Consumption (MJME/ha/d)	214	212	229	261	283
Supplements (kgDM)	0				
Feed Value (MJME/kgDM)	0				
Difference/day	-7	-10	-3	0	-11
Observed Growthrate	20	16	20	24	27
Final Pasture Cover	1797	1643	1485	1514	1551
Final Green Cover	1193	910	1350	1350	1350
Final Dead Cover	605	732	135	164	201
Average Green Cover	1296	1051	1350	1350	1350
Percentage Green	66	55	91	89	87
Percentage Dead	34	45	9	11	13

Pasture model Functions.
==========

Month	CLIMATE Soil Temp °C	Soil Moist %	Rainfall mm	Sunshine hrs	Pasture Growth Potential kgDM/ha/d	Vegetative	Reproductive Setstocked	Reproductive Rotated	RATIO % Reprod.	Spring SS Actual P.G.R	Spring Rot Actual P.G.R
Jan	17.5	19.0	30	220	21	20	16	17	0	20	20
Feb	17.5	23.0	87	195	17	16			0	16	16
Mar	16.5	25.0	80	160	23	19			0	19	19
Apr	13.5	24.1	64	142	18	13			0	13	13
May	10.5	34.4	110	72	13	8			0	8	8
Jun	9.2	33.5	95	81	9	5			0	5	5
Jul	7.5	35.4	124	80	11	6			0	6	6
Aug	8.7	37.0	165	81	14	8			0	8	8
Sept	10.0	35.2	101	133	19	11	8	11	0	11	11
Oct	11.4	34.4	84	119	39	23	17	20	100	17	20
Nov	14.3	31.0	85	150	55	31	24	26	100	24	26
Dec	15.1	27.8	76	180	37	21	16	20	100	16	20

Dead Matter Functions.
==========

Month	Soil Moisture (%)	Decay Rate kgDM/ha/d	Deathrate kgDM/ha/d	GAIN/Month	Gain/day
Jan	19.0	3.8	0.51	205	6.6
Feb	23.0	5.7	0.43	128	4.6
Mar	25.0	6.9	0.40	96	3.1
Apr	24.1	8.3	0.41	-249	-8.3
May	34.4	5.8	0.03	-180	-5.8
Jun	33.5	4.0	0.10	-120	-4.0
Jul	35.4	2.8	-0.04	-87	-2.8
Aug	37.0	1.9	-0.15	-60	-1.9
Sept	35.2	1.5	-0.02	-3	-0.1
Oct	34.4	1.2	0.03	4	0.1
Nov	31.0	1.3	0.28	29	1.0
Dec	27.8	1.5	0.34	37	1.2

Pasture Quality Functions.
==========

Month	Pot. Dig.	GDM Digest	True Dig.	ASD Dig.	DDS Dig.	TRUE DDS
Jan	70.4	71.5	70.4	62.1	73.5	70.4
Feb	66.8	66.8	66.8	55.4	68.8	66.8
Mar	65.7	65.7	65.7	51.1	65.8	65.7
Apr	69.3	69.3	69.3	49.0	64.3	64.3
May	72.1	72.1	72.1	50.4	65.3	65.3
Jun	75.7	75.7	75.7	52.9	67.0	67.0
Jul	79.0	79.0	79.0	58.6	71.0	71.0
Aug	80.5	80.5	80.5	63.6	74.5	74.5
Sept	80.5	80.5	80.5	67.4	77.2	77.2
Oct	80.0	85.1	80.0	67.2	77.0	77.0
Nov	77.5	82.4	77.5	65.1	75.6	75.6
Dec	73.2	77.8	73.2	60.4	72.3	72.3

An average daily ME intake for each monthly period for stock classes is entered into the summary sheet. This is converted to dry matter intake on a per hectare basis, by dividing by the relevant ME content of the feed. It is assumed that the stock will only consume green dry matter, hence animal intake (kg DM/HA/DAY) is subtracted from the green pasture growth rate, to produce the net accumulation/loss per day. This value is multiplied by the number of days in the month and added to the initial green pasture cover level to calculate the end of month green pasture cover. Green pasture cover during the month is averaged and used to calculate pasture growth rates, pasture quality, and dead matter accumulation. Similarly, the final dead portion of pasture cover is calculated by the model. It adds the net change in dead matter during the month - calculated by the "Dead Matter Function" - in the same manner as the green component described earlier. The derived average monthly level of dead herbage is also used in the calculation of pasture quality. Pasture cover at the end of each period is the sum of the dead and green components.

The "observed" pasture growth rate (i.e. that which actually describes the change in pasture cover between measurements) is derived by calculating the daily change in pasture cover and adding to this the average daily animal intake for that month (Equation 4.4).

$$OPGR = [(FPC - IPC)/n] + ADI \qquad \text{Eqn...4.4}$$

OPGR =	Observed pasture growth rate	(kg DM/HA/DAY)
FPC =	Final pasture cover	(kg DM/HA)
IPC =	Initial pasture cover	(kg DM/HA)
n =	Days per period	(DAYS)
ADI =	Average daily animal intake	(kg DM/HA/DAY)

The pasture quality and average green pasture cover output from the pasture model can be linked to the lactation model to provide pasture data to calculate ewe and lamb intakes, which in turn feed back and modify pasture cover. A number of iterations are required before a final solution is reached.

The pasture model requires approximately 30 minutes to run. The effect of different levels of pasture cover on pasture growth rate and pasture quality can be readily demonstrated. However, due to the nature of the data used to construct some of the components of this model, the output must be viewed with caution.

4.2.2 Comparison Between Actual Pasture Growth Rates and Model Simulated Pasture Production.

The pasture model was run for the 1984 year - the only year in which a full pasture production data set was available for Tuapaka. The initial green/dead pasture cover components and the monthly climatic data for the 1984 year were entered into the model. Animal intake per hectare was manipulated to produce a pattern of pasture cover identical to that recorded in 1984. The simulated pasture growth rates were then compared to the actual pasture growth rates recorded in 1984 (Figure 4.2). The simulation model produces pasture growth rates that closely match actual pasture growth rates for the 1984 year (r^2 = 0.95). Although, a full comparison could only be made for the one year, this result provides initial confidence to use the pasture model to investigate different sheep farming systems.

