AN ECONOMIC EVALUATION OF THE OPTIMAL EWE REPLACEMENT POLICY FOR TYPICAL CANTERBURY LIGHT LAND AND IRRIGATED PROPERTIES

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

Abstract of a thesis submitted in partial
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Every year in New Zealand large numbers of ewes which are suitable for another full year of production are killed at the freezing works. This is the result of the breeding ewe's productive life being traditionally determined by the state of its incisor teeth. The basis for this culling policy is that ewes with worn or missing teeth are considered unable to graze and therefore to produce satisfactorily.

The study takes the following form; (1) review of the relevant literature, (2) survey of farmers running 'gummy' ewes, (3) trial work analysing production and management characteristics of 'broken mouth' and 'gummy' ewes, and (4) development of two linear programming models (representing typical Canterbury light land and irrigated farms) utilising information gained in the above studies.

The survey and trial work showed that a higher lambing percentage can be expected from aged ('gummy') ewes. However, this was the case only when the ewes were given preference, over younger ewes, for good feed especially in the six week period before parturition. The results also show that the average wool weights from the aged ('gummy') ewes was lower than that expected from mixed aged ewes.

The linear programming model solutions indicate that ewes should be culled at five and six years of age, under irrigated and dryland conditions respectively. The flock structures obtained were stable. Large variations in the cull ewe, prime lamb and wool prices were needed to alter the flock structures significantly.

The results show that the traditional culling practice leads to unnecessary wastage of productive stock from the national ewe flock. Retention of 'broken' and 'gummy' mouth ewes is found to be physically possible and economically desirable, both to the individual farmer and to the nation.

CHAPTER I

INTRODUCTION

Every year in New Zealand large numbers of ewes, which are suitable for another full year of production, are killed at the freezing works. This is a result of the breeding ewes productive life being traditionally determined by the state of its incisor teeth. Ewes are culled for slaughter when their incisor teeth have either been shed or have been worn down to the gums. These ewes are termed broken, failed or 'gummy' mouthed. Often the condition of the incisor teeth is the main consideration in determining whether an animal is kept in the flock or culled and sometimes this is the only consideration. The culling decision, however, is a subjective one and can vary between farmers, even within an environment (Coop and Abrahamson, 1973).

The basis for this culling policy is that ewes with worn or missing teeth are considered unable to graze satisfactorily and, therefore, to produce satisfactorily. Research in this area is sparse and there is little evidence both within New Zealand and overseas to support or refute this claim.

The culling of ewes using the condition of their incisor teeth as the basis may mean that it is necessary to cull ewes from the ewe flock at four years of age. This is shown by the age at which ewes are culled from the New Zealand breeding ewe flock being 4.3 years on average[1]. Culling

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[1] The calculation is as follows:

$$\text{Age of culling} = \frac{\text{Number of breeding ewes}}{\text{Number of ewe hoggets (minus 15\% for culling and deaths)}}$$

Using the New Zealand Department of Statistics Sheep Returns for the year ended June 1977, the calculation becomes

$$\text{Age of culling} = \frac{42.8 \times 10^6}{(11.7 \times 10^6)0.85} = 4.3 \text{ years}$$

ewes at this stage is an undesirable practice because:

(a) the overhead cost of maintaining a flock is increased, as ewes are held for one less profitable lambing season.

(b) ewes culled at an early age because of their mouth condition may have otherwise desirable characteristics which would normally guarantee their retention in the breeding flock. The ewes are also removed before their season of highest fertility has been reached (Burton, 1947 and Coop, 1973).

(c) Early culling requires the rearing of more replacement stock, with lower culling intensity. Breeders may also be forced to purchase replacements at a high cost while at the same time retaining two-tooths which would otherwise have been culled.

(d) A ewe with a poor mouth may not be accepted by buyers as true to age. This will be particularly so in areas where age marking is not carried out. Tooth condition has always been important in the fixing of prices for sheep (Cairney, 1967).

The early culling of ewes from the New Zealand breeding flock has the following undesirable effects on New Zealand's export earnings.

(a) A source of potential production has been lost, as ewes are culled before their most productive year.

(b) With lower culling intensities genetic improvement over the whole New Zealand flock is greatly reduced.

(c) Mutton, a low return commodity, is being substituted for export lamb, a high return commodity. As more replacements are required by the breeding flock, more ewe lambs which would otherwise have been sold for export are retained for use as replacements.

It is clear from the above discussion that the following facts need to be established.

(1) The level of production that can be expected from an aged ewe with the type of mouth which at present condemns it to slaughter.

(2) Whether or not the decline in production is sufficient to warrant slaughter.

This information will then allow more accurate decisions to be made on the age at which ewes should be culled and how they should be replaced. The aim of this study is to provide insight to these issues.

The study is presented as follows:

(1) A review of the literature relevant to the above points.

(2) A description of the survey and trial work carried out to ascertain the likely production from aged 'gummy' ewes and also to identify any likely management problems.

(3) The development of representative farm linear programming models representing Canterbury light land and irrigated properties. The aim of this analysis is to identify the optimum age and means of replacement under these conditions.

(4) The analysis of the effect of changes in prime lamb, cull ewe and wool prices on the solutions obtained above.

(5) Presentation of the results and conclusions. An extrapolation of the effects of the results obtained on the whole of the New Zealand ewe flock will also be presented in the conclusions.

CHAPTER II

REVIEW OF THE LITERATURE

2.1 FACTORS AFFECTING TOOTH LOSS AND WEAR

The condition of mouths in the New Zealand flock has deteriorated over the past 50-60 years. Whereas it was common for ewes' mouths to last for 5-6 years, at present it is often necessary to cull ewes as early as 4 years of age because of excessive tooth wear or tooth loss. Barnicoat (1957) notes that this deterioration in the quality of sheep's mouths coincides with the rapid development of new farmland and to changes in stock and pasture management. The problem, however, may have been inherent in the New Zealand flock from the start.

Rohloff pers comm, in a review of the literature on mouth conditions in sheep suggests that the three major effects of teeth problems on sheep's mouths are;

(1) teeth missing,

(2) incisor tooth wear, and

(3) faults in sheep's mouths.

2.1.1 Teeth Missing

This can be due to two factors.

(a) Paradontal Disease - In this condition the teeth become loose in their sockets allowing food to penetrate the gums. Food may also be compacted between the teeth, particularly the molars. The gums then recede allowing teeth to become dislodged or even lost. Chronic abscess formation is often associated with this condition (Figure 2.1). A lack of selenium

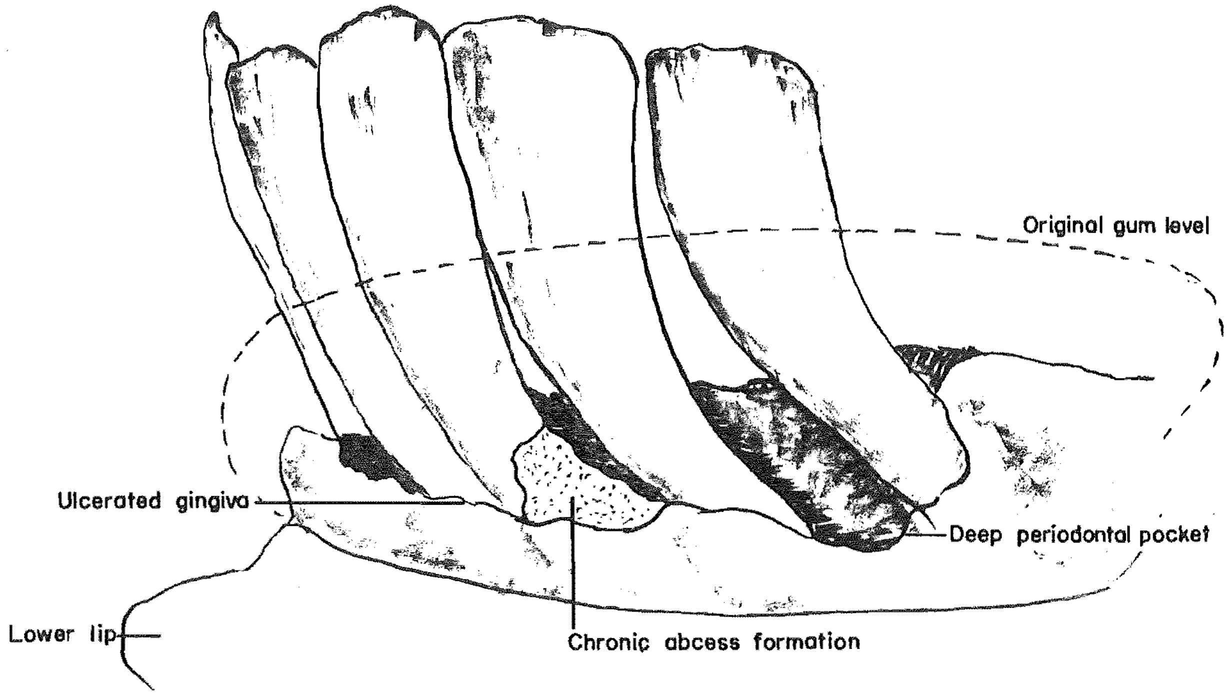

FIGURE 2.1 PARADONTAL DISEASE OF THE INCISOR TEETH OF SHEEP (Rohloff, pers.comm)

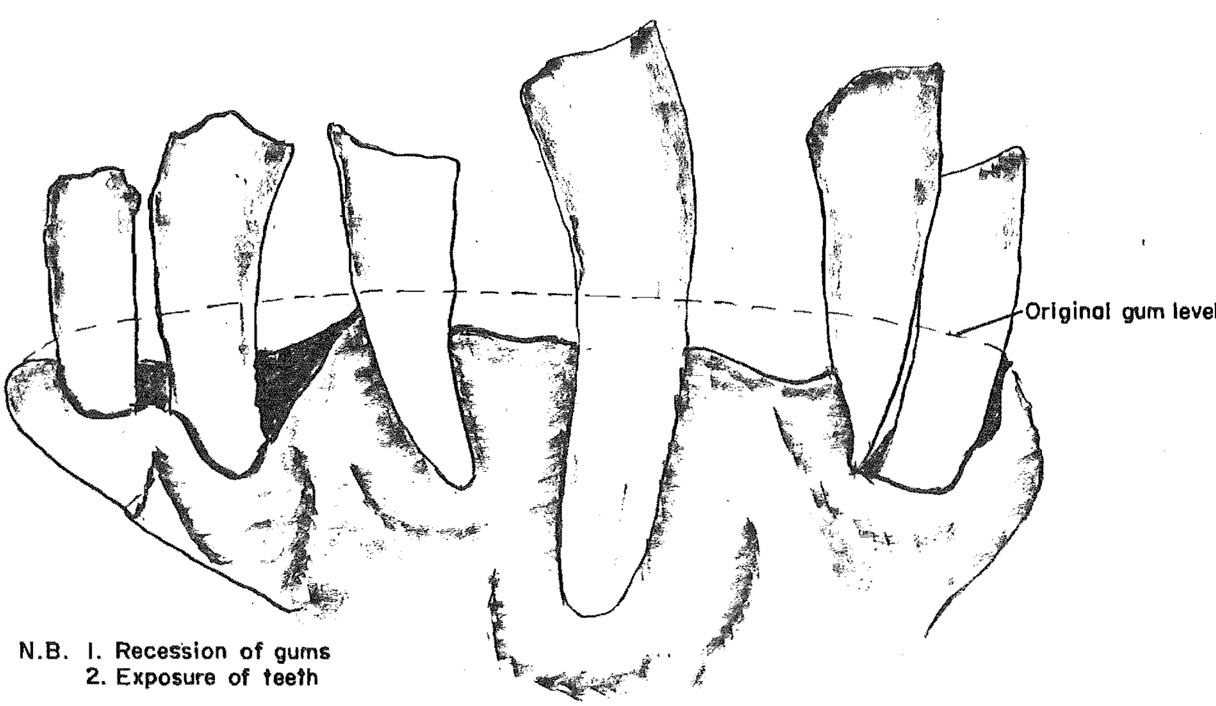

FIGURE 2.2 PERIODONTOSIS OF THE INCISOR TEETH OF SHEEP (Rohloff, pers.comm.)

appears to play some role in the cause of this condition. Hartley and Grant (1961), found that they had only half the incidence of paradontal disease in sheep dosed with selenium compared with undosed sheep. A causal relationship between fertilizer use and teeth wear was established by Porter (1970). He demonstrated that the highest incidence of paradontal disease was from pastures with the highest topdressing rate. After dosing with selenium, all groups of sheep experienced a decrease in the incidence of the disease. He concluded that a low serum selenium level is a predisposing factor in the occurrence of the disease.

(b) Periodontosis - This condition is the most common cause of broken mouth in New Zealand. Unlike paradontal disease, this disease occurs only in the incisors. Radiological studies have shown that the teeth migrate apart and out of their sockets (Benzie and Cresswell (1962)). The teeth then loosen due to the development of paradontal pockets and tooth loss eventuates (Figure 2.2).

Factors contributing to the cause and the advancement of the conditions are:

(i) Genetic - ewes showing signs of this disease should be culled. Hitchin and Walker-Love (1959) found that both paradontal disease and periodontosis are highly heritable.

(ii) Level of feeding - sheep, particularly hoggets, when fed at a low plane of nutrition show a higher incidence of these conditions. Coop and Clark (1955) found that a low plane of nutrition for hoggets resulted in a delay in the eruption of, and a subsequent earlier loss of permanent incisor teeth.

(iii) Feedstuffs - there is no evidence to suggest that excessively rank pasture is a factor contributing to teeth loss, but a diet of root crops, e.g. swedes and turnips, can lead to loosening of teeth and premature teeth loss. Duckworth et al (1962) and Gunn (1970) suggest that a diet of root crops is not the only explanation of tooth loss. They noted that there is still no explanation for differences between flocks of sheep.

(iv) Reproductive stress - reproductive stress may play some part in the premature loss of teeth. The increased post-lambing feed requirement of a ewe may necessitate more foraging for feed. It has been shown that where wethers and ewes are run under similar conditions, the ewes' teeth did not last as long as the wethers' teeth.

(v) Mineral deficiencies - as discussed above, selenium has been shown to be a pre-disposing factor in the occurrence of paradontal disease.

2.1.2 Incisor Tooth Wear

Tooth wear is an economically important problem effecting the New Zealand sheep farming industry. Tooth wear can shorten the useful life of sheep under a variety of conditions. Research work on this topic has been sparse both in New Zealand and overseas, but some trends are now obvious.

It is now clear that soil ingestion is the major cause of tooth wear. Healy and Ludwig (1965), in a study of soil ingestion by sheep found a close correlation between tooth wear and soil ingestion. Their study investigated three farms, each classified according to whether tooth wear was high, medium or low. It was found that daily soil ingestion by sheep on these farms was 11.3 kg, 4.6 kg and 0.5 kg respectively and when separated from the faeces was found to be highly abrasive.

Barnicoat (1957) found that there was no relationship between soil type and tooth wear. Sheep grazed on limestone areas did not have better mouths than sheep from areas where more abrasive soils are predominant, e.g. the pumice country of the central North Island. Healy (1967), however, has shown that soils with a strong structure, e.g. yellow brown earths and yellow brown loams, are associated with low levels of soil ingestion compared with weakly structure soils, e.g. yellow grey earths and podzols. Yellow grey earths and podzols develop under conditions of wet winters and dry summers. Both situations are conducive to dirty pasture and thus contribute to tooth wear. Tooth wear has been shown to be low on unimproved pastures (Barnicoat, 1957). The unimproved pastures are commonly associated with yellow brown earths and yellow brown loams which are shallow free draining soils. A characteristic of unimproved pastures is that at no time during the year are large areas of soil left exposed as mosses and weeds fill the gaps.

High stocking rates affect the amount of soil ingested and consequently tooth wear. Barnicoat (1957), Coop and Clark (1955) and Healy (1967) found that when stock were forced to eat short, dirty pasture the incidence of tooth wear rose. Soil ingestion was found by Barnicoat (1957) and Ludwig et al (1966), to be highest in the July to October period. It was found that although tooth wear was continuous through the year, 70% of the total years wear took place in this period. This period of the year is characterised by wet and cold conditions, very short pastures and large numbers of earth worm casts. The treading action of sheep in these conditions leads to dirty pastures. As the ewes' feed intake post-parturition is high, tooth wear is increased at this time.

Healy et al (1967), found that supplementary feeding with chou moullier and red clover hay for 8-10 weeks over the winter period reduced the amount of soil ingested by sheep. It was found that soil intake was reduced by 75% and tooth wear by 50% where supplementary feeding was practiced. Rotational grazing has also been shown by Barnicoat (1957) and Collin (1966) to reduce tooth wear because sheep are presented with longer pasture at each grazing.

The hypothesis that pasture juices play a part in teeth wear was investigated by Cutress and Healy (1965). Although they found chemical differences in pastures from high and low wear farms the juices from both types of farm showed similar and relatively low rates of attack on radioactive dentine.

2.1.3 Faults in Sheeps Mouths

The two most common faults of sheeps mouths experienced in New Zealand are overshot (prognathism) and undershot (brachygnathism) jaws. Both of these conditions lead to more rapid tooth wear.

The term overshot jaw means that the lower jaw closes in front of the dental pad. Slightly overshot jaws tend to last well, but sheep with badly overshot jaws develop an "eaten down in front appearance". The front incisor teeth wear down giving a hollowed out shape to the sheep's mouth. It has been suggested by Barnicoat (1957) that this condition is genetic in origin, but Franklin (1950) found that he could induce the condition by feeding sheep a calcium deficient diet.

The term undershot jaw refers to the situation where the incisors close behind the front of the dental pad. This condition normally leads to rapid tooth wear. The tendency is for the defect to become more pronounced with age, but there is some evidence (Barnicoat, 1957) to suggest that in a few cases the condition may improve with age especially if young sheep show only a slightly undershot conformation. Norby, et al (1945) found that this condition is highly heritable.

2.1.4 The Effect of Tooth Loss and Wear on Production

Barnicoat (1957) found that the liveweight of a ewe was not related to ewes' teeth wear. This would suggest that the heaviest ewes had not worn out their teeth in an effort to satisfy their physiological needs, but that the wear was due to other factors (Chapter II, 2.1.2). Gunn (1970) and Sykes et al (1974) noticed that ewes with broken mouths had lower live weights compared with full mouthed ewes of the same age group. They also noticed that the broken mouthed ewes were unable to maintain live weight in early pregnancy and that a major loss in live weight was experienced in late pregnancy and during lactation. Broken mouthed ewes have been found to be less able to resist infection and slower to replace protein reserves lost during pregnancy and lactation (Sykes et al (1974)), but the age of the ewe will also have an effect.

Gunn (1970) and Barnicoat (1957) showed that ewes with broken and 'gummy' mouths produced less wool than ewes of the same age with good mouths. This suggests that wool weight, although being age related (Chapter II, 2.2.2), may also be affected by the inability of broken mouthed ewes to maintain their live weight. Feed ingested is used to replenish body reserves to the detriment of fleece growth.

Gunn (1970) showed that there was no difference in the lambing percentage (lambs born to ewes mated) of 48 month broken mouthed ewes and

48 month good mouthed ewes. Lamb birth weights and ewe milk yields, as shown by lamb weight gains from birth to six weeks of age, were found to be similar, but loses of twin lambs reared by broken mouthed ewes to weaning were higher than those reared by good mouthed ewes, i.e. 26% compared with 13%. This study has shown that broken or 'gummy' mouthed ewes can be expected to produce and rear single lambs efficiently, but the drain on body reserves required to produce and rear twin lambs appears to be too high. The experiment on these ewes was continued for another year and it was found that broken mouthed ewes produced significantly fewer lambs than good mouthed ewes - 123% compared with 136%. Single and twin lambs produced and reared by broken mouthed ewes in this trial were inferior to similar lambs from good mouthed ewes. Where old ewes are run under 'liberal fat lamb' grazing conditions lambing percentage, birth weight and the milk yields of the ewes were similar for broken and full mouthed ewes, but when these ewes were subjected to feeding stress, differences in these parameters were obvious, to the detriment of the broken mouthed ewes (Barnicoat (1957)). Coop and Abrahamson (1973) in a trial on ewe feed intakes found that good, medium and poor teeth ewes produced lambs with similar birth weights and lamb growth rates (to 30 days), but these trials made no allowance for age.

2.1.5 The Effect of Tooth Loss and Wear on Food Intake

The condition of a sheep's teeth has a considerable effect on its ability to forage effectively. Field, et al (1974) and Sykes, et al (1974), however, found no evidence to suggest that teeth condition had a significant effect on dry matter intake. It was suggested, however, that a ewe with incisors loose or missing may be at a disadvantage because the area in contact with the dental pad for griping herbage must be reduced. Coop and

Abrahamson (1973), found differences in digestible organic matter intakes due to teeth condition. In their trials ewes with a medium amount of tooth wear suffered no handicap when grazing long grass and intake was 90% of good mouthed ewes on short grass. Ewes with a high degree of tooth wear ('gummy' mouths) were only able to consume 74% and 61% of that eaten by good mouthed ewes when grass was long and short respectively. The absolute intake of these poor mouthed ewes was 1.5 times maintenance requirements on long grass and 0.4 - 0.8 times maintenance requirements on short grass. The consequence of this is that a poor mouthed ewe is unable to meet its lactation requirements which are three times maintenance, and is forced to draw from its body reserves. The metabollic rate and many functions of the body are known to decline with age; so too might the ewes willingness to graze be related to age, but the effect shown by Coop and Abrahamson (1973) cannot solely be explained by age.

2.2 THE EFFECT OF AGE ON PRODUCTION

2.2.1 Lambing Percentage

Lambing percentage is thought to be the most important factor to be considered when determining the optimal replacement strategy for a flock (Hickey, 1960). Coop (1964) has shown that the nutritional regime of a breeding ewe, particularly before lambing, has the greatest effect on the number of lambs born per ewe mated, between years and locations. Age of the ewe at lambing has also been shown to have an important effect on lambing percentage and optimal replacement strategy. Hickey (1960), in a survey of large number of Romney ewes, over six years, in various geographical and climatic locations in New Zealand found that the maximum lambing percentage was attained at four years of age (Table 2.1).

TABLE 2.1

LAMBING DATA FOR ROMNEY EWES (AFTER HICKEY, 1960)

Age at Mating (Yrs)	Number Mated	Number of Lambs Docked	Lambing Percentage (%)
1.5	21,571	16,869	78.2
2.5	19,437	18,348	94.4
3.5	13,552	13,118	96.8
4.5	9,621	10,506	109.2
5.5	7,584	8,236	108.6
6.5	6,193	6,218	100.4
7.5	2,983	2,792	93.6
8.5	931	855	91.8
9.5	479	415	86.6
10.5	162	136	84.2

Other New Zealand research into this field would suggest that the age at which maximum lambing percentage is reached varies between four and seven years of age (Table 2.2).

TABLE 2.2

SUMMARY OF THE NEW ZEALAND LITERATURE SHOWING THE EFFECT OF AGE OF EWE ON LAMB PRODUCTION

Author	Oldest Age Group (Yrs)	Age of Maximum LT/EJ* (Yrs)	Breed
Barton (1947)	8+	7	Romney
Coop (1973)	7	5	Romney and Border Romney
Coop (1973)	6	5	Corriedale and Border Corriedale
Coop (1973)	7	6	Corriedale
Anon. (1977)	10	4-5	Romney
Hight and Jury (1970)	5	5	Romney

* LT/EJ = lambs tailed per ewe joined.

Overseas research shows that the age at which maximum lamb production is reached is similar to that found in New Zealand (Table 2.3). Some researchers found that the maximum production was reached in older sheep. This difference could be due to the management of the ewe and/or the locality in which the trial was carried out. The reliability of experiments in which ewes have been taken to old ages is doubtful due to the lack of numbers included in the trials brought about by culling and deaths.

The increase in lambing percentage with age has been shown by Dickerson and Glimp (1975), Hight and Jury (1970) and Turner and Dolling (1965) to be caused by an increase in the incidence of multiple births

TABLE 2.3

SUMMARY OF THE OVERSEAS LITERATURE SHOWING THE EFFECT OF EWE AGE ON LAMB PRODUCTION

Authors	Oldest Age Group (Yrs)	Age of Maximim		Breed
		LW/EJ* (Yrs)	LT/EJ** (Yrs)	
Campbell (1962)	10	7		Rambouillet
Dickerson and Glimp (1975)	9		4	Dorset and Rambouillet
Dickerson and Glimp (1975)	9		5	Corriedale and Suffolk
Dickerson and Glimp (1975)	9		5-6	Hampshire
Gregory, Roberts and James (1977)	9		5	Dorset
Gregory, Roberts and James (1977)	9		3	Border Leicester
Mullaney and Brown (1969)	7	7		Corriedale
Mullaney and Brown (1969)	6	6		Polworth
Mullaney and Brown (1969)	9	5		Merino
Mullaney and Brown (1970)	8	7		Merino
Mullaney and Brown (1970)	8		6	Corriedale
Polách (1960)	7		5	Württemberg
Sidwell, Everson and Terrill (1962)	9+	6		Hampshire, Shropshire, Southdown, Merino and Columbia x Southdale
Turner and Dolling (1965)	10	6		Merino
Vesely and Peters (1965)	7	4		Rambouillet, Romnelet, Corriedale and Romeldale

* LW/EJ = lambs weaned per ewes joined.