4.3 Summary.

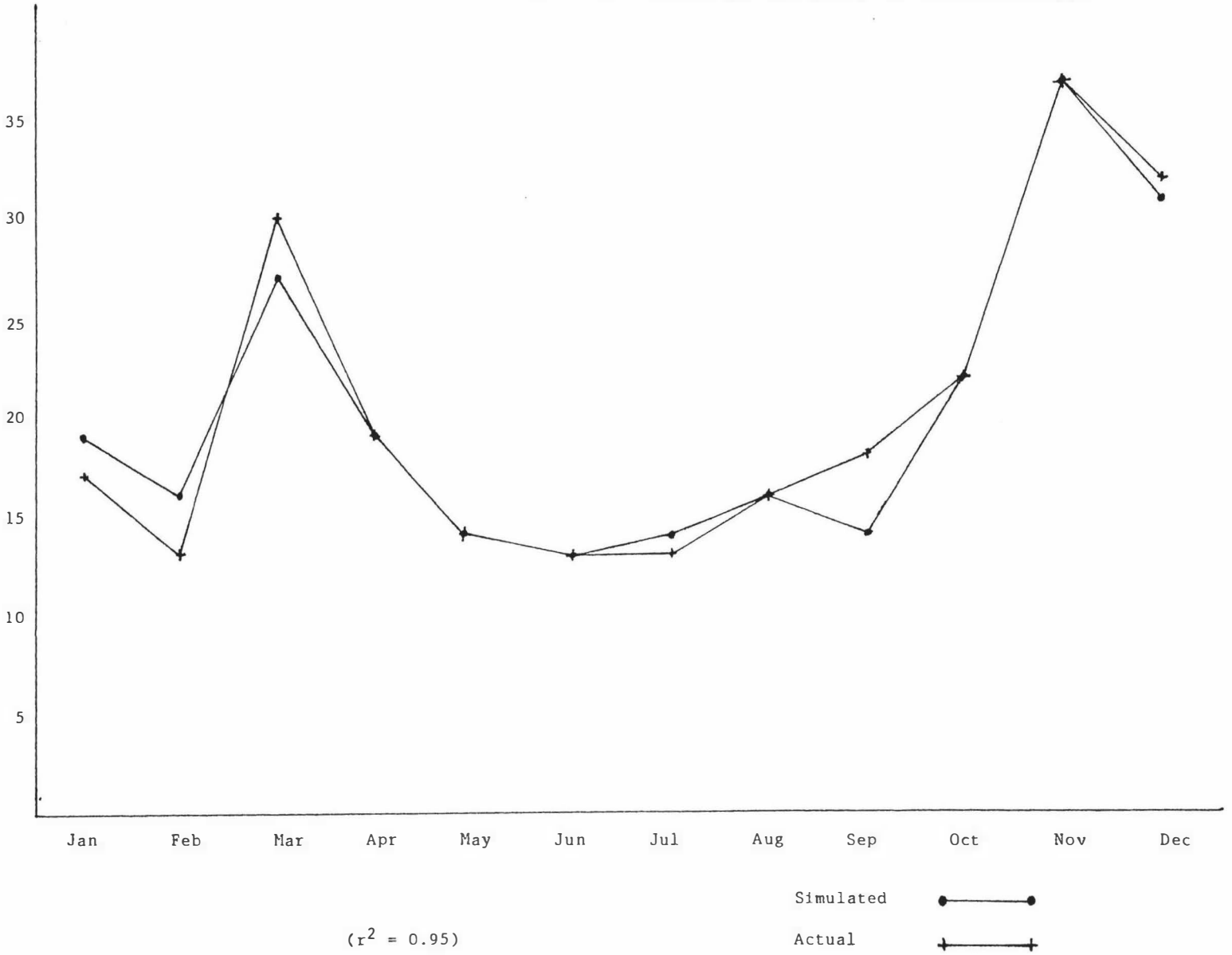
The construction of animal and pasture simulation models on spreadsheets can be achieved relatively easily. The animal sub-models derived from McCall's mathematical relationships are simple to use, and the output is well presented and easily understood. Initial tests on the validation of the wool production functions suggests that the models produce feasible results for Romney ewe hoggets with no major animal health problems.

A range of animal intakes can be entered, and output in terms of animal performance is produced. The output from these models can be compared with the results of the initial feed budgeting analysis. The models could be useful for investigating "what if" questions, such as the effect of under-feeding on a pregnant or lactating ewe. They could also be rebuilt to produce data on animal feed requirements for any given level of animal performance. This would provide a highly flexible computerised version of the M.A.F. feed tables, where animal liveweight and the required levels of performance are entered, and animal requirements are produced as output.

The pasture model has been constructed to demonstrate the effect of pasture cover on pasture growth rate and pasture quality using data collected fortnightly at Tuapaka. The paucity of data from which some relationships were derived means that the results generated should be treated with some caution - although they do simulate the data collected at Tuapaka by the author during 1984 with the required realism. However, further data needs to be collected over a number of years to fully validate the model.

The pasture model can be used to investigate the effect of different patterns of feed demand on pasture growth rates and pasture quality. It can also be linked to the animal models to investigate the effect of pasture cover and pasture quality on animal intake and subsequent performance.

Figure 4.2 A Plot of Actual Versus Simulated Pasture Growth Rates (kg DM/HA/DAY) for 1984 at Tuapaka.



(r^2 = 0.95)

The major deficiency with these sub-models is the time taken to complete a run. Run times from 15 minutes up to 3 hours do not allow the interaction between the model and the operator that was hoped for. The models were built on Microsofts' Multiplan spreadsheet program. More recently developed larger spreadsheets, such as Lotus Symphony (8192 rows deep and 256 columns wide) offer much greater flexibility and would run the models much faster (Journeaux, 1987).

Chapter Five

A Comparison of Simulation Modelling Output With Simple Feed Budgeting Techniques.

5.0 Introduction.

A number of areas where the feed budgeting approach may have limitations were identified in Chapter Three. It was concluded that these inadequacies could be quantified through the use of simulation modelling. The construction of models for this purpose was described in Chapter Four. Due to constraints placed on the size of the study, only two of the issues raised in Chapter Three will be addressed. These concern, first, the lack of objective data available from the feed tables on the expected level of wool production for a given level of feed intake, and secondly, the inability of the feed budgeting approach to take into account the interaction between pasture cover, pasture growth rate, pasture quality and animal intake, and the effects that these have on levels of animal performance. In this chapter how the models were used to address these issues, the results obtained from the simulation runs and a comparison of these with the initial feed budget results are discussed.

5.1 Wool Production Analysis.

5.1.1 Methodology.

The objective of this part of the study was to compare the output of wool production obtained from simulation modelling with that used in the analysis in Chapter Two. The simulation models used in this study consisted of -

1) Models of a twin and single rearing ewes, divided into three time periods i.e. weaning to tupping, the period of gestation, and the period of lactation.

2) A ewe hogget model for the period from weaning to two tooth shearing, where the animal reaches a post-shearing two tooth liveweight of either 50 kg or 60 kg.

3) A ram lamb modelled for the period from weaning to slaughter.

4) A ewe lamb modelled for the period from weaning to slaughter.

For each stock class the initial liveweight of the animal was entered into the simulation model, along with an estimate of the average green pasture cover for each month, the pasture quality in MJME/kg DM and the feed requirements used in the feed budget analysis in Chapter Two. From this information the model derived wool growth rates. This was performed for each stock class within the 100% and 132% flocks.

Details of liveweight, liveweight gain, the products of gestation, and milk yield were also produced, but this has not been analysed in this study.

5.1.2 Results and Discussion.

The physical wool production for each class of stock is summarised in Table 5.1. The level of wool production for the triplet rearing ewe was extrapolated from the conversion efficiency of wool production from energy (MJME) intake on an annual basis for twin and single rearing ewes. The single rearing ewe had a conversion efficiency of 1.45 MJME consumed per gram of wool produced, compared to 1.72 MJME consumed per gram of wool produced for a twin rearing ewe.

The percentage deviation between the estimates is summarised in Table 5.1 . This demonstrates that the original subjective estimates on wool production (compared with the simulated data), varied from an 8.9% over-estimation up to a 50% under-estimation.

Table 5.1 A Comparison of Wool Production (kg) Generated by Simulation With Estimates Used in the Simple Feed Budget Analysis. Figures in Brackets are the Deviation (%) Between the Estimates.

	100% Flock			132% Flock		
Wool Clip	Estimate	Simulated	Difference	Estimate	Simulated	Difference
Triplet Ewe	---	---		4.5	5.0**	(11.1)
Twin Ewe	4.5	4.6	(2.2)	4.5	4.6	(2.2)
Single Ewe	4.5	4.1	(-8.9)	4.5	4.1	(-8.9)
Lamb	1.0	1.1	(13.0)	0.8	1.0	(25.0)
Hogget	2.8	3.4	(21.4)	3.3	3.9	(18.2)
Two Tooth	2.0	3.0	(50.0)	2.5	3.6	(44.0)
Crutching	0.2	0.2		0.2	0.2	
Average Ewe Clip +	4.5	4.3	(-4.7)	4.5	4.8	(7.0)

\+ This includes 0.2kg crutchings.

** The fleece weight of the triplet rearing ewe was extrapolated from data on the feed:wool conversion efficiency of the single and twin rearing ewes, because McCalls model does not contain the mathematical relationships for a triplet rearing ewe.

The raw simulation data was then used to calculate the flock output in the same format as for the feed budget model (Section 2.5.1). Wool production at each ewe shearing was based on the proportion of triplet bearing, twin bearing and single bearing ewes in the 132% and 100% flocks, and the wool production for each respective stock class. This showed that the 100% flock ewes would clip 4.1 kg (4.3 kg less 0.2 kg crutchings) and the 132% flock ewes would clip 4.6 kg (4.8 kg less 0.2 kg crutchings).

The physical and financial indices for the two levels of performance across three stocking rates using wool production based on subjective assessment and simulation modelling are presented in Table 5.2 . In the case of the 100% flock, wool production was underestimated by 3.8 - 4.3% on a per stock unit basis, and by 3.4 - 3.6% on a per hectare basis. The net effect of this was to increase wool income by 4.0 - 4.7% and the gross margins by 4.7 - 8.7% .

The effect was greater for the 132% flock, where wool production was underestimated by 10.4 - 11.1% per stock unit, and by 9.4 - 10.2% on a per hectare basis. The net effect of this was to increase wool income by 8.6 - 10.1% and the gross margins by 9.7 - 12.3% .

The under-estimation of wool production had no effect on either the between flock, or the within flock rankings, in terms of profitability. However, it did increase the profit margin between the 132% flock and the 100% flock at the high and medium stocking rate options from 2.6 - 7.5% to 6.1 - 10.2% respectively, in favour of the high performance flock. For the low stocking rate option the profit margin between the 132% flock and the 100% flock increased from 16.5% to 20.4% .

In summary then, although using the simulated wool production values did not change the original rankings of the flocks, it did indicate that the profitability of the high performance flock was greater than originally estimated.

Table 5.2 A Comparison of the Physical and Financial Indices Based On Wool Production Generated by Simulation and the Estimates Used in the Feed Budget Analysis.

100% Flock						
Stocking Rate	12.5 S.U./HA		11.5 S.U./HA		10.5 S.U./HA	
Indices	Estimated	Simulated	Estimated	Simulated	Estimated	Simulated
Wool (kg/S.S.U)	4.6	4.8	5.0	5.2	5.2	5.4
(kg/HA)	58	60	58	60	55	57
Wool Income/S.U.	$13.88	$14.47	$15.25	$15.93	$15.89	$16.62
Wool Income/HA	$174	$181	$175	$183	$167	$175
Total Income/S.U.	$23.30	$24.21	$27.24	$28.78	$28.30	$30.26
Total Income/HA	$291	$303	$313	$331	$297	$318
Gross Margin/S.U.	$18.42	$19.31	$21.49	$23.02	$21.90	$23.84
Gross Margin/HA	$230	$241	$247	$265	$230	$250

132% Flock						
Stocking Rate	11.0 S.U./HA		10.0 S.U./HA		9.0 S.U./HA	
Indices	Estimated	Simulated	Estimated	Simulated	Estimated	Simulated
Wool (kg/S.S.U)	4.8	5.3	5.2	5.7	5.4	6.0
(kg/HA)	53	58	52	57	49	54
Wool Income/S.U.	$14.70	$15.98	$15.77	$17.32	$16.53	$18.26
Wool Income/HA	$162	$176	$158	$173	$149	$164
Total Income/S.U.	$26.60	$28.72	$32.17	$35.28	$36.64	$40.39
Total Income/HA	$293	$316	$322	$353	$330	$363
Gross Margin/S.U.	$21.48	$23.56	$26.15	$29.22	$29.79	$33.49
Gross Margin/HA	$236	$259	$262	$292	$268	$301

5.2 The Interaction Between Pasture Parameters and Animal Performance.

5.2.1 Methodology.

The capacity of the spreadsheet program was insufficient to enable the full range of stock classes on hand through the spring to be simulated as a whole farm. One stock class was therefore selected and simulated over the spring period to gauge the impact of these interactions on model output. The single rearing ewe was used for this purpose, as this stock class best approximates effects of pasture cover and stocking rate on the performance obtained from the 100% lambing flock over the period of lactation.

The model was set-up to run the same number of single bearing/single rearing ewes as specified in the original feed budget analysis. The area allocated to this mob, and hence the stocking rate was based on the ratio of the feed consumed by the single rearing ewe mob, relative to the total feed consumed by all stock classes through the spring period. This was calculated to be 129 HA and gave stocking rates on this area of 10.0, 10.9, and 11.9 S.U./HA for each of the original whole farm stocking rate options (10.5, 11.5, and 12.5 S.U./HA respectively). (The difference between these figures is explained by ewe losses, cull ewe sales, and the relatively higher intakes of the proportion of twin rearing ewes in the flock).

Ewe numbers, shearing date and land area were entered into the model as were ewe liveweight at lambing (50 kg) and lamb birthweight (5.0 kg). The latter were the same as those in the feed budget analysis. The weight of fleece on the ewe at lambing was assumed to be 4.01 kg and 0.25 kg for the lamb. These values were obtained from the wool production model (Section 5.2).

Pasture cover on September 1st was entered for each stocking rate option based on the data obtained from the feed budget analysis. These were 1307 kg DM/HA for the high stocking rate option, 1056 kg DM/HA for the medium stocking rate option, and 805 kg DM/HA for the low stocking rate option. The climatic variables - soil moisture, soil temperature, rainfall, and sunshine hours - were entered to generate pasture growth rates comparable to those used in the feed budgeting analysis. The models were then activated and the simulation model generated the required output.

5.2.2 Results and Discussion.

5.2.2.1 Introduction.

Due to the complex nature of the interactions involved in this analysis, the results and discussion have been split into three sub-sections. The first section concerns the interactions of pasture cover, pasture growth rates, animal intake and stocking rate. The second section is concerned with the effect of the different levels of ewe and lamb intake on animal performance, while pasture quality is the subject of the third section. An overall summary of results and the conclusions drawn from them follows.

5.2.2.2 The Interaction of Pasture Cover, Pasture Growth Rates, Animal Intake, and Stocking Rate.

The pattern of pasture cover for the three stocking rate options is summarised in Table 5.3 . In this section the results will be discussed, for the sake of clarity, mainly in terms of the high and low stocking rate options, as these cover the two extremes in this analysis.

Although the higher stocking rate option has a higher initial pasture cover (1307 kg DM/HA vs 805 kg DM/HA for the low stocking rate) at the start of lactation, the two options achieve similar levels of pasture cover by mid-November (1541 vs 1533 kg DM/HA). By weaning (31st Dec) the pasture cover at the low stocking rate (1995 kg DM/HA) had surpassed that of the high stocking rate (1714 kg DM/HA). The feed budget analysis predicted a similar trend in pasture cover levels, except that all three options would achieve the same pasture cover of 1800 kg DM/HA at weaning.

Table 5.3 The Effect of Stocking Rate and Initial Pasture Cover on the Pattern of Pasture Cover Achieved (kg (DM/HA).

Stocking Rate Option	High	Medium	Low
Period			
Initial Pasture Cover	1307	1056	805
Sept 1-15	1293	1098	887
Sept 16-30	1227	1104	954
Oct 1-15	1291	1204	1092
Oct 16-31	1355	1319	1264
Nov 1-15	1541	1539	1533
Nov 16-30	1719	1765	1823
Dec 1-15	1748	1825	1930
Dec 16-31	1714	1831	1995

The three stocking rates produce almost the same total dry matter over the period lambing to weaning (Table 5.4). For example, the high stocking rate option produces 3689 kg DM/HA, compared to 3661 kg DM/HA for the low stocking rate option. However, the pattern of production (Table 5.5) and the actual half monthly pasture growth rates (Table 5.4) differ.

Thus, the high stocking rate generates pasture growth rates of 19 kg DM/HA/DAY in early lactation, compared to 11 kg DM/HA/DAY for the low stocking rate. However, by mid-lactation (1st-15th Nov) the difference in pasture growth rates is reduced (42 vs 41 kg DM/HA/DAY), and by late December, the low stocking rate option's pasture growth rates (34 kg DM/HA/DAY) exceed those of the high stocking rate (30 kg DM/HA/DAY). These differences in pasture growth rates can be attributed to changes in the levels of green pasture cover through the period of lactation (Table 5.6).