** LT/EJ = lambs tailed per ewes joined.

rather than a decrease in the proportion of dry ewes, which was the generally accepted theory. Coop (1973) found that there was a very close relationship between age, liveweight and fertility. In trials covering a variety of country, flat fat lamb farms to extensive hill country, lambing percentage increased with age to five to six years and this was associated with an increase in the ewes' liveweight. The ewes' liveweight declined after the peak at six years of age and this corresponded with a decrease in lambing percentage. The decline in weight is thought to be associated with the decline in the condition of the incisor teeth and the natural ageing processes.

The greater the age at which a ewe attains her maximum production, the older the structure of the flock should be to exploit this increased production to the full. The implications of this are best shown with a static flock of 2,000 ewes in which all replacements are bred. If the 2,000 ewes were spread over seven stock classes then 357 ewe hoggets would be required each year, but if the same flock had only five age classes then 500 ewe hoggets would be required each year. Lambing percentage is only one of a number of factors contributing to a ewe's future production, but as such plays an important part in deciding the optimal age structure of a flock.

2.2.2 Wool Weight

Wool production can be affected by nutrition, stress and the age of the ewe. The age of the ewe has an important effect on wool production. McGregor and Frengley (1976) found that farmers in Canterbury, Otago and Southland estimated the fall in wool weight to be 0.5-1.0 kg. in their older ewes compared with their mixed aged ewes. Quality was also observed to fall. In New Zealand it is generally accepted that wool weight increases until the two-tooth stage and production falls after this peak. The fall is in the order of four percent per annum (Henderson, unpublished data). The following table (Table 2.4) shows that maximum production was reached at three years of age. Care should be taken in extrapolating these results to New Zealand conditions as in each of these studies the ewes were not mated until the four tooth stage. It is common practice in New Zealand to mate ewes to lamb in their two-tooth year. These results, therefore, will not take into account the effects pregnancy and lactation have in the two-tooth year. The table also shows that the wool weight per annum can drop as much as 2.3% to ten years of age. Associated with the drop in wool production is a drop in quality. Although not large it may still play a part in reducing the return from the fleece.

TABLE 2.4

SUMMARY OF OVERSEAS TRIAL WORK INTO THE EFFECT OF AGE ON WOOL PRODUCTION

Author	Oldest Age Group (Yrs)	Age At Maximum Greasy Wool Weight (Yrs)	Age At Maximum Wool Quality (Yrs)	% Decrease In Wool Weight/Annum From Peak	Breed
Brown, et al (1966)	10	3.5	-	2.3	Merino
Mullaney, et al (1969)	6	3.0	2.0	1.0	Polwarth and Corriedale
Mullaney, et al (1969)	10	3.0	2.0	1.8	Merino
Rose, M. (1974)	10	4.0	-	1.6	Merino
Thrift, F.A. &	9	3.0	-	0.9	Dorset
Whiteman, J.V. (1969)	9	4.0	-	1.9	Western

2.2.3 Ewe Death Rates

It is to be expected that ewe death rates will increase with age. The extent to which this increase occurs is an important parameter in deciding what is the optimal age composition of a flock. Very high death rates or a risk of high death rates will make a farmer alter his age classes as the retention of older ewes could make a system unprofitable, especially if the deaths occur prior to parturition. Old ewes should be culled when it becomes unprofitable to retain them and ewe death rate plays an important part in this decision.

The trend shown by Table 2.5 is one of increasing death rate with age. Up to seven years of age the increase in death rate is slow, but after this age the number of deaths experienced increases dramatically. Goot (1951) found that in young ewes of 4 years of age or less, the majority of deaths occurred at parturition or during lactation, but as ewes got older the majority of deaths occurred between tupping and lambing and at parturition. This would suggest that older ewes are less able to handle the stress of carrying a lamb(s) or the stress at parturition. Better feeding in these periods would alleviate this high death rate to a certain extent.

2.2.4 Lamb Death Rates

Barton (1947) found that the percentage of lambs born dead or which died soon after birth decreases up to the 4.5 year stage, then rises with increasing age of the ewe. This is shown clearly in Table 2.6.

TABLE 2.5

SUMMARY OF THE LITERATURE CONCERNING EWE DEATH RATES (%) WITH AGE

Author	AGE (YEARS)												Breed
	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	
Goot (1951)	4.82	3.91	8.21	8.54	11.28	11.59	17.10						Romney
Granger (1944)	0	3.0	7.0	9.0	13.0	19.0	23.0	39.0	58.0	74.0	90.0		Merino
Hickey (1960)	3.03	4.37	5.95	8.6	12.75	18.0	25.51	37.16	52.55	75.21	100.0		Romney
Rose (1972)	7.0	3.0	4.0	13.0	8.0	9.0	5.0						Merino
	5.0	7.0	6.0	11.0	8.0	12.0	13.0	20.0	29.0	52.0	68.0	85.0	
	6.0	3.0	1.0	4.0	1.0	8.0	9.0	16.0	23.0	62.0	63.0	64.0	
	5.0	8.0	7.0	13.0	11.0	14.0	16.0	23.0	30.0	45.0	72.0	100.0	
Turner, et al (1959)	2.4	2.6	1.5	2.1	2.6	2.6	7.3	7.3	1.7				Merino
	5.8	2.7	4.5	0.7	4.7	11.1	18.6	21.2	45.6				
AVERAGE	4.34	4.18	5.02	7.77	8.04	11.70	14.95	23.38	34.26	61.64	78.6	83.0	

TABLE 2.6

LAMB DEATHS ASSOCIATED WITH AGE OF EWE

Age of Ewes (Years)	Lamb Deaths (%)
1.5	12.9
2.5	9.1
3.5	8.1
4.5	4.2
5.5	6.8
6.5	8.1
7.5	4.5
8.5	-
Average	8.8

The greatest proportion of the deaths were from lambs born dead and losses after the three day old stage were small.

2.3 TECHNIQUES FOR ANALYSING THE STOCK REPLACEMENT PROBLEM

I have alread established that we are dealing with a productive system which involves declining stock performance shown by decreases in lamb and wool production and an increase in death rate. This implies that a decision must be made as to what is the best age to cull ewes and suitably replace them. There are three aspects to the replacement problem.

(i) Should the replacement ewes be bred and raised as part of the flock, or purchased?

(ii) If they are purchased, at what age should they be acquired, and

(iii) at what age should ewes be culled from the flock? (Scobie (1968))

The replacement decision is not a decision made solely on productive performance, but one that involves an analysis of the economic variables involved - prices received for wool, cast for age ewes and surplus sheep - as an integral part of the decision process.

A number of approaches to the optimal replacement problem have been tried and these are best summarised under the following headings.

(1) Actuarial Approach.

(2) Linear Programming Models.

(3) Poly-period Linear Programming.

(4) Dynamic Programming.

(5) Simulation Modelling.

2.3.1 Actuarial Approach

This approach to the replacement problem involves relating the flock composition to reproduction and mortality factors, but is limited to use with a self replacing flock. Bryne (1967) used this approach to estimate the optimal culling policy for a breeding flock of constant size using the parameters of age related reproductive rate, death rate and wool growth. Subsequent studies by Turner, et al (1968) and Egan, et al (1972) have taken into account genetic improvement and changing markets respectively.

2.3.2 Linear Programming Models

The linear programming approach has been used to aid the optimal replacement decision by Jardine, et al (1975), Johns and Pearse (1970) and

Townsley and Schroder (1964). Linear programming selects the optimal level of a set of activities each of which has a zero or positive level. The levels these activities can take are constrained by a set of simultaneous equations. The object of the linear programming approach is to solve these equations by generating a set of values for the activities to take while maximising a specific linear function (the objective function).

The price which can be obtained for the cull animal, its expected future production, the returns gained from this production and the animals expected resource requirements over the production period can be taken into account. It is then a case of matching the marginal cost associated with each ewe activity to its marginal returns, taking into account its future production. As farm costs are not all variable, they are assumed fixed in the short term, the marginal cost of retaining a ewe is therefore determined by both the direct costs associated with that ewe (shearing, animal health, etc.) and the opportunity cost of scarce resources (land, labour, etc.) required by other stock activities. A problem with the use of linear programming is that it only represents a static situation. This means that such factors as long term genetic gains from different culling options and variations in stock policy with a developing situation cannot be taken into account. If problems of obtaining the required coefficients are experienced Johns and Pearse (1970) suggest that it is best to use the static situation as moving from a static position may cause compounding of errors.

2.3.3 Poly-Period Linear Programming

This technique extends the use of linear programming from one period, usually a year, to a series of periods. It therefore overcomes the static linear programming problem of only representing the static situation. Instead of maximising present returns poly-period programming models maximise the present value of the expected return over some future period. Bryne and Healy (1969) used this approach to determine optimal sheep breeding policies in both stable and developing situations. This technique could also be used to investigate the effect of genetic gain with time and the effect of seasonal changes with time giving an indication of income flows over time and an appreciation of feed deficit periods.

2.3.4 Dynamic Programming

Throsby (1964) described dynamic programming as being "concerned with processes which involve a sequence of decisions extending over some total time period of definite or indefinite duration". Linear programming implies that the constraints placed on variables are linear whereas dynamic programming is able to handle non-linearity and discontinuity. Dynamic programming can thus be used to study the whole decision process, giving at the same time an indication of the sensitivity of the optimal policies to variations in various parameters. The adaptability of this technique makes it ideal for use where probabilistic elements need to be incorporated into a study, and this makes it a suitable technique for studying the replacement problem. Use of dynamic programming for this type of study has been limited because adequate data and computing facilities have not been available. Throsby (1964) gave a general model and McArthur (1973) used dynamic programming to find the optimal culling policy for a dairy herd.

2.3.5 Simulation Modelling

Simulation modelling is a comparatively new technique and the use of it for stock replacement analysis has been negligible. Dent (1971) describes the use of the simulation technique to find the optimal stock policy for a pig unit, using a skeleton modelling approach. Skeleton models have the advantage that they can be added to in the future to enable a whole farm model to be developed. A simulation model allows a total appreciation of a stock system and parameters within that system can be easily varied to allow sensitivity analysis of coefficients which were imprecisely quantified in setting up the model.

CHAPTER III

SURVEY AND EXPERIMENTAL WORK

3.1 A SUMMARY OF THE SURVEY OF THE PRACTICE OF RUNNING GUMMY EWES[1]

3.1.1 Description

In the late winter of 1976 a personal interview survey was carried out in Canterbury, Otago and Southland to investigate the factors involved in running gummy and broken mouthed ewes and their expected production and financial returns[1]. Fifty-eight farmers were interviewed, 26 in Canterbury, 8 in Otago, and 24 in Southland. Of these 58 farmers, 50 were accepted for the purposes of the survey. The eight were excluded because insufficient information was available or because the practice of running gummy ewes had only begun in the 1976/77 season. Accurate information comparing the performance of mixed age and gummy ewes with respect to wool weights, lambing percentages, losses, age of ewes, etc. was hard to obtain and the survey results in the main represent opinions based on the farmers' experience with running these sheep. The questionnaire covered a range of aspects effecting the management practice and was helpful in giving indicative information leading to this further research.

3.1.2 General Information

The farms included in the survey ranged in size from 20 ha to

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[1] Results presented as "A Survey of the Economics and Management of Gummy Ewes", Lincoln College, Department of Farm Management and Rural Valuation, Discussion Paper No. 2, McGregor, M.J. and Frengley, G.A.G. (1977).

6,880 ha. These farms were fattening and breeding or intensive livestock fattening units having stocking rates within the range 2.0 s.u./ha. to 20 s.u./ha. The number of gummy ewes held each year had increased on 45 percent of the surveyed farms with no change being shown on 39 percent of the surveyed farms in the period 1973-76.

3.1.3 Management of Gummy Ewes

The Romney ewe was the main breed represented on the surveyed farms. The average age of these gummy ewes was six years old and the oldest ewes being held were twelve years old. Mouths generally failed at five years of age, but this varied according to breed, area, climate and the type and amount of feed available. The gummy ewes were run as a one year flock, in the main, with only a small number being held for a longer period.

Fifty percent of the farmers purchased gummy ewes. The main criterion for purchase was that ewes had a good constitution and looked as if they would last another year. Breed and price were the next two important factors cited. The farmers who purchased ewes generally purchased fewer than 400 gummy ewes per annum. These ewes met their requirements when buying although in some cases, the policy of buying a mob of freezer ewes and culling those surplus to requirements was practiced. The practice of buying in-lamb ewes was carried out by one farmer. The majority of ewes were bought by private treaty because farmers were wary of buying in ewes of unknown history. The ewes were generally purchased in February to early March.

Half the farmers surveyed rotationally grazed these ewes as a deliberate policy. In 68 percent of the cases the gummy ewes were run separately through the year thus placing an extra burden on labour, but this was thought to be offset by less trouble at lambing. Farmers preferred to feed these ewes soft winter feed, but in two cases a root crop had been fed successfully. Three important points about feeding evident on these farms are that where turnips are fed

(a) feed the tops rather than the bulbs, or

(b) feed root crops which have previously been crushed with a Cambridge roller, or

(c) allow the gummy ewes more time on the root crop compared with full mouthed ewes.

This again required a little more time, but meant little change in the farmers overall management plan. Evidence that very little feed was purchased for the gummy ewes suggests that they were not an added burden on the surveyed farms, but an integral part of the management system.

The earliest lambing date was in July with the majority of farmers lambing in the August-September period. Farmers tended to lamb the gummy ewes at the same time as their main mob ewes, but there was a move evident to lamb them slightly earlier. The earlier lambing allowed farmers to have the lambs from the gummy ewes weaned earlier and where possible to cull these ewes to the freezing works earlier. The early lambing ewes tended to take the ram better when compared with the mixed aged flock. Fat lamb sires were the most commonly used rams over the gummy ewes.

There is evidence to suggest that the gummy ewes had a wet-dry problem. In other words the ewes produced a lamb/s but were unable to provide milk because no milk was produced or the ewes' udder was in bad condition. It is thought to be attributed to the age of the ewes. The wet-dry problem caused problems for farmers at lambing if too many twins were born. There would appear to be less dry-dry ewes as these had been eliminated in earlier years.

Gummy ewes were culled for both constitution and age, but the major factor on the surveyed farms was age. The reason for this was that farmers held these ewes only as a one year flock regardless of constitution at the end of that year. This judgement may be unsound in the light of other findings shown in the survey.

Ewes were culled in the January-February period as killing space was unavailable any earlier. If space was available farmers would have preferred to have their ewes killed in December. The practice of selling ewes and lambs all counted was used by two farmers, but would have been used by others if there had been a feed shortage in the early spring.

3.1.4 Expected Production From Gummy Ewes

The feeling of the farmers participating in the survey was that the lambing percentage from their gummy ewes was approximately 10-15 percent higher than that of their mixed aged ewes (including two-tooths). The factors they thought to be responsible for this increased lambing percentage were:

(a) their gummy ewes, in the majority of cases, were fed better than their mixed aged ewes at most times during the year, affecting flushing and pre-tupping body weights.

(b) the condition of the ewes was maintained at a constant level and not allowed to alter much.

(c) the fact that as a ewe gets older her productivity will rise to a plateau. This means that the gummy ewes, because of their age should produce more lambs than the younger mixed aged ewes.

(d) the incidence of fewer dry ewes.

Some farmers preferred not to get a higher lambing percentage because they felt there was a wet-dry problem with the gummy ewes and the additional lambs involved more time mothering on lambs at lambing. Also ewes rearing twins tended to loose too much condition post lambing, especially if there was a late spring. This second point could be overcome by earlier weaning or a later lambing, but the first point is thought to be an age related problem.

The majority of farmers found that wool weights were lower from their gummy ewes compared with the rest of their flock (including two tooths). A drop of 1.0 kg. or more was expected by 62 percent of the farmers. Farmers also stated that the wool from the gummy ewes was of lower quality. The major cause of the loss of wool production and quality can be attributed to the age of the sheep, but this may also be due to poor feeding over the summer.

The survey showed that death rates associated with running gummy ewes were slightly higher than would be expected from mixed aged ewes by 2-3 percent. The higher death rate was mainly due to an irreplaceable loss of condition (described generally as fading) and sleepy sickness. The problem would appear to be a feed problem, but age again may be a contributing factor.

The number of old ewe carcasses rejected at the freezing works was thought to be approximately nine percent. This is slightly higher than other cull ewes, but could be a result of poor feeding post-weaning as 88 percent of the farmers interviewed felt their cull ewes were inadequately fed from identification as culls until slaughter.

3.1.5 Financial Data

It was found that the animal health costs associated with running gummy ewes were low as farmers were not prepared to spend much money on these ewes. The farmers felt that this was an area where costs could quite easily be cut. Feed costs were low and only seven farmers had to make extra provision for feed because they were running gummy ewes. Shearing, crutching and freight costs were standard for the areas surveyed. Any differences in these costs were due to the variations in prices between the areas and not because the farms were running gummy ewes.

The average purchase price for gummy ewes was $5.00-$5.70. This, when compared with the average sale price (to the works) for the same ewes of $6.80 shows that there is a premium of $1.80-$1.10 for gummy ewes held for breeding purposes. The average price received for cull ewes was lower than average (of schedule prices for an under 22 kg. E.L. ewe) as were the ewe weights. This could be attributed to the fact that the ewes were poorly fed before slaughter and also the necessity to hold ewes longer in the 1975-76 killing season due to disputes within the freezing industry.

The lambs sold from the gummy ewes were slightly heavier than average (Meat and Wool Boards Economic Service) and prices were comparable with the average prices paid in Canterbury in the 1975/76 season. The possibility of gaining premiums for early lambs in some seasons was put forward by some farmers as a reason for lambing earlier. Another advantage of early lambing would be that lambs could be taken to a heavier weight than normal.

The wool prices were average for the 1975/76 season. The reduced wool production would appear to be a major factor influencing farmers, as too big a drop in wool production may drop returns quite considerably. It is thought that poor feeding over the summer and/or age may be the cause of such a decline in wool weight.

The gross margin analysis showed that over the eight year period 1970-1977, a policy of selling genuine five year olds and breeding own replacements was most profitable in four seasons and overall (Figure 3.1).

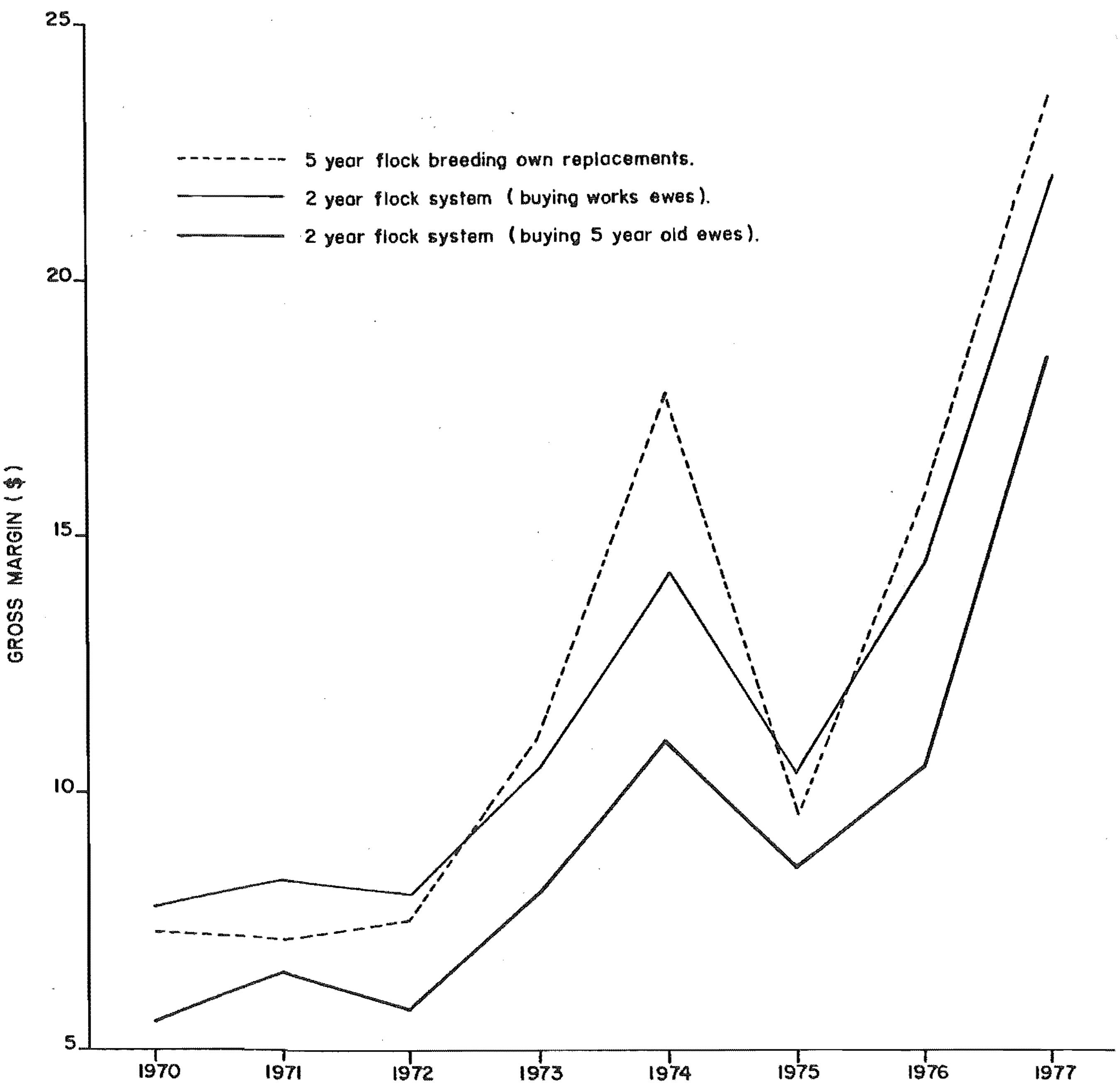

FIGURE 3.1 GROSS MARGIN ANALYSIS OF THREE FLOCK SYSTEMS VERSUS YEAR

This was not the case, however, when the cull ewe price and lamb price received by the farmer differed significantly as in the years 1970, 1971, 1972 and 1975. In this case it was more profitable to have a system of buying works ewes and running these for two years. For the main fattening properties that this survey covered, this latter system would be preferable. Buying works ewes showed a $2.54 advantage over a policy of carrying two year ewes. This higher average gross margin resulted from the higher cost of two year ewe replacements, and the lower animal health costs associated with these ewes.

3.1.6 Conclusions

The overall picture, therefore, is that gummy ewes could be expected to drop approximately 1 kg. of wool and have slightly higher losses compared to a mixed age flock, but would produce approximately 10-15 percent more lambs. This, when fitted into a two year flock system buying gummy ewes, would seem to be optimal for a fattening property. Gummy ewes represent a bank of genetic material which is lost to the New Zealand sheep industry when their quality has only just been realised. Ewes could be held for one extra lambing reducing the demand for lamb replacements, reducing the annual kill and the volume of old mutton and increasing the effective kill, and the volume of fat lambs.

3.2 SUMMARY OF TRIAL WORK

3.2.1 Introduction

From the results of an earlier survey (McGregor and Frengley, 1977) it was obvious that there were in fact differences in the production and the management requirements of "broken", and "gummy" mouthed ewes when compared with younger ewes. The survey showed that an increase in lambing percentage, a decrease in wool weight, higher losses and the need for better care prior to lambing were characteristics of this class of stock. Four trials were carried out, under both high and low rainfall conditions in Canterbury, with the aim of quantifying the production differences and also to help get a true understanding of the management requirements of broken and gummy mouthed ewes.

3.2.2 Methods Used

Three of the four trials were carried out on the property of Mr R.O. Pridie near Methven (Trials 1, 2 and 3) and a fourth (Trial 4) at Ashley Dene, the Lincoln College dryland farm.

The property of Mr R.O. Pridie is situated nine kilometres from Methven. The property is an intensive fattening property running Romney ewes at a stocking rate of 19.05 s.u./ha. The soil types; Gorge Silt Loam, Mayfield Stony Silt Loam and Wakanui Clay Loam, and a reliable, fairly evenly spread rainfall of 1,100 mm. makes the property ideally suited to the all grass wintering system practised.

Ashley Dene on the other hand is a dryland property situated ten kilometres from Lincoln College. This property is also an intensive fattening property.

First cross Border Leicester cross Corriedale ewes are run at a stocking rate of 12.0 s.u./ha. The average yearly rainfall is 600 mm. which is winter dominant. The property is prone to drought from the late spring through to mid-autumn. The climate and the soil type, Eyre very stony silt loam, makes the property suited to a large proportion of lucerne. Turnips and Tama ryegrass are grown for use in the winter.

Trial 1

In late March 1976 the old ewes which were to be retained were mouthed and split into four groups according to mouth condition and age. A fifth group taken from the main flock ewes of 2-5 year olds, was used as a control. The characteristics and number of ewes in each group are shown in Table 3.1.

TABLE 3.1

CHARACTERISTICS AND NUMBERS OF EWES INCLUDED IN TRIAL 1

Group	Age (Years)	Condition of Mouth	Number
A	6	Broken	19
B	6	Gummy	25
C	7 and 8	Broken	35
D	7 and 8	Gummy	58
Control	2 - 5	Good	50

All the ewes on the property were wintered as one mob in a rotational grazing system. This involved the mob being shifted every four days into a new 8 ha. paddock receiving hay on the third and fourth days. The rotation was sped up prior to lambing. All ewes were set stocked for lambing which started on the 1 September. Ewe liveweights, fleece weights and lambing data (number of single and twin births, and ewes and lambs dying) were recorded.

Trial 2

This trial was similar to Trial 1 with the following exceptions.