Although all three stocking rate options grow approximately the same amount of dry matter, the medium and low stocking rate options consume 11.1% and 24.6% less dry matter, respectively, than the high stocking rate option (Table 5.4). This effect is due not only to stocking rate, but also because the ewes and lambs of the lower stocking rate options consume less feed per head over the period of lactation (Table 5.4) (i.e. The ewe plus lamb unit of the high stocking rate option consume 276 kg DM/UNIT compared to 248 kg DM/UNIT for the low stocking rate option).

Changes in pasture cover over the period of lactation are a function of the balance between feed supply and feed demand (Table 5.4). Thus, in the first month of lactation feed demand (19 kg DM/HA/DAY), exceeds feed supply (18 kg DM/HA/DAY) for the high stocking rate option: in the low stocking rate option demand (11 kg DM/HA/DAY) is less than feed supply (16 kg DM/HA/DAY). As a result, pasture cover declines (-75 kg DM/HA/MONTH) for the high stocking rate option, but increases (+149 kg DM/HA/MONTH) at the low stocking rate for the first month of lactation. This suggests that greater feed reserves need to be on hand at lambing for the high stocking rate from winter saved pasture or the use of nitrogen. Alternatively, the lambing date could be shifted later.

Feed demand is also a function of ewe and lamb intakes. In early lactation the high stocking rate option has an average ewe plus lamb intake of 1.63 kg DM/UNIT/DAY compared to 1.06 kg DM/UNIT/DAY for the low stocking rate option (Table 5.7). This is primarily due to the higher level of green pasture cover on the high stocking rate area. The combined effect of a lower stocking rate with reduced ewe and lamb intakes (due to low green pasture cover) is to increase pasture cover in early lactation. This is despite the reduced pasture growth rates resulting from the lower levels of green pasture cover.

By mid-lactation the differences in green pasture cover have been reduced (1207 vs 1173 kg DM/HA) and as a result, ewe plus lamb intakes are similar (2.47 vs 2.32 kg DM/UNIT/DAY). By late lactation, the green pasture cover level of the low stocking rate option is considerably higher than the high stocking rate option (1530 vs 1300 kg DM/HA) and the ewe plus lamb unit of the low stocking rate option consume a higher level of dry matter (3.00 vs 2.73 kg DM/UNIT/DAY).

Table 5.4 The Effect of Stocking Rate and Initial Pasture Cover Levels on Feed Supply and Feed Demand.

Stocking Rate Option	High			Medium			Low		
Period:	Supply kg DM/HA/D	Demand kg DM/HA/D	Difference kg DM/HA/D	Supply kg DM/HA/D	Demand kg DM/HA/D	Difference kg DM/HA/D	Supply kg DM/HA/D	Demand kg DM/HA/D	Difference kg DM/HA/D
Sept 1-15	18	19	-1	18	15	3	16	11	5
Sept 16-30	18	23	-5	18	17	1	17	12	5
Oct 1-15	28	24	4	27	20	7	25	16	9
Oct 16-31	29	25	4	28	21	7	27	16	11
Nov 1-15	42	29	13	41	27	14	41	23	18
Nov 16-30	44	32	12	45	30	15	45	26	19
Dec 1-15	33	31	2	34	30	4	35	28	7
Dec 16-31	30	32	-2	32	31	1	34	30	4
Total Supply (kg DM/HA)	3689			3705			3661		
*% Deviation				+0.4%			-0.8%		
Total Demand (kg DM/H.D)		3282			2917			2476	
*% Deviation					-11.1%			-24.6%	
Per head demand (kg DM/HD)		276			268			248	
*% Deviation					-3.0%			-10.2%	

* From High S.R. Option

Table 5.5 The Proportion of Total Feed Supply Produced Over the Period of Lactation for the Three Stocking Rate Options.

Stocking Rate Option	High	Medium	Low
September	14.7%	14.6%	13.5%
October	26.9%	23.0%	22.0%
November	35.0%	34.8%	35.2%
December	26.4%	27.6%	29.3%

Table 5.6 The Effect of the Average Level of Green Pasture Cover (kg DM/HA) On Pasture Growth Rates (P.G.R.) (kg DM/HA/DAY).

Stocking Rate Option	High		Medium		Low	
	Av. Green Pasture Cover	P.G.R.	Av. Green Pasture Cover	P.G.R.	Av. Green Pasture Cover	P.G.R.
Sep 1-15	1145	18	922	18	693	16
Sep 16-30	1094	18	938	18	760	17
Oct 1-15	1077	28	977	27	851	25
Oct 16-31	1119	29	1063	28	987	27
Nov 1-15	1207	42	1195	41	1173	41
Nov 16-30	1335	44	1364	45	1398	45
Dec 1-15	1374	33	1439	34	1526	35
Dec 16-31	1300	30	1397	32	1530	34

Examination of the ewe intakes shows that they follow the same pattern as discussed above (Table 5.8). Low stocking rate ewes achieve the same level of ewe intake (1.8 kg DM/EWE/DAY) as the high stocking rate option in early November, but their lambs do not reach the same level of dry matter intake as their counterparts until early December. Thus, overall the low stocking rate lambs consume less dry matter than the high stocking rate lambs (0.86 vs 0.72 kg DM/LAMB/DAY). This difference in lamb intakes can be attributed to differences in lamb liveweight (- McCall's functions suggest that lamb dry matter intake is particularly sensitive to this parameter). Analysis of lamb liveweights shows that at the end of November the low stocking rate lambs were 3.4 kg lighter than the high stocking rate (Table 5.7).

As the differences in lamb liveweight between the stocking rate options in late lactation declines, the low stocking rate lamb intake exceeds that of the high stocking rate option (1.21 vs 1.16 kg DM/LAMB/DAY), because of the higher green pasture cover (1530 vs 1300 kg DM/HA) and lower stocking rate take effect.

The average half monthly ewe intakes for the three stocking rate options are summarised in Table 5.8. Ewe intake is basically a function of green pasture cover and stocking rate. In early lactation the high stocking rate ewes consume 45% more dry matter (1.6 vs 1.1 kg DM/EWE/DAY) than the low stocking rate option. This can be attributed to the higher levels of green pasture cover (1145 vs 693 kg DM/HA) for the high stocking rate option. It is not until mid-lactation when differences in green pasture cover levels are small that the low stocking rate ewes reach a similar level of intake and then begin to exceed that of the high stocking rate ewes. Ewe intakes across all stocking rates increase from the start of November due to the effects of shearing on intake.

The higher ewe intakes of the low stocking rate option in late lactation compensates to some degree for the low levels of intake in early lactation. As a result only 10% less dry matter is consumed by the low stocking rate ewes over the period of lactation (Table 5.4).

5.2.2.3 The Effect of Ewe and Lamb Intake on Animal Performance.

The effect of pasture cover and stocking rate on ewe intake effects subsequent ewe performance in three ways; liveweight gain (or loss), wool production, and milk yield. These are summarised in Table 5.7 - 5.10. As would be expected the level of liveweight gain or loss is dependent on the level of dry matter intake.

The higher levels of intake achieved by the high stocking rate ewes (1.6 vs 1.1 kg DM/EWE/DAY) in early lactation reduces their rate of liveweight loss (-140 vs -352 gm/DAY for the low stocking rate ewes). The higher intakes of the high stocking rate ewes allows the ewes to reach a positive energy balance much more quickly than the low stocking rate ewes (September 1st vs November 1st). As a result the high stocking rate ewes are 8.4 kg heavier than the low stocking rate ewes post-shearing in mid-November (47.7 vs 39.3 kg).

Table 5.7 The Effect of Average Green Pasture Cover (kg DM/HA) and Lamb Liveweight (kg) on Ewe and Lamb Dry Matter Intakes (kg DM/HD/DAY).

Stocking Rate Option	High				Medium				Low			
Period	Av.Green Pasture Cover	Lamb Liveweight	Lamb Intake	Ewe Intake	Av.Green Pasture Cover	Lamb Liveweight	Lamb Intake	Ewe Intake	Av.Green Pasture Cover	Lamb Liveweight	Lamb Intake	Ewe Intake
Initial Liveweight		5.0				5.0				5.0		
Sept 1-15	1145	11.2	0.03	1.6	922	10.9	0.00	1.4	693	9.1	0.00	1.1
Sept 16-30	1094	14.2	0.03	1.9	938	13.8	0.02	1.6	760	11.8	0.01	1.2
Oct 1-15	1077	16.7	0.21	1.8	977	16.2	0.18	1.7	851	14.2	0.11	1.5
Oct 16-31	1199	19.3	0.40	1.7	1063	18.5	0.35	1.5	987	16.2	0.25	1.4
Nov 1-15**	1207	22.6	0.66	1.8	1195	21.8	0.63	1.8	1173	19.4	0.53	1.8
Nov 16-30	1335	26.1	0.86	1.9	1364	25.3	0.83	1.9	1398	22.7	0.72	1.9
Dec 1-15	1374	29.4	0.99	1.6	1439	29.0	1.02	1.7	1526	26.7	0.99	1.8
Dec 16-31	1300	32.9	1.16	1.6	1397	32.9	1.21	1.7	1530	31.0	1.21	1.8
Total Intake			66	210			65	202			58	190
Total Ewe Plus Lamb Intake				276				267				248

** Ewe shearing

Table 5.8 A Summary of Ewe Intakes (kg DM/EWE/DAY), Ewe Liveweight (kg) and Ewe Liveweight Gain (gm/DAY) Over Lactation.

Stocking Rate Option	High			Medium			Low		
Period	Intake	Final LW	LWG	Intake	Final LW	LWG	Intake	Final LW	LWG
Sept 1-15	1.6	47.9	-140	1.4	45.8	-283	1.1	44.7	-352
Sept 16-30	1.9	48.3	25	1.6	44.2	-107	1.2	41.6	-208
Oct 1-15	1.8	49.0	51	1.7	44.4	17	1.5	40.8	-53
Oct 16-31	1.7	50.0	64	1.5	45.0	38	1.4	40.5	-21
Nov 1-15	1.8	52.1/47.7*	141	1.8	47.7/43.4*	176	1.8	43.5/39.3*	202
Nov 16-30	1.9	50.4	179	1.9	46.6	218	1.9	43.1	249
Dec 1-15	1.6	52.0	108	1.7	48.9	154	1.8	46.2	209
Dec 16-31	1.6	53.6	108	1.7	51.2	151	1.8	49.3	201
Total Intake	210			202			190		

*Removal of fleece at shearing

However, post-shearing, the low stocking rate ewes achieve higher levels of intake (1.8 vs 1.6 kg DM/EWE/DAY) and achieve higher liveweight gains (201 vs 108 gm/DAY). However, this is insufficient to compensate for the liveweight lost in early lactation, and the low stocking rate ewes are still 4.3 kg lighter than the high stocking rate ewes at weaning (49.3 vs 53.6 kg).

Ewe milk production is dependent on ewe intake and ewe liveweight. Ewe milk yield responds to ewe intake, but in this case, ewe intake is only limiting ewe milk production in early lactation for the medium and low stocking rate options (Table 5.9).

Table 5.9 The Effect of Stocking Rate and Pasture Cover Levels on Ewe Milk Production Over Lactation (l/DAY).

Stocking Rate Option	High	Medium	Low
Period			
Sept 1-15	1.77	1.69	1.37
Sept 16-30	1.63	1.62	1.45
Oct 1-15	1.32	1.32	1.32
Oct 15-31	1.03	1.03	1.03
Nov 1-15	0.77	0.77	0.77
Nov 16-30	0.57	0.57	0.57
Dec 1-15	0.42	0.42	0.42
Dec 16-31	0.30	0.30	0.30

Although the high stocking rate ewes' intake is 45% higher than the low stocking rate ewes' in early lactation, the difference in ewe milk yield is only 29% (1.77 vs 1.37 l/DAY). This is because the low stocking rate ewes partially compensate for the reduced intake by mobilizing body tissue (reflected in the higher rate of liveweight loss recorded by the low stocking rate ewes in early lactation (Table 5.8)).

The same level of milk production (1.32 l/DAY) is achieved by the sixth week of lactation, even though there is still a large difference in ewe intakes (1.8 vs 1.5 kg DM/EWE/DAY). The low stocking rate ewes compensate for the reduced intake through the mobilization of body tissue (-53 gm/DAY), whereas the high stocking rate ewes are in a positive energy balance at that stage and are replenishing lost tissue reserves (+51 gm/DAY).

From early October until weaning the high and low stocking rate options achieve the same levels of milk production. However, it is not until mid-November that they achieve the same levels of dry matter intake. Thus, whereas the high stocking rate ewes are in a positive energy balance from mid-September to weaning, the low stocking rate ewes are forced to buffer the low levels of intake with body reserves until early November (Table 5.9). The cost of this buffering effect, is reflected in the differences in ewe liveweight at the end of October (50.0 vs 40.5 kg).

In summary, over the lambing to weaning period, the low stocking rate ewes produce 7.3% less milk (109.8 vs 118.5 LITRES) than the high stocking rate ewes, despite consuming 10% less feed (190.7 vs 211.8 kg DM/EWE). This is reflected in the 4.3 kg difference in ewe liveweight at weaning.

The third area where ewe intake influences animal performance is wool production. Thus, in early lactation, the high stocking rate ewe wool growth rate is over twice that of the low stocking rate ewes (7 vs 3 gm/DAY) (Table 5.10), the same rate by mid-lactation (17 gm/DAY) and 3 gm/DAY less than the low stocking rate ewes' level of wool production (19 vs 22 gm/DAY) by late lactation. In total the medium and low stocking rate ewes grew 90 grams and 150 grams less wool respectively than those at the high stocking rate over the period of lactation (equivalent to a drop in wool production of 5.1% to 8.5%).

Table 5.10 A Summary of Ewe Intakes (kg DM/HA/DAY) and Wool Growth Rates (gm/DAY).

Stocking Rate Option	High		Medium		Low	
Period	Intake	Wool Growth	Intake	Wool Growth	Intake	Wool Growth
Sept 1-15	1.6	7	1.4	4	1.1	3
Sept 16-30	1.9	10	1.6	7	1.2	5
Oct 1-15	1.8	12	1.7	11	1.5	9
Oct 16-31	1.7	13	1.5	12	1.4	10
Nov 1-15	1.8	17	1.8	17	1.8	17
Nov 16-30	1.9	20	1.9	20	1.9	20
Dec 1-15	1.6	18	1.7	19	1.8	20
Dec 16-31	1.6	19	1.7	20	1.8	22
Total per head	210	1772	202	1682	190	1622

Reduced ewe milk yields due to restricted ewe intakes limit lamb growth rates in early lactation (Table 5.11). The low stocking rate lambs (LSRL) receive only 1.37 litres/DAY of milk compared to 1.77 litres/DAY for the high stocking rate lambs (HSRL) (Table 5.9), and this is reflected in the large differences in lamb liveweight gain during the first two weeks of lactation (280 vs 426 gm/DAY) (Table 5.11).

By early October both groups of lambs are receiving the same levels of milk production (1.32 l/DAY). However, the HSRL in total are consuming 0.1 kg DM/LAMB/DAY more than the LSRL (Table 5.7) because of the higher levels of green pasture cover (1077 vs 851 kg DM/HA). By mid-November the HSRL are still consuming higher levels of dry matter than the LSRL (0.86 vs 0.72 kg DM/LAMB/DAY) because of their higher liveweight (22.6 vs 19.4 kg) and this is reflected in the rates of liveweight gain (246 vs 234 gm/DAY) (Table 5.11). This trend is reversed in the last month of lactation.

At weaning the HSRL and medium stocking rate lambs achieve the same liveweight (32.9 kg), but the low stocking rate lambs are 1.9 kg lighter because of their lower growth rates in early lactation (Table 5.11).

Table 5.11 The Effect of Stocking Rate and Pasture Cover Levels on Lamb Liveweight Gain Over Lactation (gm/DAY).