(i) Only two groups of ewes were represented in this trial. These were "gummy" mouthed (63 ewes) and "broken" mouthed (43 ewes). Production from a control group taken from the main flock ewes was recorded, but accurate data at lambing was not obtained for the reasons outlined below.

(ii) The trial ewes were only rotationally grazed with the rest of the flock from the beginning of August. Unlike the previous trial the ewes were set-stocked until after lambing on better feed under no competition from younger and better mouthed ewes. The reason for this extra feed boost prior to lambing was to avoid loss of liveweight in early August. When the ewes were separated there was not adequate feed for the control ewes to be run with them so any comparisons made from this trial should be regarded with care.

The ewe liveweights, fleece weights and lambing data were again recorded.

Trial 3

In March 1978 the trial ewes were mouthed and split into three groups; "gummy" mouthed (64), "broken" mouthed (51) and control (35). The "gummy" and "broken" mouthed ewes were six to ten years of age whereas the control ewes varied from two to five years of age. The trial ewes were wintered within a mob of 1,500 two year old and stud ewes. The trial ewes were run with these ewes as it was hoped that the competition for feed that the old ewes had experienced in earlier trials would be reduced. The mob was rotationally grazed throughout the winter. A system of shifting every fourth day and feeding hay on the third and fourth days was used. The interval between shifts was reduced to two-days prior to lambing. At lambing on the 1 September, the ewes were set stocked. Ewes and lambs were mobbed up after tailing and again rotated around paddocks. Ewe liveweights were recorded until just prior to lambing. Lambing data was recorded as described in Trial 1, but no fleece weights were recorded because of the inconvenience it caused in the shearing shed.

Trial 4

In early February 1977, 391 six and seven year old ewes were mouthed and put into the following groups.

(i) "Gummy" mouthed - 131 ewes.

(ii) "Broken" mouthed - 159 ewes.

(iii) Full mouthed - 101 ewes.

These ewes were grazed on pasture from tupping in mid March until the end of May with an ad libitum ration of hay being fed between the end of March until end of May. The ewes were then break fed turnips and given a supplement of hay until mid-July when they were set stocked on turnips for two weeks. Prior to lambing greenfeed (Tama ryegrass and a Tama ryegrass-oats mix) was fed to the ewes. At lambing, 18 August, the ewes were being fed greenfeed and saved pasture. They were mobbed up with their lambs at tailing and rotational grazed on lucerne. Ewe liveweights, fleece weights and lambing data were recorded as in Trial 1. In addition the lambs were weighted at birth and at twenty day intervals until they were 80 days old.

3.2.3 Results

(a) Ewe liveweights. Figures 3.2, 3.3, 3.4, and 3.5 show the

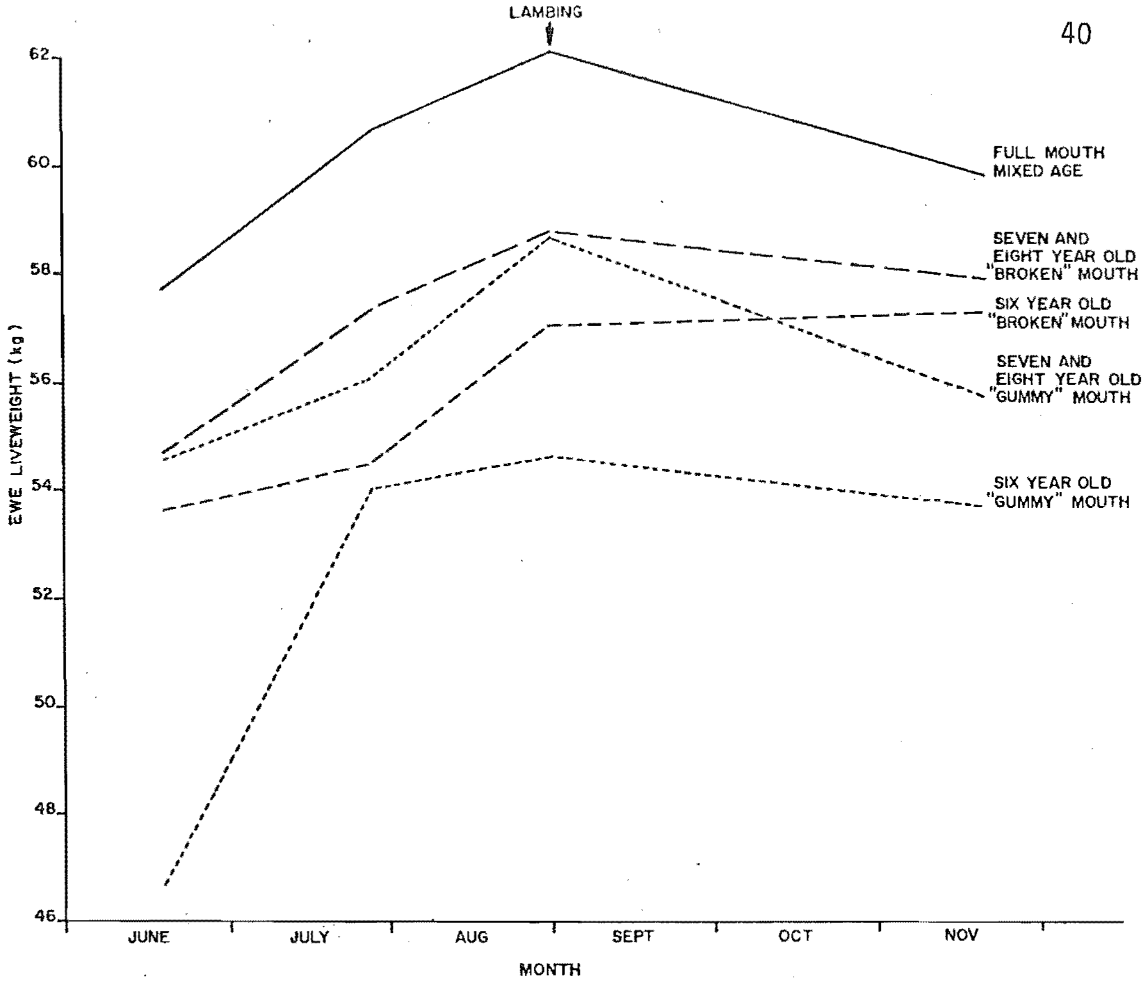

FIGURE 3.2 EWE LIVEWEIGHTS (Trial I)

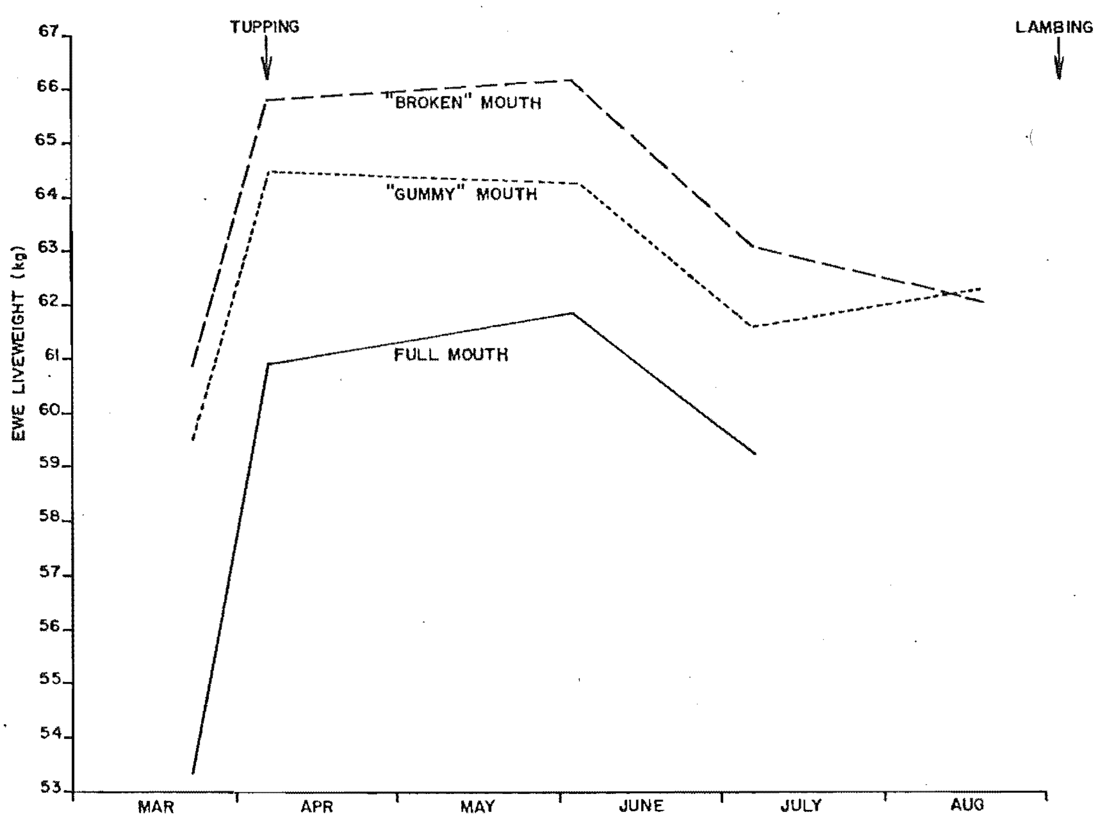

FIGURE 3.3 EWE LIVEWEIGHTS (Trial 2)

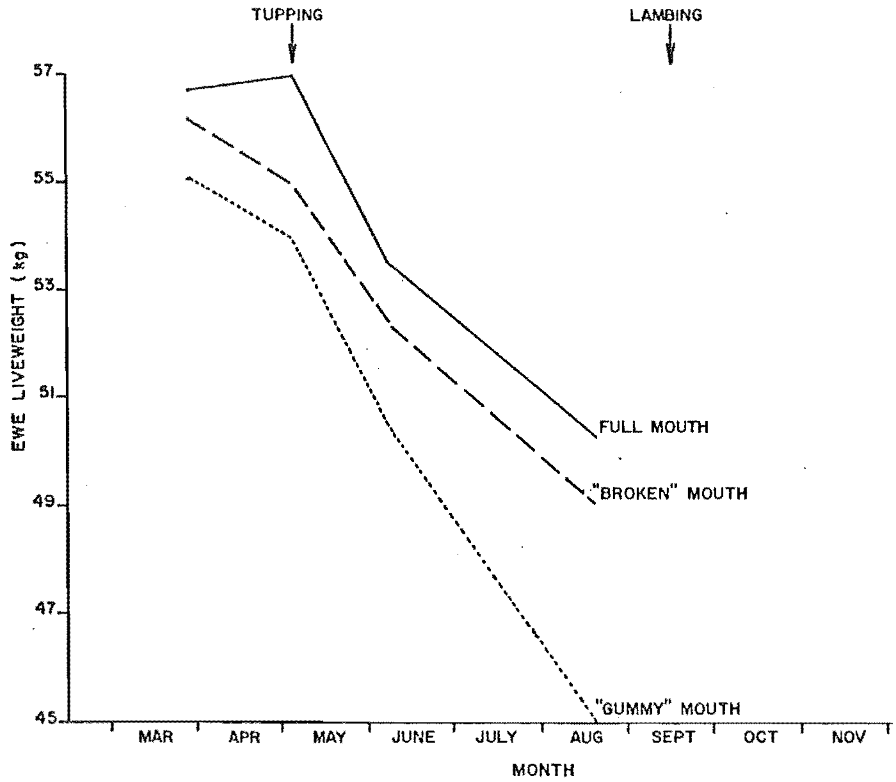

FIGURE 3.4 EWE LIVEWEIGHTS (Trial 3)

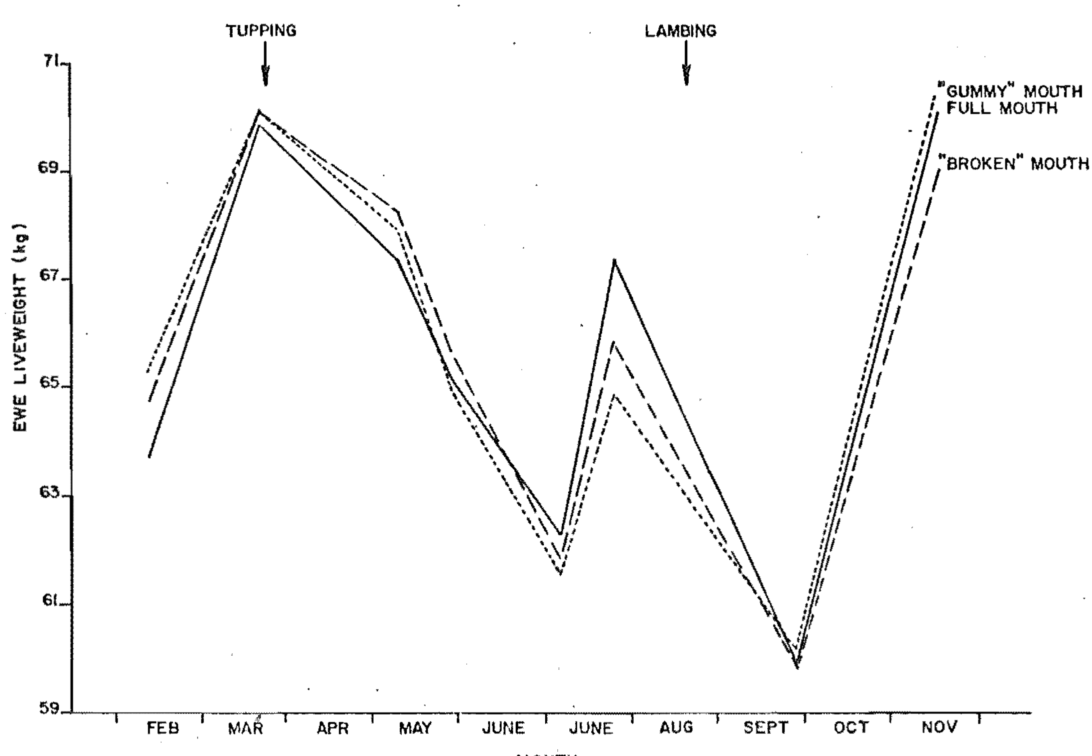

FIGURE 3.5 EWE LIVEWEIGHTS (Trial 4)

liveweight records for the four trials. The liveweight of the ewes in Trial 1 rose until lambing and fell thereafter. The "gummy" mouthed ewes showed a slightly higher weight loss post-lambing compared with the "broken" and full mouthed ewes. In Trial 2 the full mouthed ewes started the trial in lighter condition, but their pre-tupping liveweight gains were high. All groups of ewes lost a similar amount of weight until the end of July when the "broken" and "gummy" mouthed ewes were removed from the rotational grazing regime to set stocking. The removal of the ewes from the large mob halted the drop in liveweight and the "gummy" mouthed ewes in fact gained weight prior to lambing. The liveweights in Trial 3 show the effects a poor autumn can have on ewes. Only the full mouthed ewes gained weight prior to tupping and all ewes lost weight after tupping. The greatest weight loss was shown by the "gummy" mouthed ewes. The Border-Corriedale ewes (Trial 4) showed very little difference in weight over the trial period. The liveweight of the ewes increased before tupping and was allowed to drop until six weeks before lambing when liveweight increased. After lambing the liveweight decreased, but rose again in mid to late September.

(b) Lambing percentage. The lambing percentage results are presented in Table 3.3. The older ewes, both "gummy" and "broken" mouthed, had a higher lambing percentage than the mixed aged ewes in Trial 1. The "broken" mouth and "gummy" ewes had 22.5% and 26.5% more lambs respectively than the younger ewes. It is also shown that the seven and eight year old ewes had a higher lambing percentage than similar ewes which were six years old. It was evident in this trial that the "gummy" ewes had a higher lambing percentage compared with the broken mouthed ewes and that this increase was due to the greater number of twin lambs produced, i.e. 61% compared with 52.5% respectively.

TABLE 3.2

SUMMARY OF THE TRIAL RESULTS

Trial Number	Age (Years)	Condition of Mouth	Lambs Born / Ewes Mated (%)	Lambs Tailed / Ewes Mated (%)	Lambs Sold / Ewes Mated (%)	Single Births (%)	Twin Births (%)	Triplet Births (%)	Ewe Deaths Mating to Tailing (%)	Wool Weight (kg)
Trial 1	2T-5	Good	109	96	-	-	-	-	3	4.22
	6	Broken	127	110	-	58	42	-	0	3.81
	6	Gummy	140	116	-	43	57	-	8	
	7-8	Broken	146	127	-	37	63	-	4	
	7-8	Gummy	148	129	-	35	65	-	2	
Trial 2	2T-5	Good	127	107	-	-	-	-	7	4.46
	6-8	Broken	50	48	-	38	57	-	65	3.83
	8-9	Gummy	102	98	-	25	67	5	38	3.45
Trial 3	4-5	Good	136	120	-	60	40	-	29	-
	6-8	Broken	123	113	-	77	23	-	24	-
	8-10	Gummy	124	98	-	76	24	-	34	-
Trial 4	2T-5	Good	-	-	130	-	-	-	5	3.70
	6-7	Good	-	-	101	27	67	6	27	3.22
	6-7	Broken	-	-	104	25	65	10	32	3.32
	6-7	Gummy	-	-	97	23	70	7	38	3.20

The results of Trial 2 show that the "broken" mouthed ewes had a very low lambing percentage (lambs tailed/ewes mated), however, the "gummy" mouthed ewes had only a 9 percent lower lambing percentage than the mixed aged ewes. Bad weather over lambing and loss of condition in the trial ewes in late pregnancy were the major factors causing the low lambing percentages. This is borne out by the very high death rate recorded by the "broken" mouth trial ewes.

The lambing percentage (lambs tailed/ewes mated) from Trial 3 show that both the "broken" and "gummy" mouthed ewes had lower lambing percentages than the mixed aged ewes. The results also show that the number of twins born was low for all three groups. This is possibly due to poor feeding before and during tupping. Lack of feed in the late-winter period also contributed to high ewe and lamb losses.

The Ashley Dene trial (Trial 4) shows that the lambing percentage (lamb survival to sale/ewes mated) of the six and seven year old ewes was considerably lower than that of the mixed-aged ewes. It should be noted, however, that the mixed aged ewes lambed later than the old ewes and therefore missed the inclement weather experienced when the old ewes were lambing. A ten percent incidence of Hairy-shaker disease in the lambs born to trial ewes also had a major effect on the trial results as the majority of lambs with this condition died at or soon after birth. Age of the ewe clearly plays a part in the results of this experiment in that the older ewes had a lower lambing percentage; the condition of the mouth has also been shown to have an effect. This trial again showed that there was a greater incidence of multiple births from the older trial ewes.

(c) Ewe death rate. The ewe death rates in each of the four trials are shown in Table 3.3 Ewe death rates were relatively low in the first trial (Trial 1), but in the other three trials the death rate from the older ewes was considerably higher than younger sheep on the property. The high death rate experienced by these ewes is a reflection on their age (Trial 3 and 4) and the condition of the ewe's mouth (Trial 4). The average death rate of 25 percent obtained from the "broken" and "gummy" mouthed ewes in the four trials illustrates how susceptible these ewes are to any stress, particularly a feeding stress in mid to late pregnancy.

(d) Lamb growth rates. Weighing of lambs at birth and in the following 80 days was only carried out in Trial 4. The results of this work are presented in the following table.

TABLE 3.3

RESULTS OF LAMB WEIGHINGS IN TRIAL 4

Age of Ewe (Years)	Condition of Mouth	Lamb Birth Weight (kg)	Lamb 20 Day Weight (kg)	Lamb 40 Day Weight (kg)	Lamb 80 Day Weight (kg)
6 - 7	Good	5.03	9.39	14.06	26.73
6 - 7	Broken	4.84	9.52	13.49	27.25
6 - 7	Gummy	5.09	9.25	13.42	27.24

The above values have been corrected for age, sex and birth rank. It is clear from these results that the condition of the ewe's mouth had no effect on the lamb birth weight and subsequent growth rate. Although the birth and growth rates of lambs from the other three trials were not recorded it seemed from observation that the lambs from "broken" and "gummy" mouthed ewes were slower to mature and the ewes were in a lot of cases unable to supply sufficient milk to support the lambs, particularly twins.

(e) Wool weights. The results of the fleece weighings are shown in Table 3.3. It should be noted that the fleece weights shown do not include crutchings. In all trials the wool weights of the "broken" and "gummy" mouthed ewes are below that of the mixed aged flock. The results also show that the wool weights of the "broken" mouth ewes are higher than those of the "gummy" mouth ewes. The average wool weights of the "broken" and "gummy" mouthed ewes were 0.51 kg and 0.76 kg lower than the average wool weight of the mixed aged ewes. The results of Trial 4 clearly show that age has an effect on the wool weight. The older good mouthed ewes had a wool weight 0.48 kg lighter than the younger good mouthed ewes.

3.2.4 Conclusions

The four trials have shown that old ewes and particularly those with poor mouths cannot stand feeding stress, particularly in mid to late pregnancy. Once these ewes loose condition it was found that they continued to loose weight and the ewes invariably died. Trials 1-3 showed that old ewes can be run in a rotational grazing system, but some effort must be made to ensure that competition for feed, particularly from younger ewes, is reduced to a minimum. Trial 4 showed that poor mouthed ewes could be fed turnips to supplement their winter diet, but again it was clear that they needed better treatment. This better treatment being in the form of no competition with younger sheep and a longer period of time on a break of turnips.

Although Trial 1 showed a higher lambing percentage for the older ewes, a lower lambing percentage may be expected under normal conditions. The lower lambing percentage is brought about by high ewe deaths prior to and at lambing. It is clear from the trials, however, that the older ewes produced a higher proportion of multiple births. This is an age related response rather than related to the mouth condition.

The old ewe death rates were found to be higher than that of the mixed aged ewes except in Trial 1 where favourable conditions throughout the trial no doubt played a part. It is obvious, however, that old ewes, and particularly those with poor mouths, need preferential treatment before lambing and that an effort should be made throughout the year to maintain the ewe's liveweight.

Trial 4 showed that mouth condition had no effect on the lamb birth weights and growth rates. It was found in all trials that the incidence of ewes with little or no milk was higher from the older ewes than the younger ewes. This is possibly due to the age of the ewe rather than the condition of the ewe's mouth and hence her ability to graze at lambing.

Wool weights from the "broken" and "gummy" mouthed ewes was found to be lower than for the mixed aged ewes in the trials. The drop in wool weight is related to the age of the ewe, but the condition of the ewe's mouth was also shown to have an effect. The ewe with a "gummy" mouth would use its feed intake to maintain liveweight meaning the energy allocation for wool growth would be small. The loss in wool weight can be as great as 1.0 kg. less than the mixed aged ewes, but with better feeding of these ewes a smaller loss could be expected.

The trials have shown that old ewes can be run on a farm with little or no disruption to the management. It has also highlighted the point that ewes still have productive value after their mouths have worn, even to the toothless or gummy state.

CHAPTER IV

THE LINEAR PROGRAMMING MODELS

4.1 INTRODUCTION

The aims of this study were to determine the optimal stock policy for fat lamb producing farms under dryland and irrigated conditions in Canterbury while at the same time maximising annual profits[1]. The sensitivity of the optimal solutions to changes in the fat lamb, cull ewe and wool prices was then analysed.

A non-stochastic linear programming approach was used. This took the general form -

$$\text{Maximise} \quad Z = \sum_{j=1}^{n} C_j x_j$$

$$\text{subject to} \quad b_i \geqslant \sum_{j=1}^{n} a_{ij} x_j \text{ , where } i = 1,2, \ldots m$$

$$\text{and to all} \quad x_j \geqslant 0$$

where Z = total annual net revenue.

x_j = level of the j^n activity where there are n activities.

C_j = per unit net revenue of the j^{th} activity, being defined as the gross revenue per unit minus the direct costs associated with the j^{th} activity.

b_i = available level of the i^{th} resource where there are m limiting resources.

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1 Annual Profits = Gross Annual Income - Annual Variable Costs.

a_{ij} = the per unit requirement of the j^{th} activity for the i^{th} resource.

The non-stochastic linear programming approach allowed an accurate representation of the problem to be studied and was most suitable for analysing short run changes in profit from a fixed resource base.

Two linear programming models were developed representing typical dryland and irrigated fat lamb producing enterprises in Canterbury. The tableaus developed for these models were solved on the University of Canterbury's Burroughs B6700 computer using the TEMPO linear programming package. The following discussion relates to these two models.

4.2 MODEL DEVELOPMENT

4.2.1 Dryland Model

This model was developed to represent a typical fat lamb producing farm under non-irrigated Canterbury conditions. The term non-irrigated farming implies farming on light land soils which are prone to drought periods, particularly in the summer-autumn period. Large variations in animal production are experienced on these soils due to variations in feed supply brought about by the unreliable climate. The introduction of lucerne has meant that a more reliable feed supply than pasture is available over the summer dry period, but it is winter dormant. This has meant that where large areas of lucerne are grown, provision of winter feed is essential. The traditional stocking practice has been to run an aged Corriedale flock allowing mid-summer destocking. This meant the purchase of five and six year old ewes from the North Canterbury hill country and holding them for one to two years. All ewes were mated to a fat lamb sire. The current trend is towards first cross Border Liecester cross Corriedale ewes mated to a fat lamb sire. This has allowed farmers to take advantage of the first cross hybrid vigour, but has created problems in replacing cull ewes. The possible options are a two flock system of Corriedale ewes mated to a Border Liecester ram to breed replacements with the first cross ewes mated to a fat lamb sire, or the purchase of replacements.