Stocking Rate Option	High		Medium		Low	
Period	LWG	LW	LWG	LW	LWG	LW
Initial Liveweight		5.0		5.0		5.0
Sept 1-15	426	11.2	400	10.9	280	9.1
Sept 16-30	202	14.2	205	13.8	191	11.8
Oct 1-15	179	16.7	168	16.2	165	14.2
Oct 16-31	183	19.3	163	18.5	141	16.2
Nov 1-15	236	22.6	234	21.8	225	19.4
Nov 16-30	246	26.1	245	25.3	234	22.7
Dec 1-15	239	29.4	263	29.0	285	26.7
Dec 16-31	254	32.9	281	32.9	308	31.0
Average LWG	229		229		213	

Analysis of the ME intakes (Table 5.12) shows that the medium stocking rate option consumed 1.2% less energy to achieve the same weaning weight as the high stocking rate option. This suggests that the medium stocking rate lambs consumed sufficient dry matter in late lactation to compensate for the lower levels of milk intake in early lactation. The LSRL consumed 10% less energy than the HSRL (1162 vs 1288 MJME/LAMB). This was responsible for the 1.9 kg difference in weaning weights.

Lamb wool growth rates reflect lamb ME intakes (Table 5.12) and there is only a small ($<$ 8%) difference between the three stocking rate options in the amount of wool produced (1.79 vs 1.77 vs 1.66 kg) by weaning (Table 5.12). The levels of wool production include 0.25 kg from birth and are high relative to those currently achieved at Tuapaka (1.2 kg). However, model lamb weaning weight are also 6 - 9 kg higher than those recorded at Tuapaka.

Table 5.12 The Effect of Energy Intake (MJME/DAY) on Lamb Wool Production Over Lactation (gm/HD/DAY).

Stocking Rate Option	High		Medium		Low	
Period	Intake (MJME/DAY)	Wool Growth (gm/DAY)	Intake (MJ/ME/DAY)	Wool Growth (gm/DAY)	Intake (MJ/ME/DAY)	Wool Growth (gm/DAY)
Sept 1-15	8.1	10	7.7	10	6.3	8
Sept 16-30	7.8	8	7.7	8	6.7	7
Oct 1-15	8.5	9	8.2	9	7.3	8
Oct 16-31	9.4	11	8.9	10	7.7	9
Nov 1-15	11.2	13	10.8	13	9.7	12
Nov 16-30	12.5	15	12.2	15	11.0	14
Dec 1-15	12.8	17	13.1	17	12.7	17
Dec 16-31	14.0	19	14.6	20	14.6	20
Total ME Intake	1288		1272		1162	
% Difference		1.2%		9.8%		
Final Fleece Weight (kg)		1.79		1.77		1.66

5.2.2.4 The Effect of Sward Composition on Pasture Quality.

The quality of the feed consumed was a function of the average digestibility of the sward. Although the average digestibility of the sward and the ME content of the sward was different across stocking rate options (Table 5.13), this difference was not large enough to affect the ME content of the diet of the grazing animals. The digestibility of the high stocking rate sward was 74.9% compared to 72.0% for the low stocking rate option in early lactation. This equated to ME contents of 11.2 and 10.7 MJME/kg DM respectively for the two swards.

By mid-lactation the digestibility of the high stocking rate sward was similar to that of the the low stocking rate sward (70.3% vs 70.5%), and both equated to an ME content of 10.5 MJME/kg DM. The digestibility of the low stocking rate sward exceeded that of the high stocking rate sward (64.9% vs 63.7%) in late lactation, reflected in the difference in ME content of the herbage (9.7 vs 9.5 MJME/kg DM).

Table 5.13 The Average Sward Digestibility, Energy Content and Quality of Pasture Consumed for the Three Stocking Rate Options Over Lactation.

Stocking Rate Option	High		Medium		Low		
Period	Digestibility	MJME/kg DM	Digestibility	MJME/kg DM	Digestibility	MJME/kg DM	Quality of** Pasture Consumed (MJME/kg DM)
Sept 1-15	74.9	11.2	73.8	11.0	72.0	10.7	12.0
Sept 16-30	74.4	11.1	73.6	11.0	72.4	10.8	12.0
Oct 1-15	73.4	10.9	72.9	10.9	72.2	10.8	11.9
Oct 16-31	73.0	10.9	72.8	10.9	72.6	10.8	11.9
Nov 1-15	70.3	10.5	70.4	10.5	70.5	10.5	11.6
Nov 16-30	69.9	10.4	70.1	10.5	70.4	10.5	11.6
Dec 1-15	65.3	9.7	65.7	9.8	66.1	9.9	10.9
Dec 16-31	63.7	9.5	64.2	9.6	64.9	9.7	10.9

**Identical for three stocking rates.

Differences in digestibility correspond to the percentage green dry matter content of the swards (Table 5.14). The higher digestibility of the high stocking rate sward in early lactation is a result of the higher proportion of green herbage (88% vs 82%). By mid-lactation this difference is removed (83% vs 84%), and in late lactation the green content of the low stocking rate sward is 3% higher than the high stocking rate sward (76% vs 73%). At weaning, the three stocking rate options have similar levels of dead matter (466 vs 469 vs 474 kg DM/HA) (Table 5.14), but there are major differences in the level of green dry matter (1248 kg, 1362 and 1521 kg DM/HA respectively).

The rate of dead matter accumulation, summarised in Table 5.15, is dependent on the level of green pasture cover. In early lactation the rate of dead matter accumulation is highest for the high stocking rate option(0.7 vs 0.5 kg DM/HA/DAY), as it has the highest level of green pasture cover. The two options reach similar rates of dead matter accumulation by mid-lactation (3.4 vs 3.3 kg DM/HA/DAY) because the levels of green pasture cover are similar at this point in time. The low stocking rate option achieves a higher rate of dead matter accumulation in late lactation (5.2 vs 4.3 kg DM/HA/DAY) because of higher levels of green pasture cover.

Table 5.14 The Effect of Stocking Rate and Pasture Cover on the Percentage of Green Dry Matter Present.

Stocking Rate Option	High	Medium	Low
Period:			
Sept 1-15	88%	86%	82%
Sept 16-30	86%	85%	83%
Oct 1-15	85%	84%	83%
Oct 16-31	84%	84%	84%
Nov 1-15	83%	83%	84%
Nov 16-30	81%	82%	83%
Dec 1-15	77%	78%	80%
Dec 16-31	73%	74%	76%
Components at 31st December:			
Total Pasture Cover	1714	1831	1995
Green Pasture Cover	1248	1362	1521
Dead Pasture Cover	466	469	474

Table 5.15 The Effect of Average Green Pasture Cover Levels (kg DM/HA) on Dead Matter Accumulation Rates (kg DM/HA/DAY).

Stocking Rate Option	High		Medium		Low	
Period	Average Green Pasture Cover	Dead Matter Accumulation Rate	Average Green Pasture Cover	Dead Matter Accumulation Rate	Average Green Pasture Cover	Dead Matter Accumulation Rate
Sept 1-15	1145	0.7	922	0.6	693	0.5
Sept 16-30	1094	0.7	938	0.6	760	0.5
Oct 1-15	1077	1.4	977	1.3	851	1.1
Oct 16-31	1119	1.4	1063	1.4	987	1.3
Nov 1-15	1207	3.4	1195	3.3	1173	3.3
Nov 16-30	1335	3.7	1364	3.9	1398	3.9
Dec 1-15	1374	4.9	1439	5.1	1526	5.5
Dec 16-31	1300	4.3	1397	4.7	1530	5.2

5.2.2.5 Summary and Discussion of Results.

An overall summary of the differences between the three stocking rate options at weaning is shown in Table 5.16. Pasture production for the three options is almost identical (3689 vs 3705 vs 3661 kg DM/HA), but the amount of feed consumed per hectare declined as stocking rate was reduced. (The high stocking rate option consuming 3282 kg DM/HA compared to 2476 kg DM/HA for the low stocking rate).Pasture cover at weaning was therefore highest for the low stocking rate (1995 vs 1714 kg DM/HA), despite the low level at lambing (805 vs 1307 kg DM/HA).

Table 5.16 A Summary of the Position of the Three Stocking Rate Options at Weaning and a Comparison of the Differences Against the High Stocking Rate Option, With Allowance Made for the Feed Cost of Differences in Liveweight.

Stocking Rate Option	High		Medium		Low
Position at Weaning					
Ewe Liveweight (kg)	53.6		51.2		49.3
Difference (kg)		2.4		4.3	
Difference (%)		4.5		8.0	
Feed Cost/Head (kg DM)		13.3		23.8	
Feed Cost/ha (kg DM/HA)		145		237	
Lamb Liveweight (kg)	32.9		32.9		31.0
Difference (kg)		0.0		1.9	
Difference (%)		0.0		5.8	
Feed Cost/Head (kg DM)		0		21.8	
Feed Cost/ha (kg DM/HA)		0		217	
Total Feed Cost/HA (kg DM/HA)		145		454	
Final Pasture Cover (kg DM/HA	1714		1831		1995
Difference (kg)		-117		-281	
Difference (%)		-6.8		-16.4	
Nett Feed Difference (kg DM/HA)		28		-173	
Nett Feed Difference (%)		1.6		-10.1	
Ewe Wool Production (kg)	1.77		1.68		1.62
Difference (gm)		90		150	
Difference (%)		5.1		8.5	
Lamb Wool Production (kg)	1.79		1.77		1.66
Difference (gm)		20		110	
Difference (%)		1.1		6.1	
Total Feed Grown (kg DM/HA)	3689		3705		3661
Difference (kg DM/HA)		-16		28	
Difference (%)		-0.4		0.8	
Total Feed Consumed (kg DM/HA)					
Difference (kg DM/HA)					
Difference (%)					
Feed Consumed/UNIT**	276		268		248
Difference (kg DM/UNIT)		-8		-28	
Difference		-2.9		-10.1	

** UNIT = Ewe plus Lamb

The feed consumed per unit (ewe + lamb) was highest for the high stocking rate option (276 kg DM/UNIT) compared to 268 kg DM/UNIT and 248 kg DM/UNIT for the medium and low stocking rate options respectively. The impact of this lower level of intake per unit is reflected in the ewe and lamb weaning weights. This is primarily due to the effect of the low levels of pasture cover in early lactation restricting ewe intakes. When differences in liveweight and pasture cover are converted to a common energy basis the high and medium stocking rate options, reached approximately equivalent end points at weaning and the low stocking rate option had the equivalent of 10% less feed on hand.

The objective of this section of the study was to evaluate the effect of the interactions between pasture cover, pasture growth rate, animal intake, and animal performance. The feed budgeting analysis in Chapter Two showed that for the 100% flock across three stocking rates, and starting at different levels of pasture cover at lambing, the systems would achieve the same level of pasture cover at weaning, and achieve the same levels of animal performance.

The analysis in this chapter has shown that the high and medium stocking rate options did reach an almost equivalent position at weaning, when differences in liveweight and pasture cover were converted to a common denominator (kg DM/HA). However, the path by which these two options reached this point in terms of the pattern of ewe and lamb liveweight gain, and the pattern of pasture growth rates and pasture cover was quite different.

The low stocking rate option had 10% less feed on hand than the two higher stocking rate options at weaning. In this case it could be concluded that the failure of the feed budgeting approach to take into account the interaction between pasture cover, pasture growth rate, animal intake, and animal performance has produced results which may be misleading, mainly because pasture cover levels fell below 1000 kg DM/HA during the period of lactation.

In broad terms then, the simple feed budgeting approach used in Chapter Two produces realistic answers if pasture cover is kept within certain bounds. The results suggest that this lower boundary may be about 1000 kg DM/HA. An upper boundary of 1600 - 1700 kg DM/HA over the late spring in order to maintain pasture quality is probably required (Butler, 1986) although the relationships in McCall's model do not agree with this.

It is questionable whether the model adequately reflects true differences in pasture quality, if lamina content is not taken into account. It could be postulated that the high stocking rate option achieves better pasture control (1714 vs 1831 vs 1995 kg DM/HA at weaning), and hence should have a higher level of pasture quality than the lower stocking rate options.

The high weight gains (246 - 308 gm/DAY) achieved by the lambs in late lactation on pasture cover levels of between 1700 - 1900 kg DM/HA appears infeasible given that lamb growth rates of over 200 gm/DAY have not been recorded on Tuapaka in late lactation. Butler (1986) in his review of literature on the effect of sward characteristics on animal intake over the spring and summer period found that the lamina content of the sward was the best determinant of intake. Butler noted however, that very few grazing models, including McCall's (1984) modelled lamina accumulation. This omission could account for the apparently high levels of lamb liveweight gain achieved in late lactation.

5.3 Conclusion.

The conclusions that could be drawn from this chapter are -

1) Subjective assessment of wool production for use in a simple feed budget analysis can under-estimate actual production and hence financial returns by up to 12% . This could be significant when making a choice between different sheep farming systems. In the current economic environment, for example, farmers are looking at alternative systems such as all-wool farming, autumn - winter lambing and heavy weight lamb production. The sub-models could be used for investigating these options in greater detail (For example, the effect of different nutrition and shearing regimes could be determined).

2) Simple feed budgeting analysis provides data, in a gross sense, similar to that derived from more complex simulation models, if pasture cover levels are maintained within certain bounds. These appear to be 1000 - 1700 kg DM/HA during the period of lactation for sheep systems.

3) The simple feed budgeting analysis does not account for the different patterns of pasture cover and liveweight that occur due to the interaction of the components of the pastoral system. This is probably not important in a broad design sense, but it could have critical repercussions where the data was to be used as an aid for fine tuning the management system.

4) The pasture cover bounds that need to be set to ensure the validity of the simple feed budgeting approach, require further research - particularly the interaction between pasture cover, and pasture quality in late spring.

Chapter Six

Conclusion.

6.0 Chapter Outline.

In the first section of this chapter the methodology used in this study is appraised and possible improvements are suggested. The conclusions drawn from the study are outlined and discussed in the second section. This is followed by an outline of potential research topics arising from this study.

6.1 Evaluation of Research Methodology.

A large part of this study was devoted to the comparison of two methodologies - simple feed budgeting versus more complex simulation modelling. To avoid duplication of discussion, the comparison shall be discussed in section 6.3 and this section shall consider the technology used to achieve the comparison.

Spreadsheet technology was used to construct the feed budget/financial model outlined in Chapter Two. This technology provided a number of advantages. No prior computer programming skills were required to build the feed budget model - the time taken to master the spreadsheet program was two days. The spreadsheet program allowed the construction of problem specific models. These could be built relatively quickly (one to two weeks) and once the initial model framework had been constructed, changes could be made simply and quickly.

The spreadsheet program allowed relatively sophisticated feed budgets to be constructed (as demonstrated in Chapter Two). The program allowed the model to perform iterations and could link several sub-routines or spreadsheets if required. The row by column structure of the spreadsheet allowed the model to be formatted to simplify input and to produce tabulated, easily understood output. The models described in Chapter Two are simple and quick to run (five minutes). Overall, the spreadsheet program was found to be ideal for simple feed budget and financial analysis.

The spreadsheet program was also used for the construction of several simulation models and provided many of the advantages mentioned above. However, there were also a number of disadvantages. Due to the size and the complexity of the mathematical relationships, the individual models required considerable time to construct (up to one month per model). Most time input was required for designing the model structure to ensure that the complex iterative routines functioned correctly. The Multiplan program has limited "if" statement routines and no facility to incorporate dates into formula. These two areas were a major limitation. Spreadsheet programs with these facilities, such as Lotus Symphony, should be adopted if researchers wish to use spreadsheets for simulation modelling with these requirements.