Assumptions made in developing this model are:

(a) the farm size is 300 hectares,

(b) a first cross Border Liecester cross Corriedale flock is run,

(c) replacements for the ewe flock are purchased.

(d) the management of the property is of an average, but easily attainable standard, and

(e) labour and capital are not restricting.

The first three assumptions are representative of the situation on similar farms, operating under these conditions at present. The fourth assumption means that stock and feed management is of such a standard that the potential production of each can be reached. Labour and capital are assumed to be non-restricting as reliable coefficients for each of these resources were unavailable.

The model developed has 310 activities constrained by 109 rows. The activities represented are shown in Appendix A1 and discussion relating to these and the associated constraints follows.

4.2.2 Irrigated Model

This model was developed to represent a typical fat lamb farm under irrigated Canterbury conditions. An area of 80,960 hectares is irrigated by various forms of irrigation in Canterbury. The use of irrigation on fat lamb producing farms has resulted in reliable summer and autumn growth and as a consequence stocking rates have increased. On these irrigated soils, farmers have also moved away from running Corriedale and Border Liecester cross Corriedale ewes (typical in the dryland state) to Coopworth ewes (now typical of the irrigated state). Replacement ewes are obtained by retaining ewe lambs or by buying young stock, particularly two-tooth ewes.

Assumptions made in developing this model are:

(a) the farm size is 200 hectares,

(b) a Coopworth flock is run,

(c) the model represents an all grass system with no cash or greenfeed cropping,

(d) the management of the property is of an average, but readily attainable standard, and

(e) labour and capital are not restricting.

The first three assumptions, although restricting the scope of the study, are representative of current practice. The model has been constructed to enable these assumptions to be easily examined. The fourth assumption means that stock and feed management is of such a standard that the potential production of each can be reached. Labour and capital are assumed to be non-restricting as reliable coefficients for each of these resources were unavailable.

The irrigation model has 207 activities constrained by 90 rows. The activities represented are shown in Appendix A2 and a discussion of these and the associated constraints follows.

4.3 THE OBJECTIVE FUNCTION

The objective in both models was to maximise the net revenue. The following equations, one representing the non-irrigated and the other irrigated situation summarise the objective function row used for each modelled situation.

4.3.1 Dryland Farm Objective Function

$$Z = -\sum_{j=1}^{a} A_j r_{ij} - \sum_{j=a+1}^{b} B_j r_{ij} + \sum_{j=b+1}^{c} C_j r_{ij} +$$

(Net revenue) (Buy stock) (Lamb and wool production) (Sell cull ewes)

$$\sum_{j=c+1}^{d} D_j r_{ij} + \sum_{j=d+1}^{e} E_j r_{ij} - \sum_{j=e+1}^{f} F_j r_{ij} - \sum_{j=f+1}^{g} G_j r_{ij} -$$

(Sell lambs) (Sell wool) (Pasture and lucerne feed supply) (Pasture and lucerne renewal)

$$\sum_{j=g+1}^{h} H_j r_{ij} - \sum_{j=k+1}^{l} L_j r_{ij} - \sum_{j=l+1}^{m} M_j r_{ij} - \sum_{j=m+1}^{n} N_j r_{ij} \quad (3:1)$$

(Forage crops) (Make hay) (Feed hay) (Buy hay)

where: a = 1, ..., 7 b = 8, ..., 53 c = 54, ..., 64

d = 65, ..., 73 e = 74 and 75 f = 76 and 77

g = 78, ..., 80 h = 81, ..., 187 k = 188, ..., 264

l = 265, ...,276 m = 277, ..., 308 n = 309 and 310

4.3.2 Irrigated Farm Objective Function

$$Z = -\sum_{j=1}^{a} A_j r_{ij} - \sum_{j=a+1}^{b} B_j r_{ij} + \sum_{j=b+1}^{c} C_j r_{ij} +$$

(Net revenue) (Buy stock) (Lamb and wool production) (Sell cull ewes)

$$\sum_{j=c+1}^{d} D_j r_{ij} + \sum_{j=d+1}^{e} E_j r_{ij} - \sum_{j=e+1}^{f} F_j r_{ij} - \sum_{j=f+1}^{g} G_j r_{ij} -$$

(Sell lambs) (Sell wool) (Pasture and lucerne feed supply) (Pasture and lucerne renewal)

$$\sum_{j=k+1}^{l} L_j r_{ij} - \sum_{j=l+1}^{m} M_j r_{ij} - \sum_{j=m+1}^{n} N_j r_{ij} \qquad (3:2)$$

(Make hay) (Feed hay) (Buy hay)

Where: a = 1, ..., 5 b = 6 ..., 52 c = 53, ..., 69

d = 70, ..., 90 e = 91 and 92 f = 93, ..., 96

g = 97, ..., 100 k = 101, ...,177 l = 178, ..., 187

m = 188, ..., 205 n = 206 and 207

The net revenue values for each activity are expressed as gross margins (Appendix B1 and B2). Costs and prices refer to the 1977-78 values. Costs used are per the "Lincoln College Department of Farm Management and Rural Valuation, Farm Budget Manual, Part 2, Financial 1978". Prices for stock and wool were taken from sale reports in "The Press" between December 1977 and March 1978. The values used for buying and selling wool are the average for those activities over that period. Prices used for cull stock sold to the freezing works were per schedule over the same period (December to March).

Once the values for a base model were obtained a parametric analysis of some prices was carried out. The experimentation carried out on both models involved an analysis of the sensitivity of the base model (obtained using 1977/78 prices) to changes in the prime lamb and cull ewe price. The sensitivity of the base runs of each model to changes in the wool price were also investigated.

To test the sensitivity of the models to changes in the prime lamb and cull ewe prices the following four optimisations were completed. They involved simultaneously:

(i) decreasing the lamb price by 20% and increasing the cull ewe price by 20% (Run 1),

(ii) decreasing the lamb price by 10% and increasing the cull ewe price by 10% (Run 2),

(iii) increasing the lamb price by 10% and decreasing the cull ewe price by 10% (Run 3), and

(iv) increasing the lamb price by 20% and decreasing the cull ewe price by 20% (Run 4).

Likewise to test the sensitivity of the models to changes in the wool price another four runs were carried out. These four runs involved;

(i) decreasing the wool price by 40% (Run 5),

(ii) decreasing the wool price by 20% (Run 6),

(iii) increasing the wool price by 20% (Run 7), and

(iv) increasing the wool price by 40% (Run 8).

The actual values used for the above experimentation can be found in Appendix B3.

4.4 STOCK CONSTRAINTS

4.4.1 Feed Demand And Supply Equations

These constraint rows (48 in total) equate the feed demanded by the stock activities with the feed supply. This discussion will concern the feed demand only and the feed supply component of the equations will be discussed below in the section dealing with feed constraints.

The general equation for the dryland model is described below.

$$\underbrace{\sum_{j=a+1}^{b} B_j r_{ij}}_{\text{(Lamb and wool production)}} + \underbrace{\sum_{j=b+1}^{c} C_j r_{ij}}_{\text{(Cull ewes)}} + \underbrace{\sum_{j=c+1}^{d} D_j r_{ij}}_{\text{(Sell lambs)}} - \underbrace{\sum_{j=e+1}^{f} F_j r_{ij}}_{\text{(Pasture and lucerne feed supply)}} -$$

$$\underbrace{\sum_{j=f+1}^{g} G_j r_{ij}}_{\text{(Pasture and lucerne renewal)}} - \underbrace{\sum_{j=g+1}^{h} H_j r_{ij}}_{\text{(Forage crops)}} + \underbrace{\sum_{j=h+1}^{k} K_j r_{ij} - \sum_{j=h+1}^{k} K_j r_{ij}}_{\text{(Feed transfer and substitution)}} +$$

$$\underbrace{\sum_{j=k+1}^{l} L_j r_{ij}}_{\text{(Make hay)}} - \underbrace{\sum_{j=l+1}^{m} M_j r_{ij}}_{\text{(Feed hay)}} \leqslant 0 \qquad (4{:}3)$$

Where:

$a = 1, \ldots, 7$ $\quad b = 8, \ldots, 53,$ $\quad c = 54, \ldots, 64$ $\quad d = 65, \ldots, 73$

$f = 76$ and 77 $\quad g = 78, \ldots, 80$ $\quad h = 81, \ldots, 187$

$k = 188, \ldots, 264$ $\quad l = 265, \ldots, 276$ $\quad m = 277, \ldots, 308$

The general equation for the irrigated model is described below:

$$\underbrace{\sum_{j=a+1}^{b} B_j r_{ij}}_{\text{(Lamb and wool production)}} + \underbrace{\sum_{j=b+1}^{c} C_j r_{ij}}_{\text{(Cull ewes)}} + \underbrace{\sum_{j=c+1}^{d} D_j r_{ij}}_{\text{(Sell lambs)}} - \underbrace{\sum_{j=e+1}^{f} F_j r_{ij}}_{\text{(Pasture and lucerne feed supply)}} -$$

$$\underbrace{\sum_{j=f+1}^{g} G_j r_{ij}}_{\text{(Pasture and lucerne renewal)}} + \underbrace{\sum_{j=g+1}^{k} K_j r_{ij} - \sum_{j=g+1}^{k} K_j r_{ij}}_{\text{(Feed transfer and substitution)}} + \underbrace{\sum_{j=k+1}^{l} L_j r_{ij}}_{\text{(Make hay)}} -$$

$$\underbrace{\sum_{j=l+1}^{m} M_j r_{ij}}_{\text{(Feed hay)}} \leqslant 0 \qquad (4{:}4)$$

where: a = 1, ..., 5   b = 6, ..., 52   c = 53, ..., 69

d = 70, ..., 90   e = 91 and 92   f = 93, ..., 96

g = 97, ..., 100   k = 101, ..., 177   l = 178, ..., 187

m = 188, ..., 205

There are 48 feed demand and supply constraint rows in each model representing sixteen feed periods and three feed qualities. The model year starts in January. Monthly periods are used from November to June inclusive and two weekly periods are used for the remainder of the year. The use of two weekly periods over the winter-early spring period is to enable a more exact analysis of this most critical period. The choice of the shorter time period enables feed supply and demand to be reconciled accurately within a period, therefore reducing the chance of unseen feed surpluses and demands occuring within a period.

Stock feed has two variable characteristics, quality and quantity. Both of these need to be considered when examining a stock system. For this reason the feed units used in this model are mega joules of metabolisable energy per kilogram of dry matter (MJME/kgDM) as they describe both factors accurately. Three qualities of feed are used in the models. These are:

(i) High quality feed $\geq$ 11.0 MJME/kgDM

(ii) Medium quality feed 9 $\leq$ 11.0 MJME/kgDM

(iii) Low quality feed < 9.0 MJME/kgDM

Sheep feed requirements have been studied by Jagusch and Coop (1971). Their paper is a summary of the research work carried out on the maintenance and annual feed requirements of breeding ewes and also on the post weaning feed requirements of lambs. This paper forms the basis of the feed demand information shown in Appendix C.

(a) Feed requirements of replacement ewe lambs (dryland). The feed requirements of the replacement ewe lambs depends on their purchase date and liveweight, and their subsequent management. In the dryland model ewe lambs can only be purchased. It is assumed that they are purchased at the beginning of December, therefore, the replacement ewe lamb activities require 13 months feeding until they reach the two-tooth stage. It is a common practice on dryland farms to mate any ewe lambs which have attained 45 kg liveweight by the end of March. The model, therefore, contains two replacement activities where the ewe lamb is mated to lamb on,

(i) 1 September, and

(ii) 16 September.

A third activity assumes that the ewe lamb purchased in December is reared to 50 kg 13 months later. This activity does not allow for the mating of the ewe lamb. Assumptions as to the liveweight, liveweight gain and feed quality requirements are shown in Appendix C1.

(b) Feed requirements of replacement ewe lambs (irrigated). Replacement ewe lambs can be obtained in two ways in this model,

(i) purchased (1 February), or

(ii) bred from within the flock.

There is no provision made for mating the replacement ewe lambs in the irrigated model. Ewe lambs purchased on 1 February require feed for 11 months, but ewe lambs bred from within the flock require feeding from weaning until the end of December the following year. The feed requirements of ewe lambs, bred from within the flock, depend on their date of birth. A ewe lamb from a ewe lambing in early August will require feed earlier than say one from a ewe lambing in mid-September. Again assumptions as to the liveweight, liveweight gains and feed quality requirements are shown in Appendix C1.

(c) Feed requirements of ewes (dryland and irrigated). The feed requirements are tied to the physiological state of the ewe in the period, its liveweight and the feed quality available. The feed requirements of a ewe varies throughout the year with the critical feed periods being at tupping and the three months encompasing parturition. They also vary according to the lambing date of the ewe. Moving the lambing date back or forward by two weeks means a proportionate shift in the ewe feed requirements. As there are four lambing dates used in the model, there are four feed requirement profiles for each ewe age group (Appendix C2). Low quality feed is used solely to supply maintenance and sub-maintenance feed requirements. Medium and high quality feed, on the other hand, can be used to meet above maintenance feed requirements or substituted to meet maintenance and sub-maintenance requirements.

For the purposes of this study the ewe liveweight has been assumed to be constant throughout the year. Although this is not the case in the real situation, changes in the physiological state take the variation in liveweight within the year into account. The ewe liveweights, and consequently ewe feed requirements, increase with age from the two-tooth stage to six years of age. After six years the ewes are assumed to have broken or "gummy" mouths and liveweight will fall due to age and feeding problems (Appendix C2). The drop in liveweight is 3 kg per year.

The seven, eight and nine year old ewes are represented by two activities for each of the four lambing dates. One of these activities has feed requirements as described above. The other activity assumes that there is a ten percent higher feed requirement for the ewe for the six week period prior to parturition. The extra feed has the effect of reducing the death rate and also increasing the lamb survival rate compared with a ewe of the same age and lambing date not fed this increased ration.

(d) Feed requirements of cull stock (dryland and irrigated). All cull ewes are sold in ewe fairs (mid February) or to the freezing works (end February). They, therefore, require feed in January and February. The level of feeding depends on where the ewes are to be sold. The aim when selling excess ewe lambs and two-tooths is to have them as heavy as possible at the date of sale. Cull ewes sold to the freezing works are fed a sub-maintenance diet over this period as the feed they consume can be used to fatten lambs or hoggets. The assumptions made in calculating the feed requirements of cull ewes are included as Appendix C3.

(e) Feed requirements of fattening lambs (dryland and irrigated). Wether lambs not sold fat off the mother at weaning are fed until they reach a killable weight. The amount of feed a wether lamb requires depends on when it was born and its weaning date. For the purposes of this study it has been assumed that 70% of the lambs to be fattened reach a killable weight six weeks after weaning. The remaining lambs, i.e. 30%, take eight weeks to fatten to a killable weight post-weaning. The first 70% of the lambs are fattened from 20-25 kg liveweight and the remaining 30% from 18-25 kg liveweight. This assumes that growth rates of 119 gms/day and 125 gms/day respectively are attained. Appendix C4 outlines the assumptions made and the feed required for wether lambs not sold fat off the mother.

4.4.2 Stock Reconciliation Equations

The stock reconciliation constraints facilitate the transfer of stock from one ewe activity, i.e. two-tooth, to the next age group activity, i.e. four-tooth. The constraints allow ewes to be purchased, transferred or sold. The general equation which covers these constraints for the dryland and irrigated models is described below.

$$- \sum_{j=1}^{a} A_j r_{ij} \quad + \sum_{j=a+1}^{b} B_j r_{ij} \quad - \sum_{j=a+2}^{b} B_j r_{ij} \quad + \sum_{j=b+1}^{c} C_j r_{ij} \leqslant 0 \qquad (4:5)$$

(Buy stock) (Lamb and wool production) (Sell cull ewes)

Where: a = 1, ..., 7 b = 8, ..., 53 c = 54, ..., 64

in the dryland model, and

a = 1, ..., 5 b = 6, ..., 52 c = 53, ..., 69

in the irrigated model.

(a) Dryland model. An assumption has been made above that replacement stock are purchased. The model enables ewe lambs, two-tooths and five, six and seven year old ewes to be purchased. The purchased ewes are transferred directly to their respective ewe activities (Table 4.1). Transfer from the four year old activity to the next activity (five year old), occurs with associated deaths of seven percent. The death rates for each age group are shown in Appendix D. Death rates have been assumed to rise with age. At the end of the model year any ewe lambs, two-tooths, and four to ten year old ewes excess to requirements are transferred to the sell cull ewe activities.

(b) Irrigated model. As it was assumed that Coopworth ewes were run under the irrigated conditions, replacement stock could be bred from within the flock. Special reconciliation rows were needed (Table 4.2) to allow ewe lambs produced by two-tooth to six year old ewes to be used as flock replacements. Options to purchase ewe lambs are also available as are options to sell ewe lambs at the sale-yards (as store or replacement) or to the freezing works (as prime lambs). There are eight reconciliation rows, two for each lambing date; tieing the ewe lambing date to its

TABLE 4.1

DETACHED COEFFICIENT MATRIX SHOWING STOCK RECONCILIATIONS

Constraint \ Activity	Buy Five Year Old	Buy Six Year Old	Six-Tooth	Four Year Old	Five Year Old	Six Year Old	Seven Year Old A[1]	Seven Year Old B[2]	Sell Five Year Old	Sell Six Year Old	
Six-Tooth Reconciliation			+1.0								≤ 0
Four Year Old Reconciliation			-0.95	+1.0							≤ 0
Five Year Old Reconciliation	-1.0			-0.93	+1.0				+1.0		≤ 0
Six Year Old Reconciliation		-1.0			-0.92	+1.0				+1.0	≤ 0
Seven Year Old Reconciliation						-0.88	+1.0	+1.0			≤ 0
Eight Year Old Reconciliation							-0.85	-0.82			≤ 0

1. A refers to the ewe activity receiving a ten percent increase in feed six weeks prior to parturition.

2. B refers to the ewe activity receiving normal feeding prior to parturition.

TABLE 4.2

DETACHED COEFFICIENT MATRIX SHOWING IRRIGATED MODEL STOCK RECONCILIATIONS

Constraint \ Activity	Buy Ewe Lamb	Rear Ewe Lamb(S)[1]	Rear Ewe Lamb(P)[2]	Two Tooth	Four Tooth	Six Tooth	Sell Ewe Lamb	Sell Two Tooth	Sell Store Lamb	Sell Lamb Fatoff Mother	
Ewe Lamb Re-conciliation(S)[1]	-1.0	+1.0		-0.219	-0.228	-0.238	+1.0		+1.0		≤ 0
Ewe Lamb Re-conciliation(P)[2]			+1.0	-0.219	-0.228	-0.238				+1.0	≤ 0
Two-Tooth Reconciliation		-0.94	-0.94	+1.0				+1.0			≤ 0
Four-Tooth Reconciliation				-0.96	+1.0						≤ 0
Six-Tooth Reconciliation					-0.96	+1.0					≤ 0
Four Year Old Reconciliation						-0.95					≤ 0

1. S refers to lambs in store condition at weaning.

2. P refers to lambs in prime condition at weaning.

appropriate rearing activity, and one each for lambs in prime and store condition at weaning. It has been assumed that ewe lambs represent half of the lambs produced by the ewe activity. Subsequent reconciliations, allowing transfer between age groups, are as described above for the dryland model. Ewe death rates are also the same (see Appendix D1).

4.4.3 Lamb Reconciliations

The following equation is the general equation explaining the lamb reconciliations for both models.

$$- \sum_{j=a+1}^{b} B_j r_{ij} \quad + \quad \sum_{j=c+1}^{d} D_j r_{ij} \quad \leqslant \quad 0 \qquad (4:6)$$

(Lamb and wool production) (Sell lambs)

Where: $a = 1, \ldots, 7$ $b = 8, \ldots, 53$ $c = 54, \ldots, 64$ $d = 65, \ldots, 73$ in the dryland model, and

$a = 1, \ldots, 5$ $b = 6, \ldots, 52$ $c = 53, \ldots, 69$ $d = 70, \ldots, 90$ in the irrigated model.

These reconciliations allow lambs produced by the ewes to be sold in separate activities.

Assumptions as to the lambing percentages used for each age group can be found in Appendix D2. Lambing percentage in this case is assessed as lamb survival to sale from ewes put to the ram. Lambs are produced by all ewe activities, with the exception of one ewe lamb activity in the dryland model and all ewe lamb activities in the irrigated model. The lambing percentage rises with age to five years of age and then falls. The lambing percentage is a function of liveweight and age, Coop (1973). Seven, eight and nine year old ewes have two activities associated with each lambing date. One of these activities requires ten percent more feed for the six weeks prior to lambing. Ewes in these activities are assumed to have a ten percent higher lambing percentage. This higher lambing percentage is due to fewer ewes dying prior to and during lambing. These ewes will have a greater ability to rear lambs, particularly twins, because of this pre-lambing feed boost thus reducing lamb deaths.

The ewes produce two types of lambs at weaning.

(a) prime lambs which can be weaned prime off the mother (F.O.M.), and

(b) lambs in store condition.

Table 4.3 shows the form of the reconciliations dealing with both types of lamb. At weaning, early lambing ewes (1 and 16 August), produce 40% prime lambs while later lambing ewes (1 and 16 September) produce 50% prime lambs. This is a reflection of the greater bulk of good quality feed available to later lambing ewes. The remainder of the lambs, 60% and 50% respectively, are weaned in store condition. Lambs in prime condition at weaning can be sold at the freezing works as prime lambs or in the irrigated model the prime ewe lambs can be retained as replacements for the ewe flock (Table 4.2). Lambs in store condition at weaning can be sold as store lambs at the saleyards or fed until they reach a prime condition at which stage they are sold as prime lambs at the freezing works. The store ewe lambs produced in the irrigated model also have another option, that of being retained for replacements to the ewe flock (Table 4.2).

4.4.4 Wool Reconciliations

The general equation for these reconciliations is;

TABLE 4.3

DETACHED COEFFICIENT MATRIX SHOWING LAMB AND WOOL RECONCILIATIONS

Constraint \ Activity	Four Year Old	Five Year Old	Six Year Old	Seven Year Old A[1]	Seven Year Old B[2]	Sell Store Lamb	Fatten Lamb	Sell Lamb F.O.M.[3]	Sell Wool C[4]	Sell Wool D	
Lamb Reconciliation	-0.71	-0.725	-0.70	-0.625	-0.60	+1.0	+1.0				⩽ 0
Fat Off Mother Reconciliation	-0.71	-0.725	-0.70	-0.625	-0.60			+1.0			⩽ 0
Wool Reconciliation C	-4.3	-4.1	-3.8						+1.0		⩽ 0
Wool Reconciliation D				-3.7	-3.6					+1.0	⩽ 0

1. A refers to the ewe activity receiving a ten percent increase in feed six weeks prior to parturition.

2. B refers to the ewe activity receiving normal feeding prior to parturition.

3. F.O.M. refers to lambs weaned fat off their mothers.

4. C refers to a higher quality wool than D.

$$- \sum_{j=a+1}^{b} B_j r_{ij} + \sum_{j=d+1}^{e} E_j r_{ij} \leqslant 0 \qquad (4:7)$$

(Lamb and wool production) (Sell wool)

Where: a = 1, ..., 7 b = 8, ..., 53 d = 65, ..., 73 e = 74 and 75

in the dryland model, and

a = 1, ..., 5 b = 6, ..., 52 d = 70, ..., 90 e = 91 and 92

in the irrigated model.

There are two of these reconciliations to represent two wool qualities,

(a) higher quality wool from ewes five years old and younger, and

(b) slightly lower quality wool from older ewes.

Wool from the younger ewes is assumed to have a higher quality than from older ewes because the older ewes are more prone to suffering a break in their wool brought about by stress. The break will lower the price received for the wool.

The ewe activities supply wool to the two reconciliations (Table 4.3) and the two demand activities sell the wool. For both models it has been assumed that wool weights are highest for the two-tooth year ewes and fall thereafter (Appendix D3), the drop being approximately four percent per annum (Henderson, pers comm). Shearing costs, woolshed expenses and wool cartage (to wool store) are borne by the ewe activities and handling costs, Wool Board and Wool Stabilisation Levies are borne by the selling activities.