A major limitation of Multiplan was capacity. The model of a breeding ewe for example, had to be divided into three sub-models for the periods (weaning to tupping, tupping to lambing and lambing to weaning) because the spreadsheet could not cope with a single annual model of the breeding ewe. This also prevented the simulation of the entire Tuapaka hill country unit - the initial goal of the author. Larger spreadsheet programs such as Lotus Symphony, which is 8,192 rows deep by 256 columns wide, may be able to cope with this problem (Hall, 1986).

Other than size, the greatest limitation with the spreadsheet program was calculation time (a function of the size of the models, the number of iterative functions and the speed of the spreadsheet program). The models took between 15 minutes and 3 hours to complete a run. One aim of the study (Chapter Four) was to create microcomputer simulation models that were user friendly and interactive for use by students and farmers. The long run times restricts interactive use of these programs.

There appears to be scope for reducing the size of the models without losing accuracy (Section 4.1.4). Models with small time periods between activities (6 - 15 days) were deliberately constructed to minimise loss of accuracy, as McCall's model is based on daily periods. This is an area for further research. Recent improvements in spreadsheet technology and more powerful microcomputers may also allow these problems to be overcome. Alternatively, the models could be developed using a computer program such as Turbopascal, to reduce the problems of calculation time (Butler, pers comm).

6.2 Conclusions From the Feed Budget Analyses.

The study found that there was little difference between high and a low performance flocks run at different stocking rates in terms of matching feed demand with feed supply at Tuapaka. This was primarily because the higher intake per head of the high performance flock was compensated for by the higher stocking rate that was possible with a lower performance flock. The high performance flock also wintered a higher proportion of multiple bearing ewes that failed to rear all their lambs. This resulted in a higher winter feed cost relative to the feed consumed over the spring period, reducing the advantage of the higher lamb drop.

The high performance flock was shown to be more profitable and although this flock produced less wool per hectare, this was compensated by higher returns from lamb sales and lower costs per hectare. This indicates that Tuapaka should aim for a high performance flock to improve profitability.

A number of weaknesses with the feed budgeting approach were identified. These included:

1) The inability of the feed budget approach to to take into account the interaction of pasture cover, pasture growth rate, animal intake and animal performance.

2) The largely subjective assessment of the relationship between animal intake and wool growth.

3) The effect of seasonal variation in pasture growth rates on levels of animal performance.

Published feed tables in New Zealand provide little or no detail for many of the situations encountered in hill country sheep farming. An attempt was made to quantify these information gaps by comparing the output from the feed budget analysis with that generated by complex simulation models in two areas - wool production, and the relationship between pasture cover, pasture growth rate, animal intake and animal performance.

Considerable differences between the subjective estimates for wool production used in Chapter Two and those generated by the simulation models (up to 50% difference) were found. With wool currently comprising 45 - 60% of hill country farmers' income, models that can accurately predict wool production levels for alternative systems are important in any study of alternative hill country sheep systems. However, the comparison between simulated levels of wool production with those achieved on two of the University farms (Section 4.1.6) indicates that further work is required to define wool growth functions, particularly for situations where nil or negative liveweight gains are achieved and for different breeds.

The main advantage of the feed budgeting approach is simplicity. Results can be generated relatively quickly, and in the case of an experienced researcher the analysis will provide results that reflect reality reasonably well. The study shows that where pasture cover levels were maintained within certain bounds (e.g. above 1000 kg DM/HA) the feed budget analysis generated similar results to those obtained from the more complicated simulation models.

However, the feed budgeting approach does not adequately describe the different patterns of pasture cover and liveweight that occur due to the interaction of the components of the pastoral system. This is an important limitation where the model output is to be used as an aid for controlling (fine tuning) a system.

The alternative sheep systems were compared using average pasture growth rates only. Further analysis could be performed to determine the robustness of these systems to variations in pasture growth rates. In these analysis the greater detail generated by the simulation models with respect to the pattern of pasture cover and animal liveweight is likely to be important. Consider for example, a drought in mid-November in the case of the three stocking rate options analysed in Chapter Five. Due to the interactions of pasture cover, pasture growth rates and animal intake, the high stocking rate ewes and lambs reached higher liveweights than the lower stocking rate options, but the farms had similar levels of pasture cover. This places the high stocking rate option in a much better position because it has ewes and replacement stock at higher liveweights and lambs that can be sold or weaned earlier. In contrast, the feed budget analysis would assume that the three systems would have identical ewe and lamb liveweights and would fail to identify the advantages of the high stocking rate option.

The data upon which McCall (1984) built his hill country model was limited in some areas. Output from the lactation simulation exercise for example, indicates that the model does not simulate pasture quality with sufficient realism. While the model predicted lamb growth rates of over 200 gm/DAY in late lactation, data collected from Tuapaka over the last four years has shown that lamb growth rates have failed to exceed 200 gm/DAY in late lactation. As discussed in Section 3.2.1, this may be because lamina accumulation is not taken into account. Butler (1986) suggests that pasture quality declines during the late spring/summer period if pasture cover levels are allowed to exceed 1600 - 1700 kg DM/HA. McCall's model did not show this trend. This may be important when evaluating the three stocking rate options in the post weaning period because the final pasture cover ranged from 1714 Kg DM/HA for the high stocking rate option to 1995 Kg DM/HA for the low stocking rate option. The above comments suggest that further validation of components of McCall's model is neccessary.

The study also considered the issue of farm specific models compared to general models. The advantages of a general model is that it can be used to simulate across a range of farm types. However, it is usually difficult to modify the general model - as demonstrated with McCall's model - to simulate a specific case farm, or to look at specific components of a system. The advantage of a farm specific model, other than allowing the analysis of opportunities for that farm, is that actual farm production characteristics can be used to validate model output.

6.3 Possible Areas For Further Research.

The study has indicated a number of areas where further research is required (some have been alluded to in the previous discussion). A number of weaknesses in the feed budgeting approach were identified, but the impact of these has only been partly analysed. Further research is required to quantify the differences between the simple feed budgeting techniques and simulation techniques. A key area that was highlighted by the study, was the pasture cover bounds within which feed budgeting will produce relatively realistic answers.

The limitations imposed by the feed budget approach suggest that with increased microcomputer power, a hybrid simulation/feed budgeting program should be developed. This would allow the relative simplicity of the feed budgeting approach to be maintained, but would incorporate the greater sensitivity of complex simulation modelling. This would allow the model to:

1) Simulate the effect of pasture cover on pasture growth rates, pasture quality and animal intakes.

2) Produce output data in terms of animal production (wool, liveweight gain/loss, milk yield, foetal growth) for given levels of animal nutrition.

The development of this model has scope for use in research, teaching and on commercial properties.

The models developed in this study offer scope for research into a number of areas. These include:

1) All wool farming.

2) Early lambing.

3) Late lambing and wintering a high proportion of wether hoggets.

4) The effect of pregnancy nutrition on feotal development, ewe wool production, and ewe liveweight.

5) The effect of different levels of ewe nutrition during lactation on milk yield, wool production, ewe liveweight gain/loss and lamb growth rates.

6) Alternative ewe hogget rearing systems.

7) Alternative lamb fattening systems.

These models may be of most use to the farming community if they were set up to simulate an individual property. The model could then be run concurrently with the farm so that the output from the model and the farm could be compared. This would identify areas where management systems and the model structure could be improved. Over time the model could be expected to be improved to the point where it accurately simulated the farming system.

6.4 Conclusion.

The current economic climate means that farmers' options for increasing profitability on hill country are limited to methods which use current resources more efficiently, rather than through the use of high capital inputs.The study set out to analyse the effect of allocating a limited resource (winter/spring pasture) to ewes of different pregnancy/lactatation status. It was concluded that although there was little advantage between a high performance flock and a low performance flock run at a higher stocking rate at Tuapaka in terms of matching feed demand with feed supply, the advantage in terms of profitability was 6 - 10%. The analysis shows that there is scope for increasing hill country farmers' profit through the design of more efficient systems. However, this study has only gone a small way to addressing this issue and there is considerable scope for further research in this area.

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