4.5 FEED CONSTRAINTS

4.5.1 Feed Supply and Demand Equations

The general equation for the dryland model is

$$\sum_{j=a+1}^{b} B_j r_{ij} + \sum_{j=b+1}^{c} C_j r_{ij} + \sum_{j=c+1}^{d} D_j r_{ij} - \sum_{j=e+1}^{f} F_j r_{ij} -$$

(Lamb and wool production) (Cull ewes) (Sell lambs) (Pasture and lucerne feed supply)

$$\sum_{j=f+1}^{g} G_j r_{ij} - \sum_{j=g+1}^{h} H_j r_{ij} + \sum_{j=h+1}^{k} K_j r_{ij} - \sum_{j=h+1}^{k} K_j r_{ij} +$$

Pasture and lucerne renewal) (Forage crops) (Feed transfer and substitution)

$$\sum_{j=k+1}^{l} L_j r_{ij} - \sum_{j=l+1}^{m} M_j r_{ij} \leqslant 0 \qquad (4:8)$$

(Make hay) (Feed hay)

Where: a = 1, ..., 7 b = 8, ..., 53 c = 54, ..., 64

d = 65, ..., 73 f = 76 and 77 g = 78, ..., 80

h = 81, ..., 187 k = 188, ..., 264 l = 265, ..., 276

m = 277, ..., 308

The general equation for the irrigated model is

$$\sum_{j=a+1}^{b} B_j r_{ij} + \sum_{j=b+1}^{c} C_j r_{ij} + \sum_{j=c+1}^{d} D_j r_{ij} - \sum_{j=e+1}^{f} F_j r_{ij} -$$

(Lamb and wool production) (Cull ewes) (Sell lambs) (Pasture and lucerne feed supply)

$$\sum_{j=f+1}^{g} G_j r_{ij} \quad + \sum_{j=g+1}^{k} K_j r_{ij} \quad - \sum_{j=g+1}^{k} K_j r_{ij} \quad + \sum_{j=k+1}^{l} L_j r_{ij} \quad -$$

(Pasture and lucerne renewal) (Feed transfer and substitution) (Make hay)

$$\sum_{j=l+1}^{m} M_j r_{ij} \quad \leqslant \quad 0 \qquad (4:9)$$

(Feed hay)

Where: a = 1, ..., 5 b = 6, ..., 52 c = 53, ..., 69

d = 70, ..., 90 e = 91 and 92 f = 93, ..., 96

g = 97, ..., 100 k = 101, ..., 177 l = 178, ..., 187

m = 188, ..., 205

The assumptions effecting the time period and units of feed have been discussed above under the heading of stock constraints. The following discussion will dwell on the feed supply side of these reconciliations. Feed is supplied from a number of sources to meet the animal requirements. The feed can be supplied from;

(a) pasture and new parture - in both the dryland and irrigated models.

(b) lucerne and new lucerne - in both the dryland and irrigated models.

(c) winter-spring feed crops - turnips, Tama over-drilled into lucerne, Tama and Paroa ryegrass, Tama-ryecorn mixture and Tama-oats mixture. These activities have only been included in the dryland model.

(d) Summer feed crops - Rangi rape in the dryland model only.

(e) Hay - in both the dryland and irrigated models.

(a) Pasture and new pasture. These activities are included in both models. The dryland model has two pasture activities, pasture and new pasture, and the irrigated model has four pasture activities, two dryland and two irrigated.

Dryland pasture in Canterbury has a mean annual production of 5,870 kg DM/ha. (Rickard and Radcliffe, 1976). However, this is subject to large between year variation which can be as much as ±32% of the mean. The extent of this large variation is dependent on rainfall within a year. The growth of pasture under dryland conditions is spring dominant, the average seasonal spread of production being;

Spring	52%
Summer	18%
Autumn	20%
Winter	10%.

Irrigated pasture in Canterbury has a mean annual production of 12,000 kg D.M./ha. with a variation in production between years of ±12% of the mean (Hayman, 1977). The irrigated pasture production is more evenly spread over the spring, summer and autumn,

Spring	38%
Summer	37%
Autumn	20%
Winter	5%.

The growth rate data used in this study, Rickard and Radcliffe (1976), relate to regular cutting at two to three weekly intervals. Lynch (1954) found that a six week spelling period of pasture in Canterbury gave almost twice the yield of pasture spelled for two weeks. Smetham, pers. comm. states that there is limited evidence to suggest that rates of pasture growth in the autumn and winter in Canterbury could be twice those found by Rickard and Radcliffe (1976). For this reason all pasture growth rate data used in the two models has been increased by 20% over the whole year. Autumn-winter pasture production has been increased by 40% and production for the remainder of the year has been increased by 10%. Figure 4.1 shows the adjusted growth curves for dryland and irrigated pasture.

The utilisation of pasture by stock varies throughout the year. Appendix E1 shows the utilisation factors used in both models. Care needs to be taken when a utilisation factor is included in work of this kind because growth rate data is generally obtained by taking cuts to "mower height" (usually 2.5 cm.) and utilisation data are obtained from cuts to ground level. It is obvious that discrepencies will arise if utilisation figures, obtained as outlined above, are applied to growth rate data taken from cuts to 2.5 cm. Smetham (1976) states that herbage left post-grazing is approximately 1,000 kg D.M./ha. Allowing for this residual herbage, utilisation figures can, and should be increased by 50% when applied to growth data obtained from cuts to "mower height". This can be assumed without any effect on animal performance (Smetham pers. comm.). The utilisation figures used in these models have been adapted from published work; Rattray (1977), Rattray and Jagusch (1977), Smetham (1975) and Thomson (1977), and from farmer observations.

New pasture is drilled in February for all new pasture activities. A six week lag period between drilling and first grazing has been assumed to allow the new pasture to become established. From April to August, inclusive, the new pasture growth rates are based on work carried out by Thomson (1974). Production from the new pasture is assumed to be the same as established pasture in the spring.

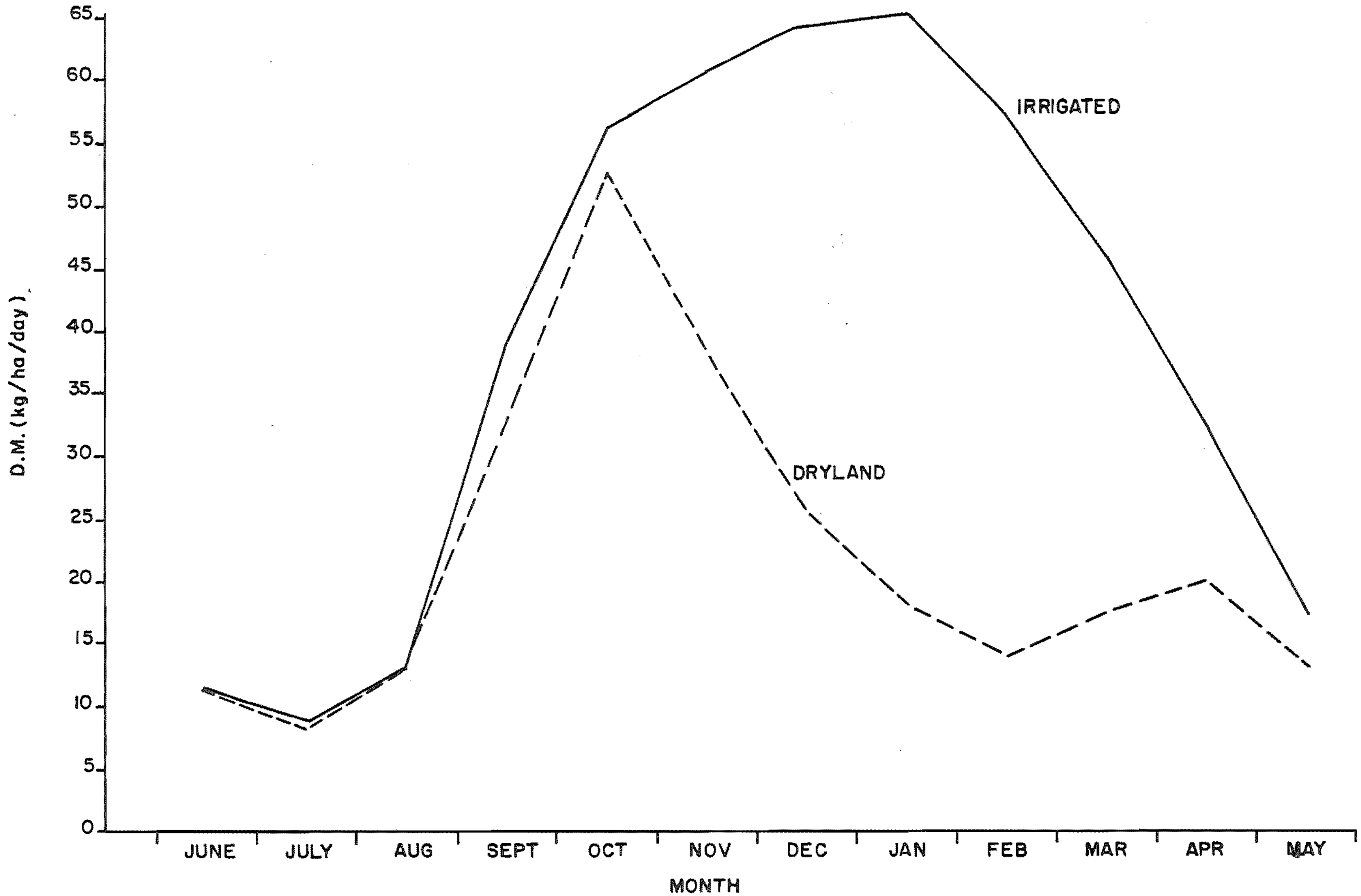

FIGURE 4.1 PASTURE PRODUCTION — GROWTH RATES
(After Aalink FPP84)

(b) Lucerne and new lucerne. The dryland model has three lucerne activities, established lucerne, establishing new lucerne and new lucerne, and the irrigated model has four lucerne activities, two dryland and two irrigated.

Lucerne has played a big part in the development of dryland farms in Canterbury. This is due to its mean annual production of 7,000 kg D.M./ha. with a ±14% variation between years (Ritchie, 1978) and its summer growth. The advantages that lucerne has over pasture on light land properties are that lucerne has;

(i) a high annual mean production,

(ii) a higher rate of growth during the late spring, summer and early autumn, and

(iii) less variance in annual production between years.

Disadvantages of lucerne compared with pasture are that lucerne;

(i) has low growth rates during late autumn, winter and early spring,

(ii) needs to be rotational grazed all year round to obtain maximum production, and

(iii) has higher establishment and maintenance costs.

Under irrigation lucerne produces 12,000 kg D.M./ha. annually with a between years variation of ±4%. The use of lucerne on irrigated properties is not very wide-spread due to the disadvantages outlined above and also because the stand life is limited compared with pasture. Lucerne is used mainly for hay production on irrigated properties.

The mean annual production of both dryland and irrigated lucerne has been increased by 20%. The reasons for the 20% increase are outlined above in the discussion on pastures. The adjusted growth curves for dryland and irrigated lucerne are shown in Figure 4.2

To obtain maximum production from lucerne it must be rotationally grazed. It is recommended that lucerne be grazed at the 10% flowering stage and that utilisation should be high. The utilisation values used in both models (Appendix E2) assume a high degree of utilisation. Lucerne is a high quality feed but late autumn and winter growth is of a lower quality (Appendix E2).

New lucerne is drilled in early-October to avoid summer drought and blue-green aphid attack. For the purposes of these models new lucerne does not produce grazing feed until December, allowing the seedlings to become established. The new lucerne stands growth rate then increases until the following June when it is assumed to be the same as an established lucerne stand.

(c) Winter-spring feed crops.

(i) Turnips - turnips are the major winter feed crop grown under dryland conditions in Canterbury. They are grown because they are quick maturing and tolerate low fertility soils. Ten turnip activities, representing two sowing dates, have been included in the dryland model. The two sowing dates used are January and February. A summary of the assumptions made for the turnip activities can be found in Appendix E3.

Turnips are generally break-fed to sheep for a set period each day. This means that a turnip crop may be fed off over a period of six to eight weeks, but dry matter yields and feed quality will vary over this feeding period. To simulate the feeding pattern and to allow for yield and quality changes each feed period between June and August inclusive has a separate turnip activity. The utilisation of turnips in practice is generally high. Turnips grazed in June or early July have been assumed to be 90% utilised and later fed turnips 85% utilised. The

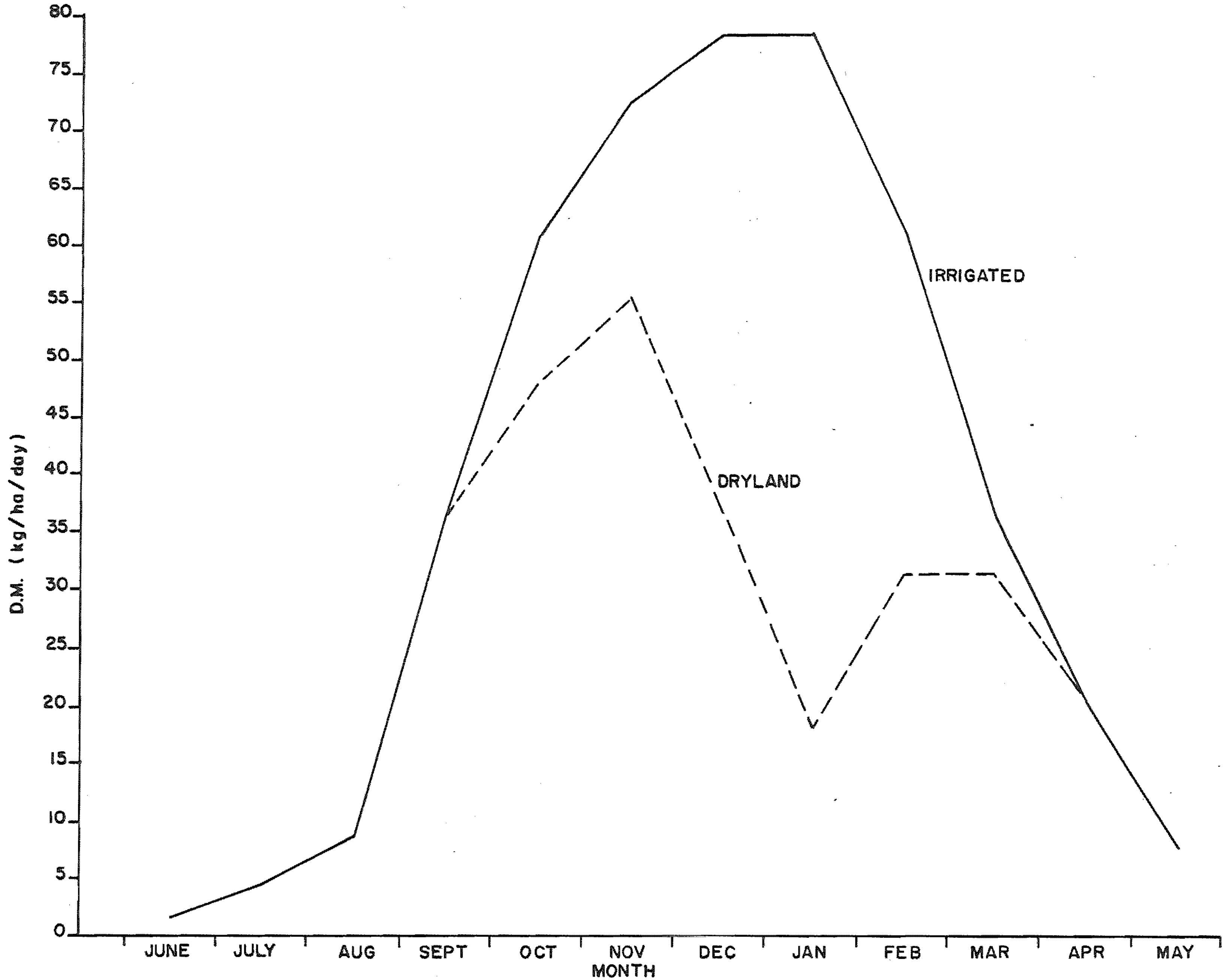

FIGURE 4.2 LUCERNE PRODUCTION - GROWTH RATES (After Aglink FPP85)

difference in utilisation is due to latter crops suffering more damage from trampling in wet conditions. Turnips have also been assumed to be a high quality feed but quality drops slightly with length of time in the ground.

(ii) Ryegrass Greenfeeds - winter active ryegrasses are used as a greenfeed to supply ewes with high quality, in situ grazing during late pregnancy and post-parturition. Pure sowings of ryegrasses require a high soil fertility and a well prepared seed bed. For this reason they are commonly sown after pasture or lucerne. A common rotation on a dryland property is as follows:

Old grass or lucerne → ryegrass greenfeed → turnips
↓
lucerne

This rotation provides both winter and spring feed and avoids land being left idle. The over drilling of winter active ryegrasses into lucerne stands can be used to overcome the lucernes relative dormancy over the winter but moist autumn conditions are required for this practice to be successful. Pure sown ryegrasses are less likely to be affected by dry autumn conditions cf overdrilled ryegrasses, especially if a summer fallow is used to conserve moisture. The recommended sowing date of ryegrasses is early March (Vartha, 1971). Two ryegrasses have been used in the dryland model. These are, Grasslands Paroa Italian ryegrass and Grasslands Tama Westerwolds ryegrass. Production from these ryegrasses is shown in Figures 4.3, 4.4 and 4.5.

In practice ryegrass greenfeeds usually remain ungrazed until late winter and then ration grazed to breeding ewes prior to and post parturition. A quick grazing in mid-winter may be used to control excess growth and Vartha and Rae (1973) found that a mid-winter grazing gave slightly superior

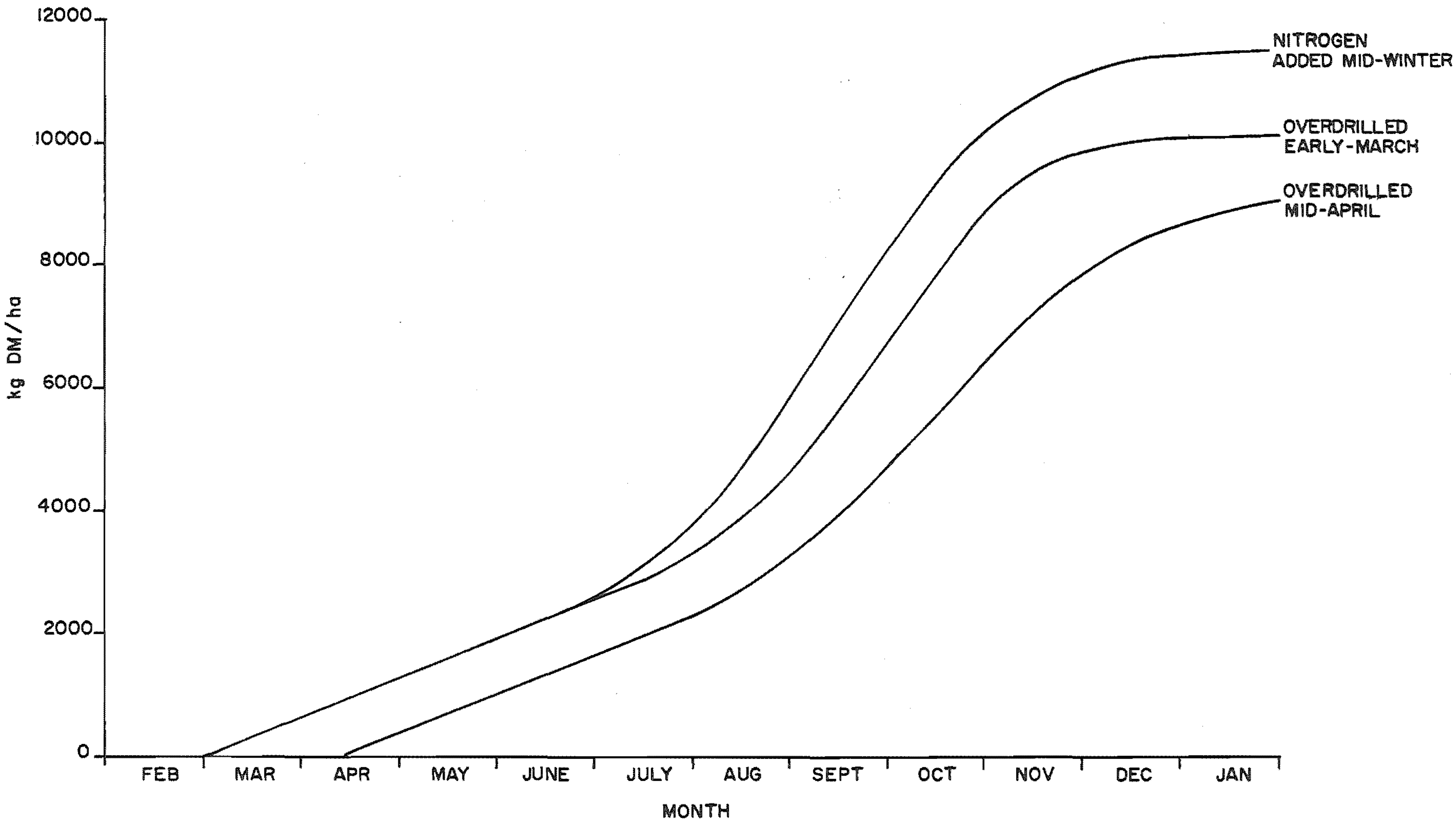

FIGURE 4.3 TAMA PRODUCTION WHEN OVERDRILLED INTO LUCERNE
(after Vartha, (1971) and Vartha, pers.comm.)

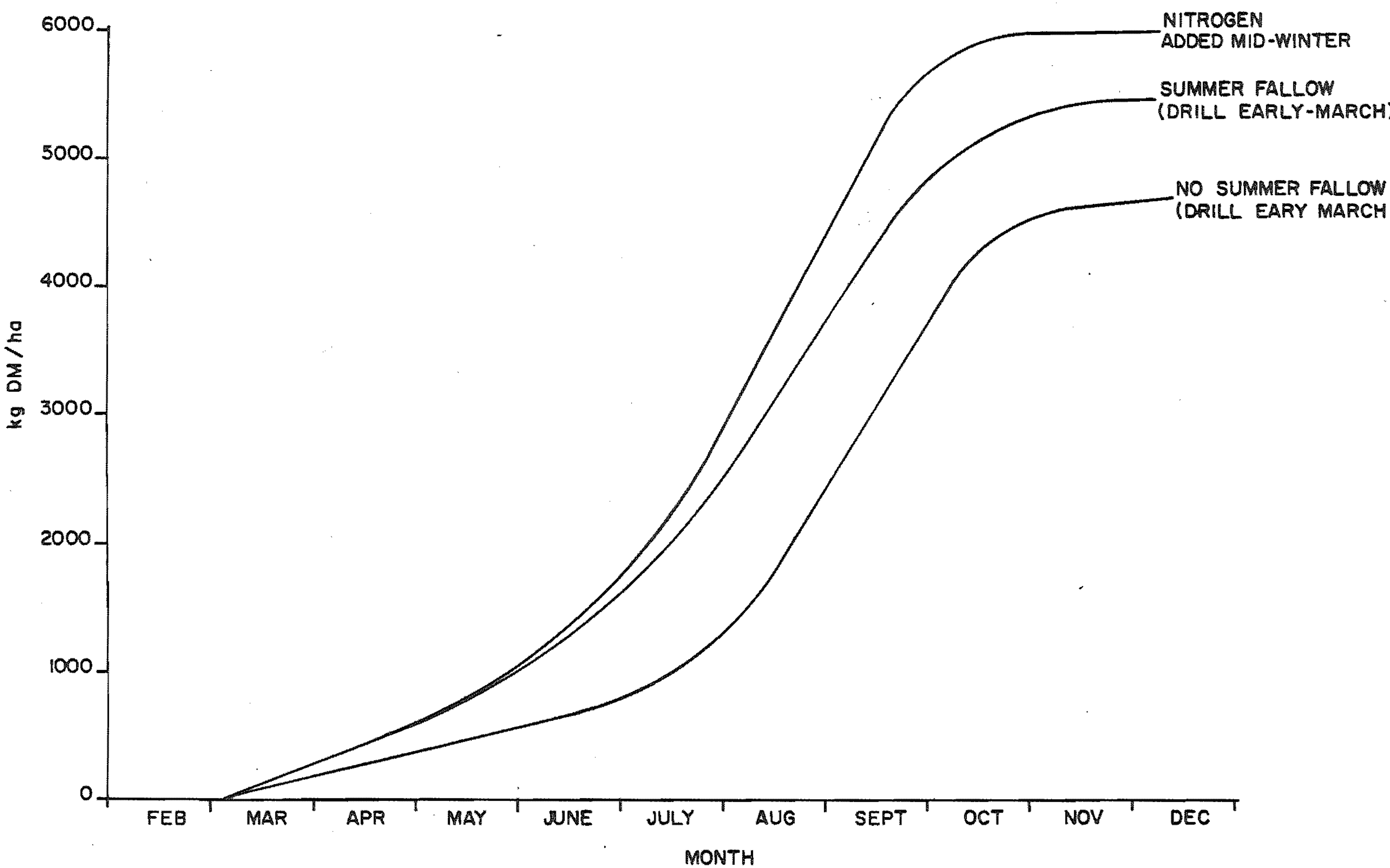

FIGURE 4.4 CUMULATIVE TAMA PRODUCTION
(after Crouchley and Bircham,(1971), McLeod,(1974), Vartha and Brown,(1977) and Vartha and Rae,(1973))

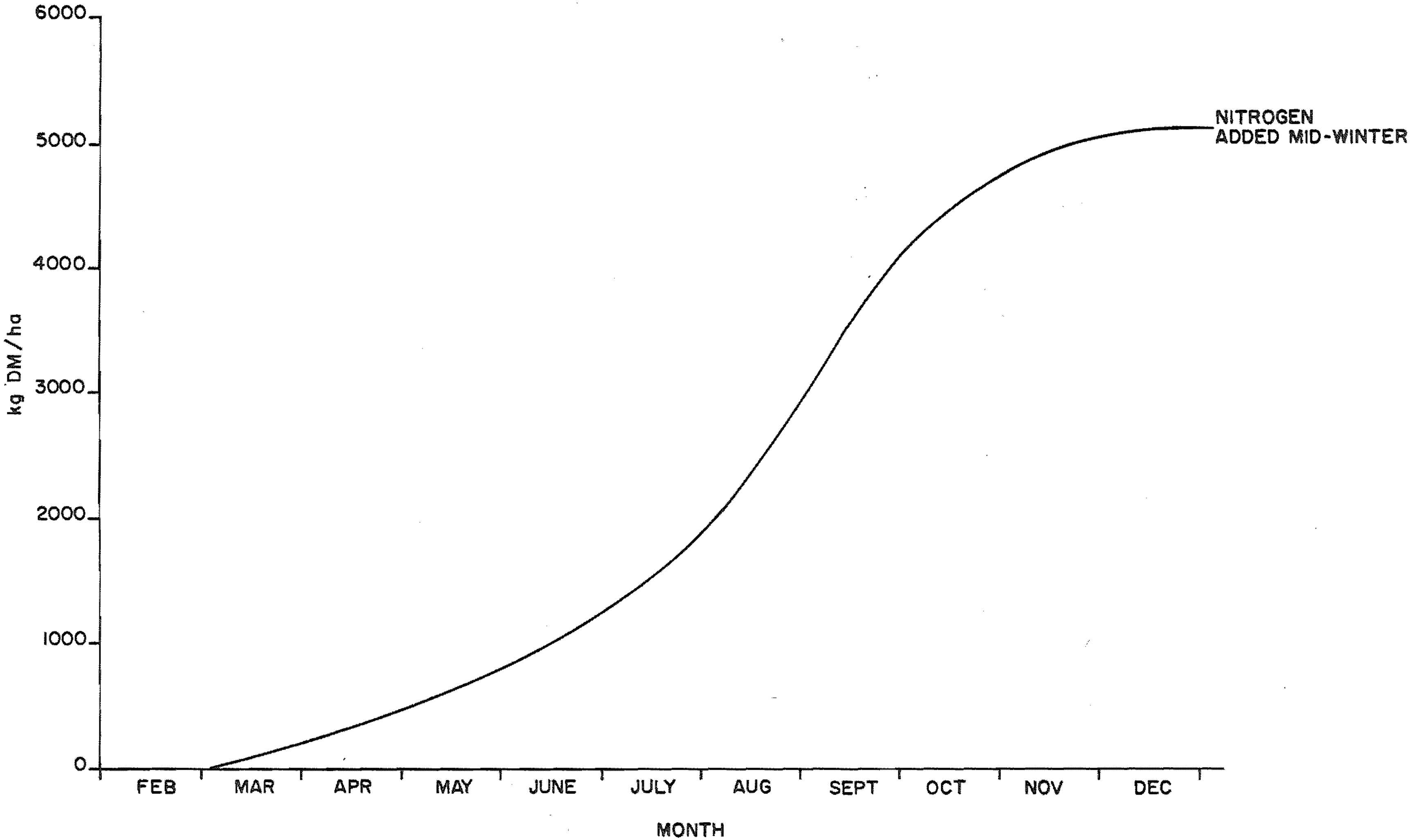

FIGURE 4.5 CUMULATIVE PAROA RYEGRASS PRODUCTION
(after McLeod, (1974) and Vartha and Rae, (1973)

spring recovery in Tama but not in Paroa. Spelling intervals between grazings need to be six weeks in the winter and four weeks in the spring to obtain optimal production and allow adequate regrowth (Scott, W.R. pers. comm.).

The application of nitrogen, mid-winter, can increase the ryegrass production (Figures 4.5 and 4.6). Vartha (1971) found responses of between 11 and 31 kg DM/kg N applied to lucerne overdrilled with Tama. Responses of 11 and 22 kg DM/kg N were found with a mid-winter application of nitrogen to Tama and Paroa respectively.

Utilisation of greenfeeds in general is not very high and rarely exceeds 70 percent. Trampling by stock and dirtying in wet conditions are the major factors reducing utilisation. Ryegrass greenfeeds are high quality feeds (≥11.0 MJME/kg DM) but quality drops slightly with maturity and successive grazings. Assumptions made on the utilisation and quality of ryegrass greenfeeds are shown in Appendix E4 and E5.

To incorporate the grazing interval restrictions into the model it was necessary to have a large number of greenfeed activities. There are 33 lucerne overdrilled with Tama, 33 pure sown Tama and 10 pure sown Paroa activities. These activities are made up as follows:

Activity	Mid-winter N application (drilled early March)	Over-drilled early March	Over-drilled mid April	Summer fallow (drilled early March)	No summer fallow (drilled early March)
Lucerne overdrilled Tama	9	12	12	-	-
Pure sown Tama	10	-	-	15	8
Pure sown Paroa	10	-	-	-	-

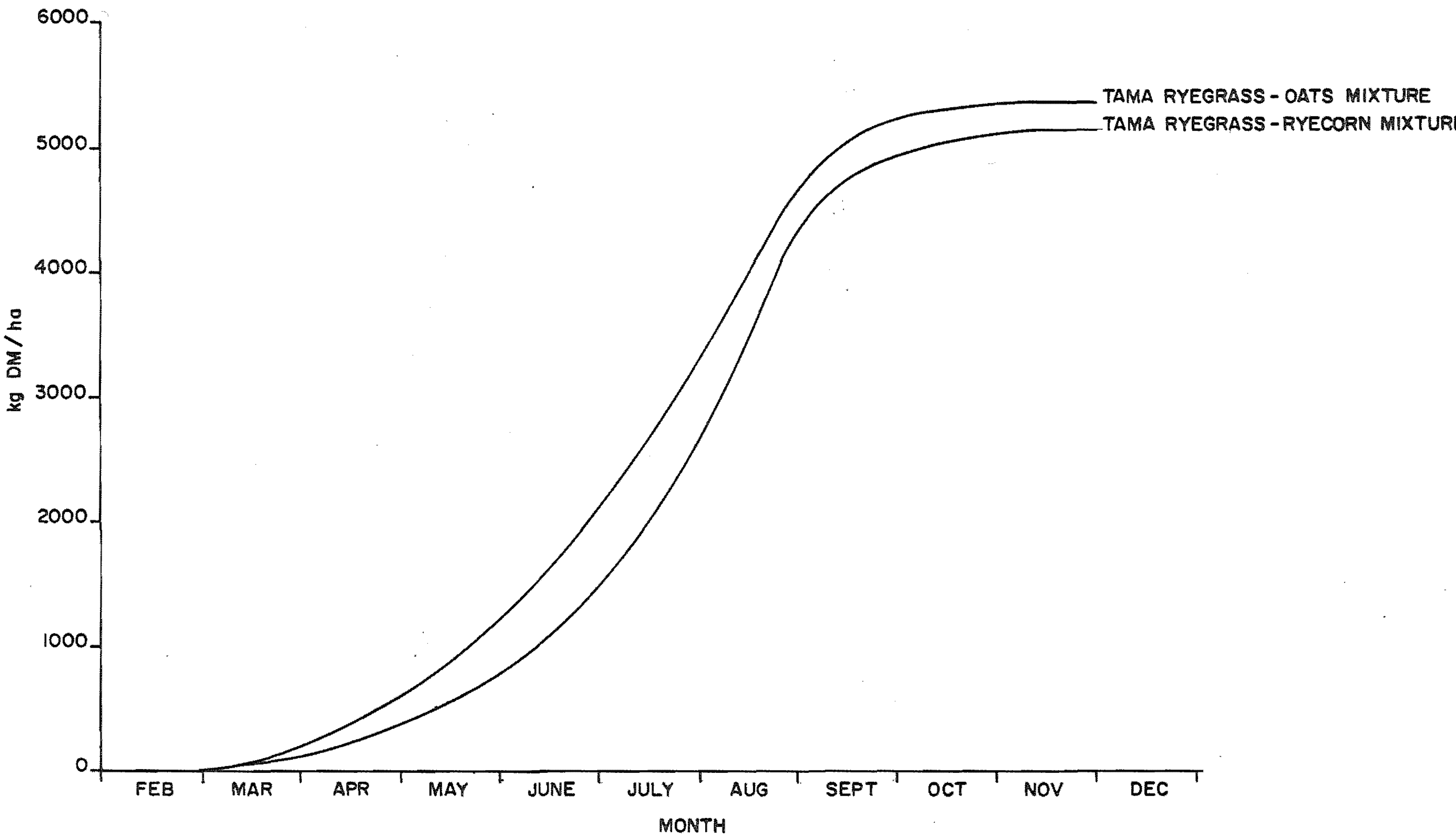

FIGURE 4.6 CUMULATIVE RYEGRASS/CEREAL MIXTURE PRODUCTION
(after Vartha and Rae,(1973))

(iii) Ryegrass-Cereal Mixtures - the establishment of Tama ryegrass is generally slow compared with cereal greenfeeds. It may, therefore, be desirable to sow a mixture of the early producing cereal and the later producing grass to give a better seasonal balance of production. These greenfeed crops would again be available for feeding to ewes in late pregnancy and post-parturition. The greenfeed crop is generally break grazed mid-winter, to utilise cereals, and again in the spring, to utilise ryegrass. After lambing, ewes and lambs can be set stocked on the crop. Vartha and Rae (1973) found that total yields to late-winter, whether grazed or not in mid-winter, were 23% and 25% higher from Tama-ryecorn and Tama-oat mixtures respectively than from Tama alone. These two ryegrass-cereal mixtures have been used in the dryland model. The feed production curves for these two mixtures are shown in Figure 4.6. Utilisation and quality of the two mixtures is similar to the Tama ryegrass activities mentioned above. Further details on the production, utilisation and feed quality of Tama-ryecorn and Tama-oat mixtures can be found in Appendix E.6.

(d) Summer Feed Crops

(i) Rape. The dryland Canterbury situation is characterised by frequent summer droughts. Consequently there is a place for growing a summer forage crop which would be suitable for feeding to livestock over this period. Rape at present is not in widespread use in Canterbury but the timing of the operations associated with the crop make it suitable to be grown between a greenfeed and a turnip crop. Rape is suited to dryland conditions because it matures very quickly although it does have the tendency to have a rapid fall off in yield once maximum dry matter production has been reached, especially from later sowings (Figure 4.7). Feed quality is high in the growth period to maturity but a fall off in quality is associated with the

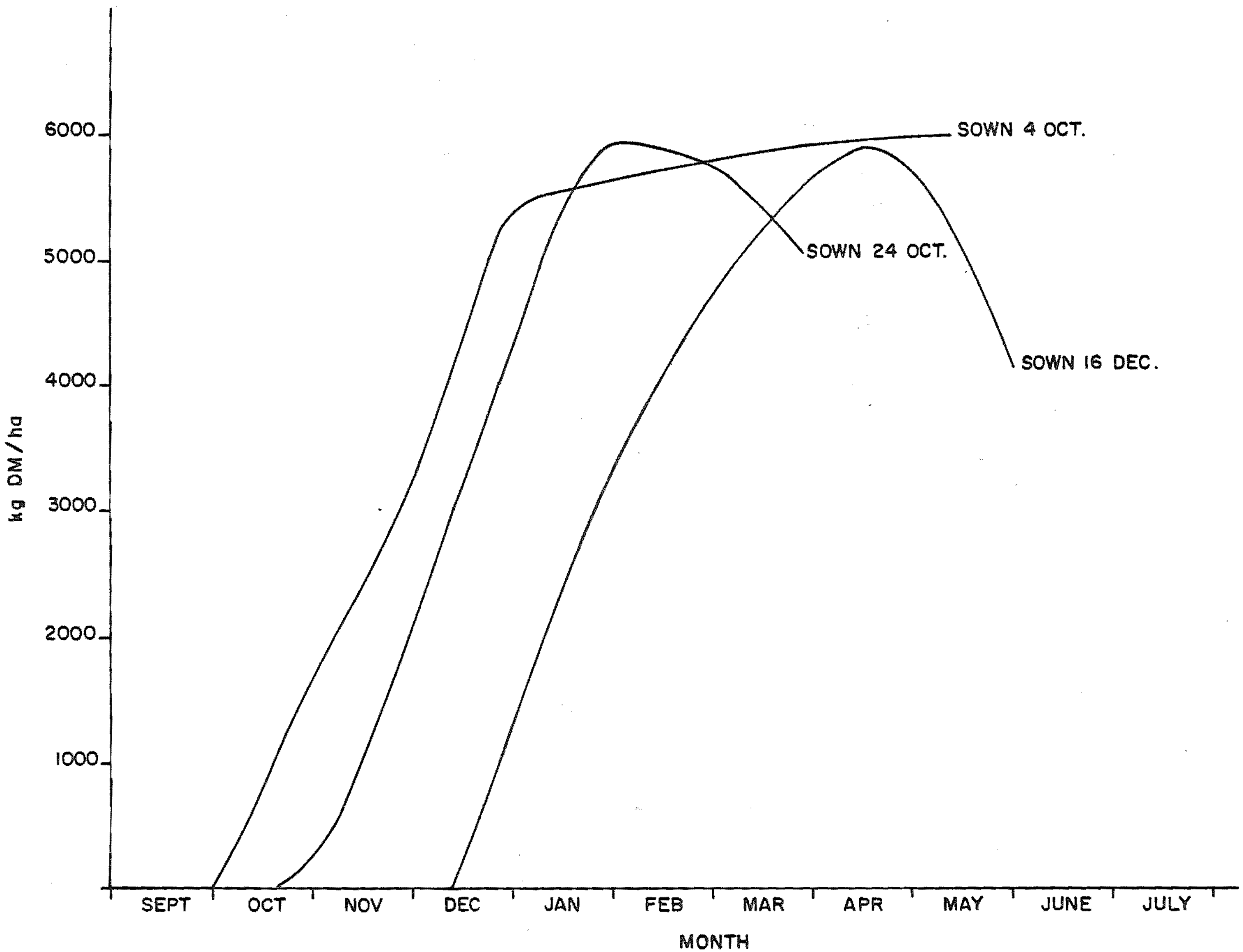

FIGURE 4.7 CUMULATIVE RAPE PRODUCTION
(after Mortlock, (1975) and Lucas (pers.comm.))

post-maturity decrease in dry matter yield. Break feeding of the crop to weaned lambs is the common method of utilising this crop. Care must be taken when feeding the crop as 'lamb scald' is associated with the feeding of immature crops. The production, feed quality and utilisation figures used for rape in the dryland model can be found in Appendix E.7.

(e) Hay

Hay is the most important conserved forage in New Zealand. Hay is used primarily to supplement ewes during the winter, when animal demand is greater than feed supply, but the feeding of hay to sheep in the summer is common under dryland Canterbury conditions. The making of hay is basically the transfer of feed from a period of abundance to a period of low feed supply. The transfer is associated with dry matter and quality losses. The extent of these losses depends on species composition, stage of maturity, environmental conditions, hay making procedures and equipment, the number of operations involving handling and in stack deterioration.

Two qualities of hay, medium and low quality, have been included in each of the models. It has been assumed that hay can only be made in the period late October to late March because suitable environmental conditions prevail over this period. The hay can be made from excess pasture and lucerne growth. Medium quality hay can be made from high quality feed and low quality hay from medium and/or low quality feed (Table 4.4). A medium quality bale of hay requires 196 MJME and a low quality bale of hay requires 147 MJME (Appendix E.8). Hay yields vary according to whether a paddock has been cut for hay previously or the time of making. For this reason the hay yields for each period are varied but the variance is only evident in the gross margins for the hay making activities.

TABLE 4.4

DETACHED COEFFICIENT MATRIX SHOWING HAY MAKING AND FEEDING ACTIVITIES

Constraint \ Activity	Pasture	Make Hay			Feed Hay			Buy Hay	
		November	December	January	June	July	August		
High quality feed November	-17424	196							≤0
High quality feed December	-19200		196						≤0
High quality feed January	-19344			196					≤0
Medium quality feed June	-3167				-137				≤0
Medium quality feed July	-2636					-137			≤0
Medium quality feed August	-3800						-137		≤0
Hay Tie		-1	-1	-1	+1	+1	+1	-1	≤0

Hay is fed throughout the year on dryland farms but on irrigated farms it is more common for hay to be fed out only in the winter. The dryland model allows hay to be fed to stock in any period in the year but the irrigated model is restricted to feeding hay in the period April to September. Medium quality hay can be fed as medium quality feed and low quality hay as low quality feed but a 30% dry matter loss from mowing to feeding out is assumed (Table 4.4).

Two hay buying activities have been included in each model. These activities and the hay ties will be discussed in a later section.

(f) Feed Transfers and Quality Substitution

Feed produced on a farm is not always eaten in the period in which it is grown. This is particularly so where lucerne and pasture are rotationally grazed. It is common on both dryland and irrigated farms for feed to be saved in the autumn for utilisation later in the winter. Allowance has been made in both models for feed (all three qualities) to be transferred from period to period (Table 4.6). Feed grown in the spring-summer period will drop in quality and quantity quickly if it is transferred through several time periods. The reasons for this are that the pasture or lucerne is growing rapidly and conditions are tending to dry out over this period. Autumn-winter growth will not deteriorate as much due to slow plant growth and cooler temperatures (Table 4.5).

TABLE 4.5

PERCENTAGE LOSS IN AVAILABLE FEED (PER MONTH) IF TRANSFERRED

Activity	Spring-Summer	Autumn-Winter
High quality feed transfer	36	26
Medium quality feed transfer	33	23
Low quality feed transfer	29	20

TABLE 4.6

DETACHED COEFFICIENT MATRIX SHOWING FEED TRANSFER ACTIVITIES

Constraint \ Activity		High quality feed transfer			Medium quality feed transfer			Low quality feed transfer			
		July to August	September to October	October to November	July to August	September to October	October to November	July to August	September to October	October to November	
High Quality Feed	July	+1									≤0
	August	-0.74									≤0
	September		+1								≤0
	October		-0.64	+1							≤0
Medium Quality Feed	July				+1						≤0
	August				-0.766						≤0
	September					+1					≤0
	October					-0.672	+1				≤0
Low Quality Feed	July							+1			≤0
	August							-0.795			≤0
	September								+1		≤0
	October								-0.71	+1	≤0

The feed transfers stop and start at the end of August to prevent autumn and winter feed from being transferred through into the spring (Table 4.5).

To overcome the problem of meeting a medium quality feed demand by stock in a period in which only high quality feed is produced, thirty-two feed quality substitution activities have been included. There are sixteen activities substituting high quality feed for medium quality and sixteen activities for substituting medium quality feed for low quality. The sixteen activities in each group represent the sixteen yearly time periods (Table 4.7). The substitution activities do not allow medium quality feed to substitute for high quality feed because in practice stock intake restrictions would preclude this. The substitution activities (common for both models) allow one MJME of high quality feed to satisfy the demand for 1.05 MJME of medium quality feed. Likewise, one MJME of medium quality feed can be used to satisfy the demand for 1.06 MJME of low quality feed.

4.5.2 Land Reconciliations

The feed supply activities, except the hay activities, require land at least for part of the year. The land reconciliation rows reconcile the demand for land by crops, lucerne and pasture with the area available period by period. The land reconciliation rows take on the following general forms:

(i) Dryland model.

$$\sum_{j=e+1}^{f} F_j r_{ij} + \sum_{j=f+1}^{g} G_j r_{ij} + \sum_{j=g+1}^{h} H_j r_{ij} \leqslant 300 \qquad (4.10)$$

(Pasture and lucerne feed supply) (Pasture and lucerne renewal) (Forage crops)

Where e = 74 and 75 f = 76 and 77 g = 78,...,80 h=81,...,187.

TABLE 4.7

DETACHED COEFFICIENT MATRIX SHOWING FEED SUBSTITUTION ACTIVITIES

Constraint \ Activity		High to medium quality substitution				Medium to low quality substitution				
		July	August	September	October	July	August	September	October	
High Quality Feed	July	+1								≤0
	August		+1							≤0
	September			+1						≤0
	October				+1					≤0
Medium Quality Feed	July	-1.05				+1				≤0
	August		-1.05				+1			≤0
	September			-1.05				+1		≤0
	October				-1.05				+1	≤0
Low Quality Feed	July					-1.06				≤0
	August						-1.06			≤0
	September							-1.06		≤0
	October								-1.06	≤0

(ii) Irrigated model

$$\underset{\text{(Pasture and lucerne)}}{\sum_{j=e+1}^{f} F_j r_{ij}} + \underset{\text{(Pasture and lucerne renewal)}}{\sum_{j=f+1}^{g} G_j r_{ij}} \leqslant 200 \qquad (4.11)$$

Where e = 91 and 92   f = 93,...,96   g = 97,...,100.

There are sixteen land reconciliation rows, one for each period, in the dryland model. These land reconciliations ensure that two land demanding activities do not use the same land simultaneously while at the same time ensuring that the total land area used does not exceed the 300 hectares available. The reconciliation rows are needed for each period as some crops require land for only part of the year, e.g. rape may require land from early October to the end of January and Tama may require land from the end December to the end November the following year (Table 4.8).

The irrigated model has only one land reconciliation row. This is due to the nature of the model, in that all the land demanding activities require land for the whole year rather than for specific periods of time. The land reconciliation rows in this case ensure that the total area of land available (200 ha), is not exceeded.

All crops require two weeks cultivation time prior to sowing. This two weeks is taken into account at the start of each crop's land requirement in both models.

4.5.3 Pasture and Lucerne Renewal Reconciliations

These reconciliations ensure that a portion of the total area in pasture and lucerne is renewed each year. They take the general form:

TABLE 4.8

DETACHED COEFFICIENT MATRIX SHOWING LAND AND RENEWAL RECONCILIATIONS, AND THE AREA TIE

Constraint \ Activity		Pasture	New Pasture	Lucerne	Transition Lucerne	New Lucerne	Turnips	Tama		Rape		
								Early Sown	Late Sown	Sown October	Sown December	
LAND	January	+1		+1		+1	+1	+1		+1	+1	≤300
	February	+1	+1	+1		+1	+1	+1			+1	≤300
	March	+1	+1	+1		+1	+1	+1				≤300
	April	+1	+1	+1		+1	+1	+1	+1			≤300
	⋮											≤300
	September B	+1	+1	+1		+1		+1	+1			≤300
	October A[1]	+1	+1	+1	+1	+1				+1		≤300
	October B[2]	+1	+1	+1	+1	+1				+1		≤300
	November	+1	+1	+1	+1	+1				+1		≤300
	December	+1	+1	+1	+1	+1	+1			+1	+1	≤300
Pasture reconciliation		+1	-5.0									≤0
Lucerne reconciliation				+1	-8.0							≤0
New lucerne reconciliation					-1	+1						≤0
Area Tie			+1		+1		-1	-1	-1	-1	-1	≤0

[1] A represents the first half of the month. [2] B represents the second half of the month.

$$\sum_{j=e+1}^{f} F_j r_{ij} \quad - \quad \sum_{j=f+1}^{g} G_j r_{ij} \quad \leqslant 0 \qquad (4.12)$$

(Pasture and lucerne feed supply) (Pasture and lucerne renewal)

Where $e = 74$ and 75 $f = 76$ and 77 $g = 78,\ldots,80$

in the dryland model, and

Where $e = 91$ and 92 $f = 93,\ldots,96$ $g = 97,\ldots,100$

in the irrigated model.

The dryland model has three renewal reconciliations (see Table 4.8). These consist of,

(i) a pasture reconciliation row which ensures that the pasture area is renewed every five years,

(ii) a lucerne reconciliation row which ensures that the area in lucerne is renewed every eight years, and

(iii) a new lucerne reconciliation row which ties the transitional lucerne activity to the new lucerne activity.

The irrigated model has four of these reconciliation rows. These are -

(i) an irrigated pasture reconciliation row which ensures that the pasture area is renewed every twenty years,

(ii) an unirrigated pasture reconciliation row which ensures that the pasture area is renewed every five years, and

(iii) and (iv) irrigated and unirrigated lucerne reconciliation rows which ensure that the lucerne area is renewed every eight years.

4.5.4 Area Tie

This constraint is peculiar to the dryland model. Its purpose is to ensure that the area in forage crops is not larger than the area in new pasture and new lucerne (Table 4.8). The general form of this equation is:

$$\underset{\text{(Pasture and lucerne renewal)}}{\sum_{j=f+1}^{g} G_j r_{ij}} \quad - \quad \underset{\text{(Forage crops)}}{\sum_{j=g+1}^{h} H_j r_{ij}} \quad \geqslant 0 \qquad (4.13)$$

Where f = 76 and 77 g = 78,...,80 h = 81,...,187
in the dryland model.

4.5.5 Hay Ties

The hay ties reconcile the bales of hay made and purchased with the hay fed.

There are two of these ties, one for each hay quality, i.e. medium and low quality, in each model. Their general equation is:

$$- \underset{\text{(Make hay)}}{\sum_{j=k+1}^{l} L_j r_{ij}} \quad + \quad \underset{\text{(Feed hay)}}{\sum_{j=l+1}^{m} M_j r_{ij}} \quad - \quad \underset{\text{(Buy hay)}}{\sum_{j=m+1}^{n} N_j r_{ij}} \leqslant 0 \qquad (4.14)$$

Where k = 188,...,264 l = 265,...,276 m = 277,...,308 n = 309 and 310
in the dryland model, and
k = 101,...,177 l = 178,...,187 m = 188,...,205 n = 206 and 207
in the irrigated model.

4.5.6 Turnip and Rape Area Reconciliations

The reconciliation rows described are peculiar to the dryland model. Their general form is:

$$\sum_{j=a+1}^{b} B_j r_{ij} \quad - \quad \sum_{j=g+1}^{h} H_j r_{ij} \quad \leqslant 0 \qquad (4.15)$$

(Ewe activities) (Forage crops)

Where a = 1,...,7 b = 8,...,53 g = 78,...,80 h = 81,...,187
in the dryland model.

There are ten of these reconciliations, five for the turnip and five for the rape activities, included in the dryland model. The rows are specific for the particular period in which the forage crops supply their feed, e.g. five turnip activities (for December sown turnips) supply feed in five separate periods. There is, therefore, a reconciliation row for each of these feed periods. The value used in the forage crop part of the equation is the same as that used in the feed supply and demand equations. The ewe activity value is that ewe's feed requirement in that period that the feed is supplied. The reconciliations, therefore, prevent the feed being supplied by the crop activities from being transferred by the transfer activities. This is brought about by ensuring that the feed supplied from these activites, in a particular period, is less than or equal to the animal demands in that period. It is necessary to prevent these feed activities from being transferred because the feed transfer activities are specific for the lucerne and pasture activities. Separate, crop specific, feed transfer values would be required to allow the turnip and rape feed supplies to be transferred.

4.5.7 Hay Feeding Reconciliations

Beetham (1973) and Rattray (1977) found that the maximum voluntary intakes of hay by ewes were 885 and 843 grams per day respectively. These values were obtained when ewes were being fed at maintenance. Hay feeding

TABLE 4.9

DETACHED COEFFICIENT MATRIX SHOWING TURNIP AREA AND HAY INTAKE RECONCILIATIONS

Activity / Constraint	Turnips			Feed Hay			Ewes				
	A	B	C	June	July	August	Two-tooth	Four-tooth	....	Nine-year old	
Turnip A area reconciliation	-33320						359	371		369	≤0
Turnip B area reconciliation		-37100					193	200		199	≤0
Turnip C area reconciliation			-37435				221	228		227	≤0
Hay intake reconciliation June				+1			-0.75	-0.75		-0.75	≤0
Hay intake reconciliation July					+1		-0.75	-0.75		-0.75	≤0
Hay intake reconciliation August						+1	-0.75	-0.75		-0.75	≤0

reconciliations are used in both models to prevent greater than 675 grams of hay being fed to ewes in the months in which hay can be fed (Table 4.9). A value lower than the maximum intakes found by Beetham (1973) and Rattray (1977) is used to ensure that ewes are not force fed on hay. The general form of the reconciliation rows is:

$$\underset{\text{(Lamb and wool production)}}{\sum_{j=a+1}^{b} B_j r_{ij}} \quad - \quad \underset{\text{(Feed hay)}}{\sum_{j=l+1}^{m} M_j r_{ij}} \quad \leq 0 \qquad (4.16)$$

Where $a = 1,\ldots,7$ $b = 8,\ldots,53$ $l = 265,\ldots,276$ $m = 277,\ldots,308$ in the dryland model, and

$a = 1,\ldots,5$ $b = 6,\ldots,52$ $l = 178,\ldots,187$ $m = 188,\ldots,205$ in the irrigated model.

CHAPTER V

RESULTS

5.1 INTRODUCTION

Earlier chapters have contained a description of the problem and the two linear programming models used to analyse the problem. In this chapter the results obtained from experimentation with the models are presented.

The objective of the study was to establish the optimal stock replacement policy for Canterbury dryland and irrigated fat lamb farms. Experimentation proceeded in two phases. The first phase involved testing the basic farm livestock programmes obtained using the 1977/78 season's prices, for stability to changes in prime lamb and cull ewe prices. The second phase involved testing the basic farm livestock programmes for stability to changes in wool prices.

The optimal solutions have been summarised with only the real variables in the basis being presented. Space limitations have meant that much information has had to be excluded from the results presented here. This information included feed transfers and feed quality substitutions. However, if this information appeared important to the discussion it has been included in the appropriate table or comment has been made in the text. The computer output also included marginal value products for resources and stability ranges for activities. These have been presented where it is thought their inclusion would have some bearing on the discussion. The reasons for excluding some values are:

(i) Because the models do not include estimates of marginal value for all farm resources and the marginal value products calculated are not the true values for the units of the scarce resources not included in the models;

(ii) The stability range over which an activity's net revenue can vary without affecting the optimal plan only applies where the net revenues of all other activities do not change. Generally, when analysing the stability of a solution, with regard to price change, it is unrealistic to assume that activity net revenues are independent;

(iii) A non-basic activity can only be included in the basis when its net revenue increases enough to reduce the marginal cost of that activity to zero. This only applies if it is assumed all other net revenues remain stable which is often unrealistic.

For the above reasons any changes to parameters or coefficients required a separate trial with the models in a similar manner to experimentation with biological systems. It was rarely possible to extrapolate accurately from the results of a particular run of a model.

The net revenue values referred to in the following discussion refer to the Total Gross Margin (T.G.M.), a measure which does not take into account fixed costs (e.g. permanent labour, depreciation, administration and interest). To obtain net farming profit the fixed costs must be deducted from the Total Gross Margin.

5.2 THE DRYLAND MODEL

5.2.1 The Optimal Solution Using 1977/78 Prices

Initially the model was run using prices for the 1977/78 season. This is termed the base run. The prices used in the parametric analysis were based on the base run values. The base run results are shown in Table 5.1.

TABLE 5.1

RESULTS OF DRYLAND MODEL BASE RUN (USING 1977/78 PRICES)

Farm Size		300 ha
Stock		
Replacement ewe lambs purchased		524
Cull six year olds sold		325
Mated ewe hoggets	lamb 1st September	524
Two tooths	lamb 15th September	493
Four tooths	lamb 15th September	473
Six tooths	lamb 15th September	454
Four year olds	lamb 15th September	432
Five year olds	lamb 1st September	401
Six year olds	lamb 1st September	369
Total breeding ewes		3146
Stocking rate (SU/ha)[1]		12.4
Stock Production		
Lambs prime off mother		1822
Lambs fattened		1822
Lambing percentage (Total lambs sold/Ewes mated)		116
Lamb meat/ha (kg)		157.9
Average wool weight (kg/head)		4.4
Wool output/ha (kg)		46.1
Death rate (%)		6.3
Feed Supply		
Lucerne (ha)		99
Lucerne overdrilled with Tama (ha)		9
Pasture (ha)		155
Turnips (ha)		37
Hay made (bales)		2328
Hay fed per animal (bales)		0.7
Net Revenue[2]		
Total net revenue ($)		40,705
Net Revenue per hectare ($/ha)		135.68

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[1] Stocking rate calculated assuming
1 Border Corriedale ewe = 1.2 SU
1 Border Corriedale ewe hogget = 1.1 SU

[2] Net Revenue refers to Total Gross Margin. It only represents Direct Costs and Returns and no account has been made for Fixed Costs.

The solution presented shows a policy of purchasing ewe lambs and holding them for seven lambings (including lambing as ewe hoggets) to be optimal. The shadow prices associated with older ewe activities (Table 5.3) show that a decrease in net revenue would result from their inclusion in the solution. The drop in net revenue is small for retaining a ewe an extra year, $0.43, but if ewes are held a further one or two years (eight and nine year olds respectively) the drops in net revenue are $2.70 and $4.70 for each year.

The replacement policy of purchasing ewe lambs was found to be optimal. Shadow prices (Table 5.3) indicate that a shift in this policy to one of purchasing older ewes would meet with a smaller decrease in the net revenue than a change to purchasing two tooths. This is an indication of the high cost of purchasing two tooths.

The solution shows that the ewe lambs, and five and six year old ewes are mated to lamb on the 1st September while the remainder of the flock (two tooths to four year olds) are mated to lamb two weeks later. This spread of lambing (41% of the ewes in the early lambing mob and the remainder in the late mob) allows maximum utilisation of spring growth before the summer dry period and also a spreading of the labour demand at this time of the year.

The production data shows that fifty percent of the lambs born are sold prime off the mother and the remainder are fattened after weaning. The rather low average lambing percentage (116%) is a reflection of the ewe hoggets being included in the solution. The average lambing percentage, with the ewe hoggets excluded, is 124%. The weight of lamb meat (157.9 kg) and wool (46.1 kg) produced per hectare is slightly below the values of 169.4 kg/ha and 51.6 kg/ha obtained over a 5 year period (1974-78) on the Lincoln College dryland farm (Ashley Dene).

The feed demand of the ewes is met by growing pasture (52% of the area), lucerne (33% of the area), turnips (12% of the area), lucerne overdrilled with Tama (3% of the area) and hay (2328 bales). The feed profile generated for the base run is shown in Figure 5.1. A feature of the feed profile is the very small area of Tama ryegrass grown for greenfeed and the fact that the Tama grown has been overdrilled into lucerne (a low cost option). The winter-spring greenfeed activities have very high shadow prices e.g. Tama - $60.79, Paroa - $130.90, Tama-Ryegrass mix - $107.07, Tama-Oats mix - $72.55 and Rape - $52.69. These activities are therefore held out by activities with lower marginal value products. The lack of high quality feed in the late winter is the factor limiting a higher average stocking rate. A significantly lower per kilogram cost of dry matter for greenfeed activities at this time of the year would be needed to overcome this problem.

The model transfers very little feed during the year. Feed is transferred from spring into early summer and from autumn into early winter. Approximately 2330 bales of hay are made in late October and early November. This hay is fed out in June and July in conjunction with turnips and pasture. As lambing approaches ewes are fed on a decreasing diet of turnips and an increasing diet of Tama, pasture and lucerne. From lambing until tupping the stock are fed lucerne and pasture. At tupping the ewes are fed mainly pasture but some lucerne may need to be fed.

5.2.2 The Effect of Varying the Prime Lamb and Cull Ewe Prices

The results of the five runs are summarised in Table 5.2. The base run and runs 1, 2 and 3 show that ewes should be retained until the end of their sixth year. However, the flock structure changed in run 4 to one of retaining ewes to the end of their seventh year. It is significant,

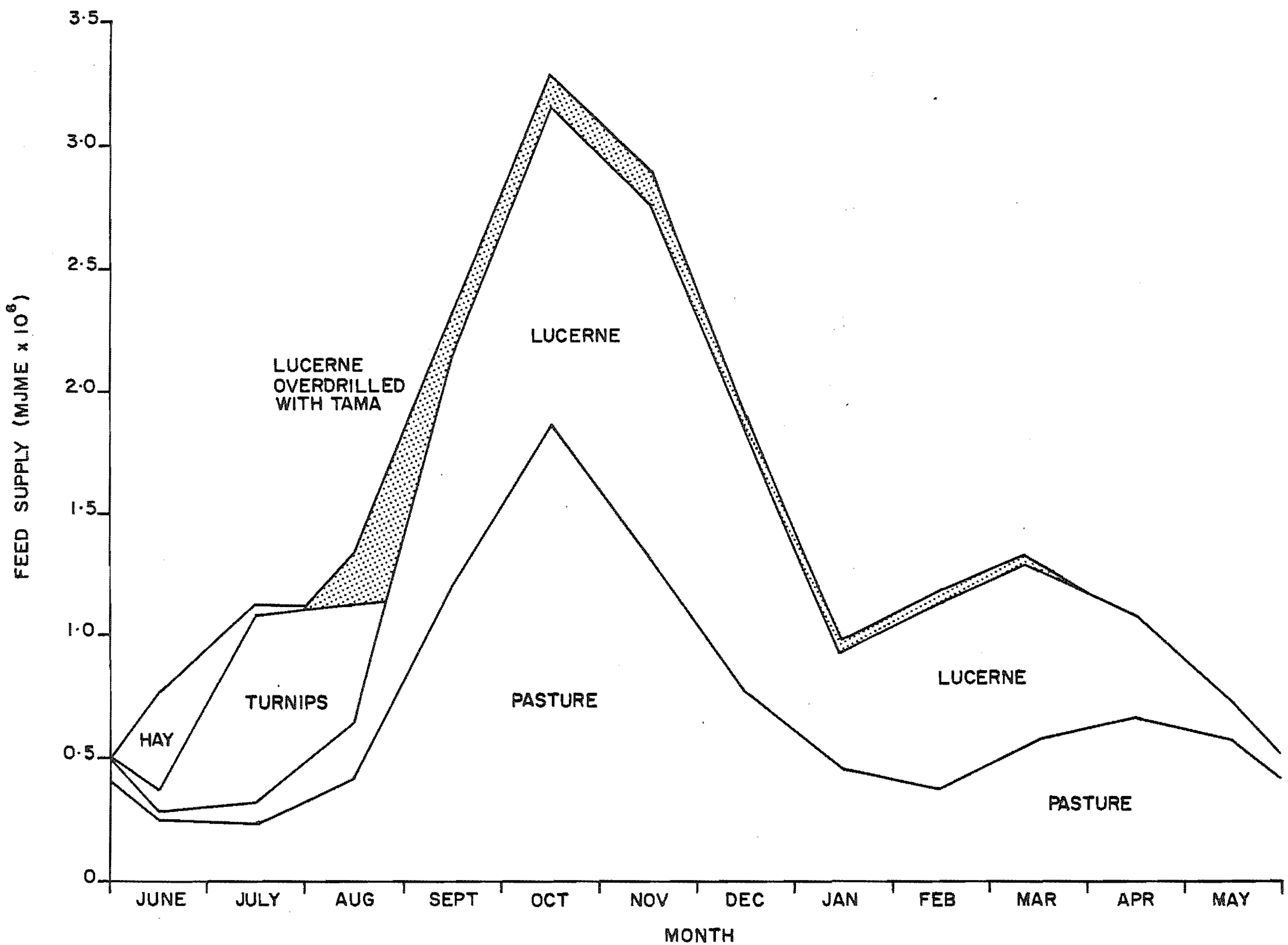

FIGURE 5.1 FEED DEMAND FOR DRYLAND MODEL BASE RUN

TABLE 5.2

CHANGES IN THE LINEAR PROGRAMMING MODEL SOLUTIONS IN RESPONSE TO CHANGES IN THE PRIME LAMB AND CULL EWE PRICES (DRYLAND MODEL)

Activity	Run 1	Run 2	Base	Run 3	Run 4
Change in prime lamb price (%)	-20	-10	1977/78	+10	+20
Change in cull ewe price (%)	+20	+10	prices	-10	-20
Stock					
Replacement ewe lambs purchased	488	515	524	556	533
Cull six year olds sold	302	319	325	344	-
Cull seven year olds sold	-	-	-	-	281
Mated ewe hoggets	488	515	524	556	533
Two tooths	459	484	493	522	501
Four tooths	440	465	473	501	481
Six tooths	423	446	454	481	462
Four year olds	402	424	432	457	438
Five year olds	374	394	401	425	408
Six year olds (broken mouth)	344	363	369	392	375
Seven year olds (gummy mouth)	-	-	-	-	330
Total breeding ewes	2930	3091	3146	3334	3528
Stocking rate (SU/ha)[1]	11.6	12.2	12.4	13.2	13.9
Stock Production					
Lambs prime off mother	1695	1789	1822	1930	2058
Lambs fattened	1695	1789	1822	1930	2058
Lambing percentage (total lambs sold/ewes mated)	116	116	116	116	117
Lamb meat per hectare (kg)	146.9	155.0	157.9	167.3	178.4
Average wool weight (kg/head)	4.4	4.4	4.4	4.4	4.3
Wool per hectare (kg)	42.8	45.2	46.0	48.0	51.0
Death rate	6.3	6.3	6.3	6.3	7.1
Feed Supply					
Lucerne (ha)	61	89	99	138	171
Lucerne overdrilled with Tama (ha)	5	8	9	12	15
Pasture (ha)	195	166	155	116	81
Turnips (ha)	39	37	37	34	33
TOTAL FARM AREA	300	300	300	300	300
Hay made and fed (bales)	-	1741	2328	4625	7807
Hay fed per animal (bales)	-	0.6	0.7	1.4	2.2
Net Revenue[2]					
Total net revenue ($)	33300	37600	40700	44500	48500
Net revenue per hectare ($/ha)	111.0	125.3	135.7	148.3	161.7

[1] Stocking rate calculated assuming: 1 Border Corriedale ewe = 1.2 SU
1 Border Corriedale ewe hogget = 1.1 SU

[2] Net Revenue refers to Total Gross Margin. It only represents Direct Costs and Returns and no account has been made for Fixed Costs.

however, that it took a 20% increase in the lamb price and a corresponding decrease in the cull ewe price to bring about a change in the flock structure. The shadow price (Table 5.3) for seven year old ewes decreased in runs 1-3 and finally in run 4 the seven year old ewe activity was included in the optimal solution. The eight and nine year old ewe activities also show this trend but it is clear from the results that their inclusion in the solution will result in a significant fall in the net revenue. The shadow price values for the culling policies show that at low lamb and high cull ewe prices (run 1) the sale of ewes at five years of age becomes more attractive.

The replacement policy for all runs is consistently one of purchasing ewe lambs. A larger number are purchased as the prime lamb price increases and the cull ewe price decreases (runs 1-3) but in run 4 the number of ewe lambs purchased decreased. This is in response to an increase in the age structure of the flock. The shadow prices (Table 5.3) suggest that at low prime lamb and high cull ewe prices (runs 1 and 2), inclusion of the six year old purchasing activity would have only a small effect on the net revenue. At high prime lamb and low cull ewe prices (runs 3 and 4) the inclusion of the two tooth purchasing activity would have the smallest effect on the net revenue.

In all runs the ewe lambs and old ewes (five, six and seven year olds) are mated to lamb on the 1st September and the remainder of the flock are mated to lamb on the 15th September. This, as stated above, allows more efficient use of spring and early summer growth while at the same time spreading labour requirements at lambing. Production per head is stable in all runs except run 4 in which the lambing percentage increases to 117% and the wool weight decreases by 0.1 kg to 4.3 kg per head. The change in the flock structure has led to these production changes. On the other hand production per hectare increases from run 1 to run 4. This is a reflection of the increased stocking rate and the increase in per head performance in

TABLE 5.3

SHADOW PRICES OBTAINED FOR ACTIVITIES IN RESPONSE TO SIMULTANEOUS CHANGES IN THE PRIME LAMB AND CULL EWE PRICES (DRYLAND MODEL)

Activity	Run 1	Run 2	Base	Run 3	Run 4
Change in Prime Lamb Price (%) Change in Cull Ewe Price (%)	-20 +20	-10 +10	1977/78 Prices	+10 -10	+20 -20
Purchasing					
Two tooths	2.44	1.33	1.54	0.97	0.55
Five year olds	0.49	1.17	0.91	1.07	1.20
Six year olds	0.32	0.48	0.93	1.40	1.80
Seven year olds	0.50	0.75	1.22	2.04	2.72
Ewe Age Groups					
Seven year olds	1.01	0.96	0.43	0.11	1.70*
Eight year olds	3.73	3.67	2.70	1.79	1.42
Nine year olds	9.32	9.10	4.70	5.87	5.12
Culling Policies					
Four year olds	1.08	1.22	2.31	2.98	3.67
Five year olds	0.18	0.26	0.84	1.19	1.63
Six year olds	0*	0*	0*	0*	0.15
Seven year olds	1.19	1.13	0.51	0.12	2.00*
Eight year olds	4.84	4.69	2.02	2.33	1.84
Nine year olds	14.34	14.00	5.34	9.03	7.88

* Activity included in basis.

the case of the lamb meat per hectare but only of the increase in stocking rate in the case of the wool output per hectare.

An increase in stocking rate implies that more feed will be required to maintain the additional stock. The extra total feed requirement is met by an increased area of lucerne and lucerne overdrilled with Tama. The increased total lucerne area is brought about by a substitution of lucerne for pasture and turnips (Table 5.2). The results also show a 235% increase in the quantity of hay made and fed. This hay is made from the excess feed supplied by the lucerne in mid to late spring. Figure 5.2 shows that the hay is fed out in May, June, July and early August in conjunction with turnips and pasture. The increased Tama area allows the ewes to get a pre-lambing boost. From lambing to the following winter the ewes and their offspring are fed mainly lucerne. This may present some problems, especially if lucerne is used to flush the ewes, as there is evidence to suggest that lambing percentages can be reduced due to the effect of high levels of phyto-oestrogens in lucerne (Ritchie (1978)).

At low stocking rates (runs 1 and 2) the area in lucerne and lucerne overdrilled with Tama is reduced. The area in pasture and turnips, however, is increased. No hay is fed out in run 1, a reflection of the lower stocking rate in this run.

The three major changes mentioned in the above text:

(i) stock numbers,

(ii) stock production, and

(iii) feed supply, especially the amount of hay made and fed,

are the main reactions to the lamb price change but the overall affect is reflected in the net revenue. The changes in net revenue from the base value correspond very closely to the change in lamb price (Figure 5.3). A 20% increase in lamb price (run 4) creates a 20% increase in net revenue and

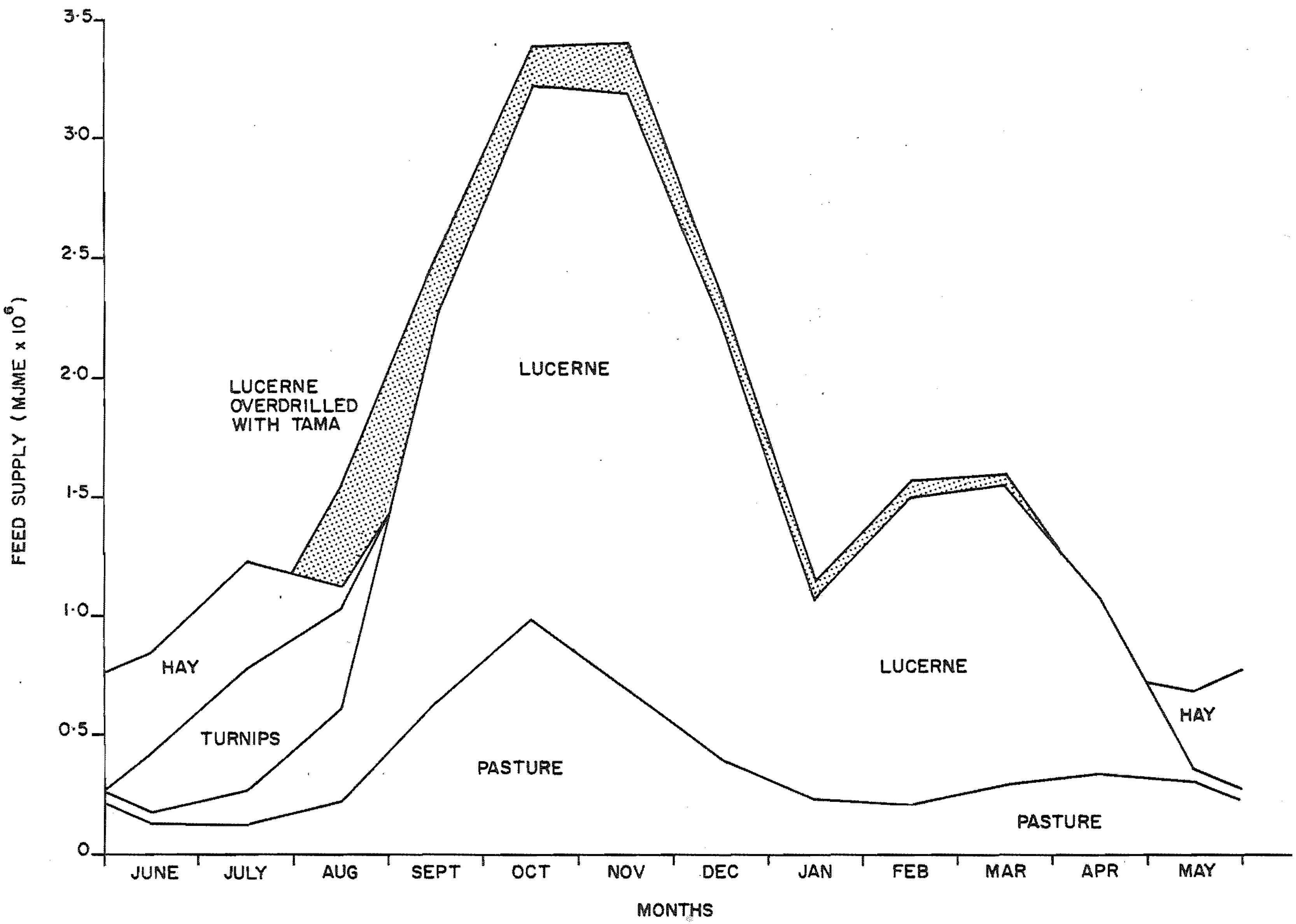

FIGURE 5.2 FEED SUPPLY FOR DRYLAND MODEL (RUN 4)

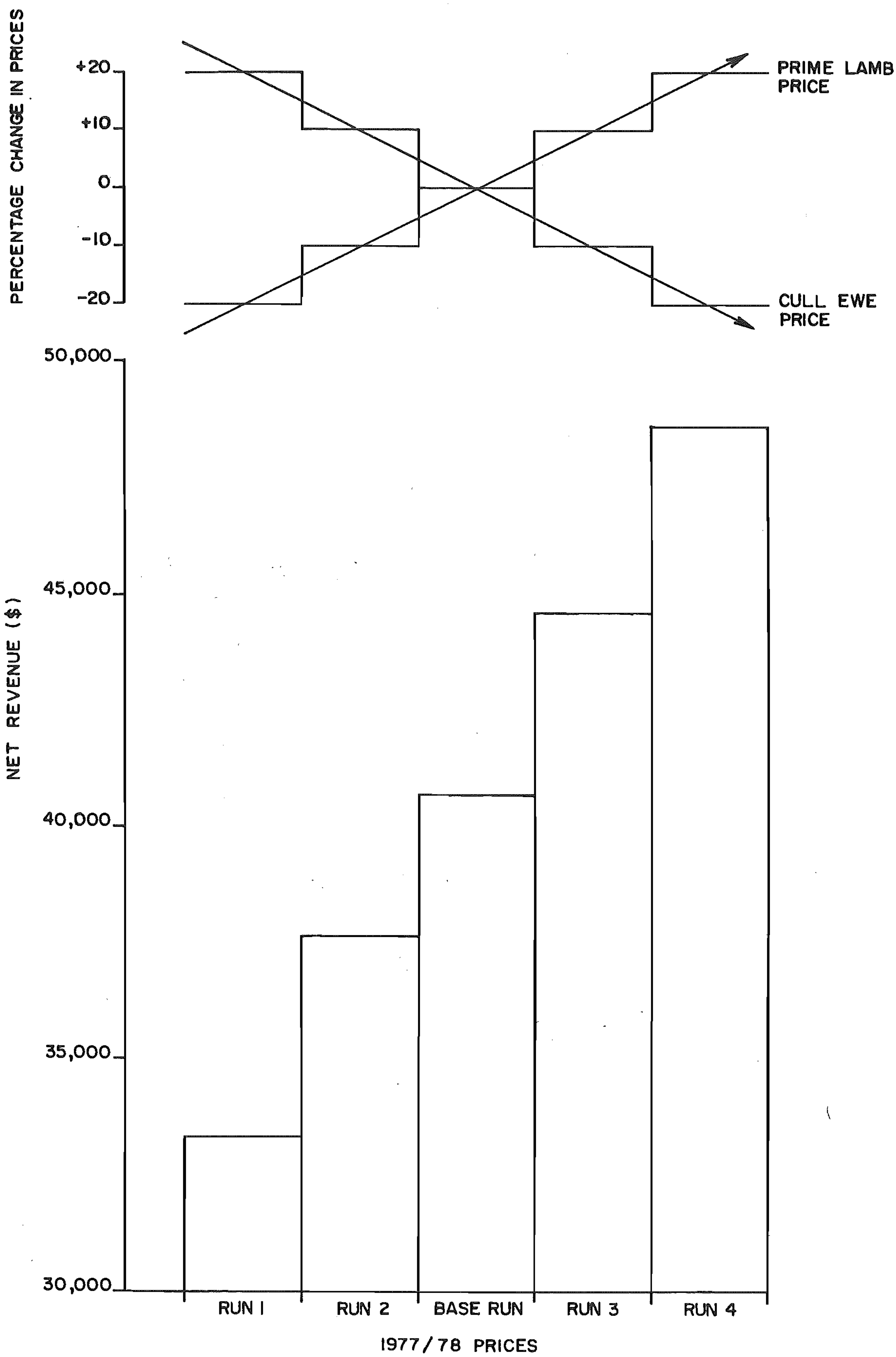

FIGURE 5.3 THE EFFECT ON NET REVENUE OF VARYING PRIME LAMB AND CULL EWE PRICE

an equivalent drop in the lamb price (run 1) induces an 18% decrease in the net revenue.

In summary it is clear from runs 1-4 that the dryland farm model reacts to a proportionate increase in lamb price and a simultaneous proportionate decrease in cull ewe return by increasing the overall stock numbers. The model also takes advantage of a higher overall lambing percentage offered by an older flock structure (run 4) even when this entails a drop in wool weight. The extra feed required for the increased number of ewes is supplied by a larger area of lucerne and lucerne overdrilled with Tama. A sharp rise in hay use is also evident. The reaction to higher cull ewe returns and lower lamb returns is the opposite. Stocking rates decrease, the replacement policy remains the same and the flock age structure is maintained. As ewe numbers decrease so does the area in lucerne and overdrilled lucerne while the pasture and turnip area increases correspondingly. Hay use also becomes negligible (run 1) as there is less pressure to transfer feed.

5.2.3 The Effect of Varying the Wool Price

The results of the parametric study with the dryland models' wool prices are shown in Table 5.4. The results show that ewes should be replaced after seven lambings (including a lambing as a ewe hogget). Runs 6-8 show this to be the optimal flock structure but run 5 suggests that where low wool prices are experienced ewes should be retained for an extra lambing. The flock structure changed only after a 40% decrease in wool price (run 5). For this reason the base run (present price flock structure) result can be thought of as very stable. The shadow price data (Table 5.5) shows that the seven year old value decreases with decreasing wool prices until the activity is included (run 5) at the lowest wool price used. All other ewe activities outside the solution have higher shadow prices with the nine year old activity in particular having very high values in all runs. The policy of culling six year old ewes is optimum for runs 6-8 but in run 5 the ewes are culled as seven year olds. The shadow price associated with the seven year old culling activity falls with a decrease in wool prices until the activity is included in run 5. At higher wool prices the non basic activity having the least effect on net revenue, when forced into the solution, is the cull five year olds.

The results (Table 5.4) indicate that large variations in the wool price have no effect on the replacement policy adopted in the base run. The policy adopted in all runs (runs 5-8) is the purchase, and subsequent mating of ewe lambs. Table 5.5 suggests that this is a stable policy because only at low wool prices does the shadow price decrease to a low enough level to indicate a possible change in policy. At low wool prices (run 5) the non basic activity with the lowest shadow price is the purchase of five year old ewes. A similar situation exists at high wool prices (run 8) but the shadow prices for all excluded activities are high.

As the wool price is forced down, the management system is adjusted to recover some of the lost revenue. This is achieved by slight increases in the lambing percentage brought about by retaining ewes an extra year (run 5). Lambing percentage increased by 1% but wool weight has dropped by 0.1 kg per head in this run. Following Table 5.4 it can be seen that stocking rate is forced up by increases in wool price. The variation in stocking rate is low when considered in relation to the change in wool price. The stocking rate is 7% lower, and 14% higher, than the base run in runs 5 and 8 respectively. The weight of lamb and wool produced per hectare moves with the increases and decreases in stocking rate but when the flock structure is altered (run 5), the changes in production per animal have the effect of mitigating the full effects of the stocking rate changes.

TABLE 5.4

CHANGES IN THE LINEAR PROGRAMMING MODEL SOLUTIONS IN RESPONSE TO CHANGES IN THE WOOL PRICE ALONE (DRYLAND MODEL)

Activity	Run 5	Run 6	Base	Run 7	Run 8
Change in wool price (%)	-40	-20	1977/78 prices	+20	+40
Stock					
Replacement ewe lambs purchased	438	518	524	556	599
Cull six year olds sold	-	321	325	344	371
Cull seven year olds sold	231	-	-	-	-
Mated ewe hoggets	438	518	524	556	599
Two tooths	411	487	493	522	563
Four tooths	395	468	473	501	540
Six tooths	379	449	454	481	519
Four year olds	360	426	432	457	493
Five year olds	335	397	401	425	458
Six year olds (broken mouth)	308	365	369	392	422
Seven year olds (gummy mouth)	271	-	-	-	-
Total breeding ewes	2897	3110	3146	3334	3594
Stocking rate (SU/ha)[1]	11.4	12.2	12.4	13.1	14.2
Stock Production					
Lambs prime off mother	1691	1800	1822	1930	2080
Lambs fattened	1691	1800	1822	1930	2080
Lambing percentage (total lambs sold/ewes mated)	117	116	116	116	116
Lamb meat per hectare (kg)	146.6	156.0	157.9	167.3	180.3
Average wool weight	4.3	4.4	4.4	4.4	4.4
Wool output per hectare (kg)	41.9	45.5	46.0	47.8	52.6
Death rate (%)	7.1	6.3	6.3	6.3	6.3
Feed Supply					
Lucerne (ha)	61	89	99	138	171
Lucerne overdrilled with Tama (ha)	5	8	9	12	15
Pasture (ha)	195	166	155	116	81
Turnips (ha)	39	37	37	34	33
TOTAL FARM AREA	300	300	300	300	300
Hay made and fed (bales)	-	1741	2328	4625	7807
Hay fed per animal (bales)	-	0.6	0.7	1.4	2.2
Net Revenue[2]					
Total net revenue ($)	33300	37600	40700	44500	48500
Net revenue per hectare ($/ha)	111.0	125.3	135.7	148.3	161.7

[1] Stocking rate calculated assuming: 1 Border Corriedale ewe = 1.2 SU
1 Border Corriedale ewe hogget = 1.1 SU

[2] Net Revenue refers to Total Gross Margin. It only represents Direct Costs and Returns and no account has been made for Fixed Costs.

TABLE 5.5

SHADOW PRICES OBTAINED FOR ACTIVITIES IN RESPONSE TO CHANGES IN THE WOOL PRICE (DRYLAND MODEL)

Activity	Run 5	Run 6	Base	Run 7	Run 8
Change in wool price (%)	-40	-20	1977/78 prices	+20	+40
Purchasing					
Two tooths	1.34	1.48	1.54	1.52	1.66
Five year olds	0.06	0.53	0.91	1.25	1.64
Six year olds	0.76	1.09	0.93	1.51	1.74
Seven year olds	2.01	2.15	1.22	2.15	2.15
Ewe Age Groups					
Seven year olds	0*	0.13	0.43	0.69	0.99
Eight year olds	1.37	1.80	2.70	3.08	3.74
Nine year olds	3.23	5.87	4.70	8.18	9.38
Culling Policies					
Four year olds	3.16	2.69	2.31	1.97	1.58
Five year olds	1.39	1.06	0.84	0.64	0.41
Six year olds	0.14	0.88*	1.20*	0*	2.15*
Seven year olds	0.17*	0.15	0.51	0.82	1.17
Eight year olds	1.78	2.35	2.02	4.00	4.86
Nine year olds	4.97	9.04	5.34	12.59	14.43

*Denotes activity included in basis.

The feed supply composition varies significantly with the wool price. Analysis of the linear programming solutions shown in Table 5.4 shows that as the wool return increases, the areas in lucerne and lucerne overdrilled with Tama increase as does the number of bales of hay made and fed. The area in pasture and turnips is consequently reduced. The opposite trend is shown when the wool price is decreased. As the wool price increases more ewes are carried and these put more pressure on the available feed supply. As a consequence the area in lucerne is increased, as it has a higher annual total yield than pasture, but the winter dormancy of the lucerne results in a feed deficit over the winter period. The resultant deficit is taken up by an increased reliance on hay (in the early winter) and a larger area of Tama overdrilled into lucerne (in the late winter). As in earlier discussions, the shadow prices attributable to the other winter feed activities, are very high.

Changes in the total net revenue coincide with variations in the wool price (Figure 5.4). A 40% increase in the wool price has the effect of increasing the net revenue by 25% (run 8) and a 40% decrease in the wool price reduces the net revenue 23% compared with the base run value. This would suggest that under dryland conditions variations in wool price will have less effect on the total system than similar changes in the lamb and cull ewe prices.

To summarise, the dryland management system adjusts to increases in wool price (shown in Table 5.4) by increasing stock numbers to increase the total wool produced and net revenue. The method of replacement remains stable and the age structure of the flock only alters when the wool price is very low. Increases in the areas of lucerne and Tama overdrilled into lucerne as well as a substantial increase in hay are needed to support the

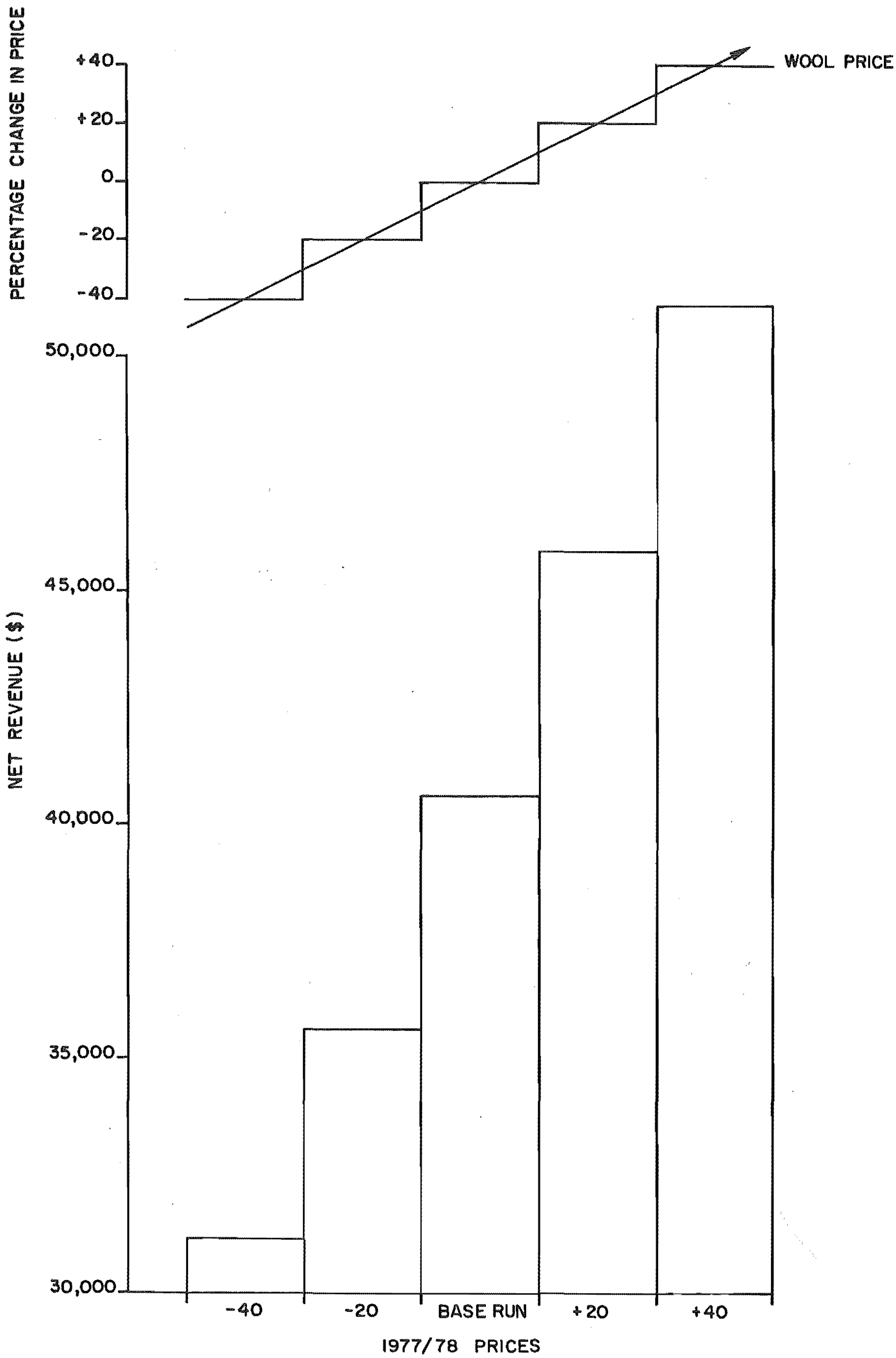

FIGURE 5.4 THE EFFECT ON NET REVENUE OF VARYING WOOL PRICE

increased stocking rate (from 11.4-14.2 SU/ha). Decreases in wool prices bring a decrease in stock numbers. A decrease in wool price of 40% (run 5) causes a change in the age structure of the flock. Ewes are held for an extra year to enable their higher lambing percentage to offset the drop in wool price. The changes in the feed supply are the opposite to those described above for an increase in wool price. Changes in the price of wool are shown to have only a minor effect on the net revenue.

5.3 THE IRRIGATED MODEL

5.3.1 The Optimal Solution Using 1977/78 Prices

A summary of the optimal solution for the irrigated model, using the 1977/78 season's prices, is shown in Table 5.6. The prices used in this run, referred to as the base run, are the reference point for the investigations carried out on this model (the details are given in Section 5.2). The base run solution is used as the bench mark for comparison with the solutions obtained from these investigations.

The base run solution indicates that ewes should be retained for six lambings (all ewes should be culled after lambing as a six year old). The shadow price data (Table 5.8) show that the inclusion of seven year old ewes would have the smallest effect on the net revenue. The shadow price for this activity, however, is high although lower than those of other activities. The shadow prices also indicate that culling five year old ewes would be the next best culling alternative.

The results show that a policy of breeding replacements as opposed to buying replacement stock is optimal. Thirty percent of the ewe lambs produced are retained as replacements for the ewe flock. Table 5.8 shows that all the other replacement policies have high shadow prices with the

TABLE 5.6

RESULTS OF THE IRRIGATED MODEL BASE RUN (USING 1977/78 PRICES)

Farm Size		200 ha
Stock		
Cull six year olds sold		410
Ewe hoggets		662
Two tooths	lamb 15th September	622
Four tooths		597
Six tooths		573
Four year olds		545
Five year olds		507
Six year olds		466
Total breeding ewes		3972
Stocking rate (SU/ha)[1]		21.5
Stock Production		
Lambs prime off mother		2231
Lambs fattened		1569
Replacement ewe lambs		662
Lambing percentage (Total lambs sold/Ewes mated)		135
Lamb meat/ha (kg)		290.0
Average wool weight (kg/head)		4.7
kg Wool/ha (kg)		94.1
Death rate (%)		6.3
Feed Supply		
Pasture (ha)		200
Hay made (bales)		3198
Hay fed per animal (bales)		0.8
Net Revenue[2]		
Total net revenue ($)		67100
Net revenue/ha ($/ha)		335.5

[1] Stocking rate calculated assuming
1.0 Coopworth ewe = 1.1 SU
1.0 Coopworth ewe hogget = 1.0 SU

[2] Net Revenue refers to Total Gross Margin. It only represents Total Returns minus Direct Costs and no account has been made for Fixed Costs.

two tooth purchasing activity having the lowest at $1.90. These values indicate that under irrigated conditions the policy of breeding replacements is stable.

All ewes in the base run solution are mated to lamb on the 15th September, typical for this type of farm. The shadow prices for the excluded lambing dates, 15th August and 1st September, are $1.24/ewe and $0.30/ewe respectively. The lambing date chosen in the basis ensures maximum availability and utilisation of feed during spring and early summer, the critical feed supply period; thus ensuring a pre-lambing feed boost for ewes and maximum lamb growth until weaning. An earlier lambing date would mean that less feed would be available mid-late spring and early summer or carrying capacity would need to be reduced over this period.

Feed for the 3972 ewes is supplied from 200 ha (the whole farm) of irrigated pasture and 3198 bales of meadow hay which are made on the property. Figure 5.5 shows the feed demand profile generated by the base run. The system generated is an all grass farming system for the whole year. Hay is fed out from the end of July until early September, thus overcoming the feed deficit over this period. Hay feeding is common in all grass wintering systems in Canterbury but in general hay would be fed out earlier than shown in this solution. This, however, would be related to the pressure for feed under which the farm is operated. The other feed supply activities contained in this model (irrigated lucerne, and dryland pasture and lucerne) are not in the solution. They have extremely high shadow prices showing that their inclusion in the solution would depress the net revenue significantly.

The production/ha values compare favourably with those obtained at Winchmore Irrigation Research Station over a number of years. Those values are presented below:

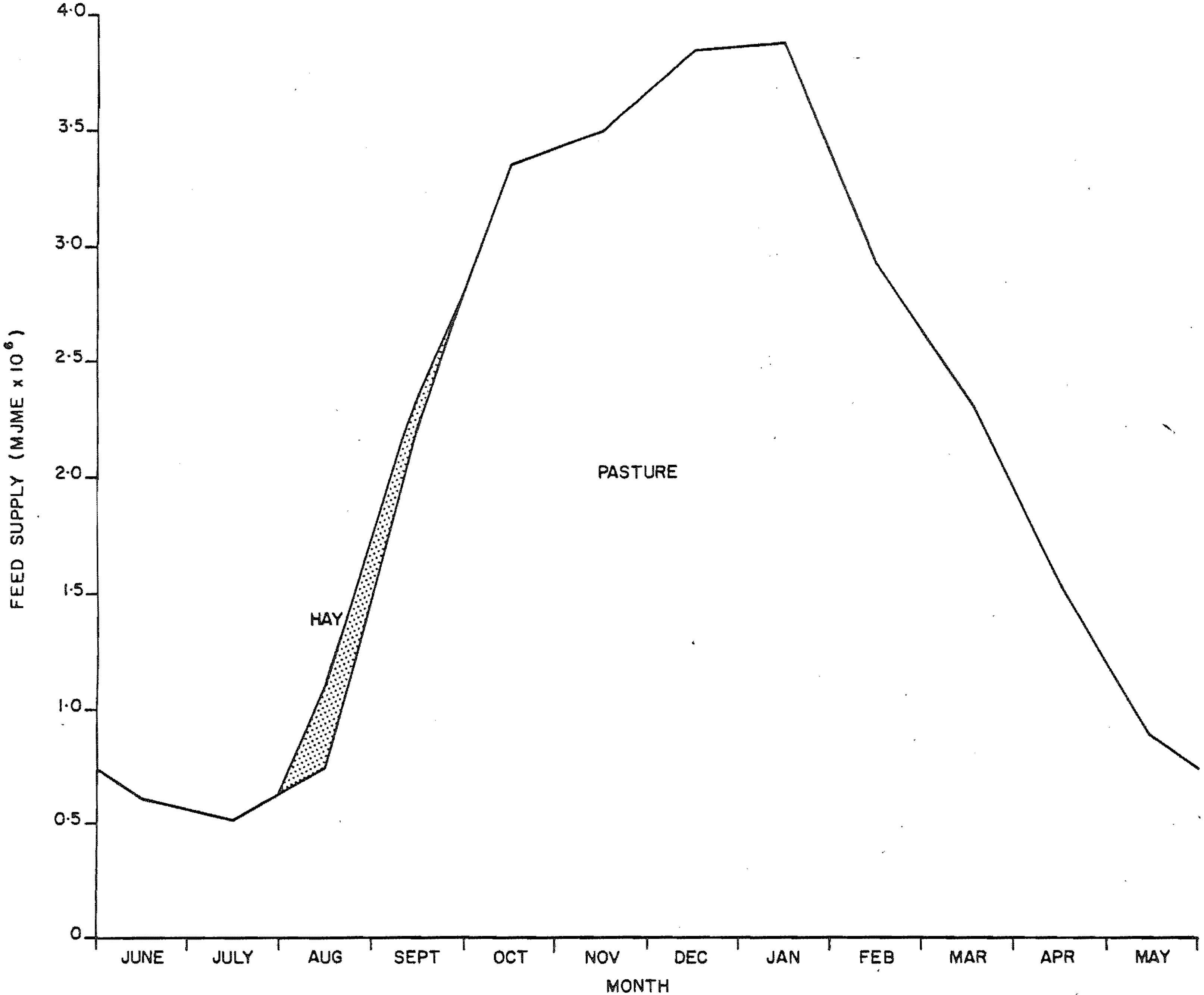

FIGURE 5.5 FEED DEMAND PROFILE GENERATED BY IRRIGATED MODEL BASE RUN

Stock Performance (Winchmore)[1]

Stocking rate	17.3 SU/ha	22.2 SU/ha
Number of years records	13	5
Lamb meat/ha	267 kg	307 kg
Wool/ha	78 kg	102 kg

The stocking rate generated in the solution is 21.5 SU/ha which falls between the above figures. The production figures obtained from the solution would appear to coincide with the Winchmore values.

5.3.2 The Effect of Varying the Prime Lamb and Cull Ewe Prices

The five optimal solutions for the parametric analysis carried out in this part of the research are summarised in Table 5.7. The results show two flock age structures to be optimal. Runs 1 and 2 show that ewes should be retained until the end of their fifth year but the base run and runs 3 and 4 indicate that ewes should be culled after six years. A change in flock structure (to a policy of retaining ewes until the end of their fifth year) occurred when the prime lamb price had been decreased 10% and the cull ewe price had been increased 10%. The shadow prices (Table 5.8) for the six year old ewe activity decrease from run 1 to run 2 and finally in the base run through to run 4 the activity is included in the optimum solution. The shadow prices in these latter runs indicate that the system is extended to its limit and inclusion of extra units of these activities would depress net revenue. Shadow prices for the seven year old ewe activity decrease from run 1 through to run 4. The value of $0.53 in run 4, however, is still high and suggests that a larger increase in lamb price and a larger decrease in cull ewe price would be required before this activity would be included. The culling policy shadow prices also show that at low lamb and

[1] R. Moses, pers. comm.

TABLE 5.7

CHANGES IN THE LINEAR PROGRAMMING MODEL SOLUTIONS IN RESPONSE TO SIMULTANEOUS CHANGES IN THE PRIME LAMB AND CULL EWE PRICES (IRRIGATED MODEL)

Activity	Run 1	Run 2	Base	Run 3	Run 4
Change in prime lamb price (%)	-20	-10	1977/78	+10	+20
Change in cull ewe price (%)	+20	+10	prices	-10	-20
Stock					
Replacement two tooths purchased	-	-	-	440	685
Cull ewe lambs	-	-	-	178	1229
Cull five year olds	523	524	-	-	-
Cull six year olds	-	-	410	446	451
Ewe hoggets	742	744	662	252	-
Two tooths	697	700	622	677	685
Four tooths	670	672	597	650	657
Six tooths	643	645	573	624	631
Four year olds	611	613	545	593	599
Five year olds	568	570	507	551	557
Six year olds (broken mouth)	-	-	466	507	512
Total breeding ewes	3931	3944	3972	3854	3641
Stocking rate (SU/ha)[1]	21.2	21.3	21.5	21.1	20.0
Stock Production					
Lambs prime off mother	2134	2140	2231	2430	2458
Lambs fattened	1392	1396	1569	2000	1229
Replacement ewe lambs	742	744	662	252	-
Lambing percentage (total lambs sold/ewes mated)	134	134	135	135	135
Lamb meat per hectare	277.4	278.2	290.0	315.9	319.5
Average wool weight (kg/head)	4.8	4.8	4.7	4.7	4.7
kg Wool per hectare	94.3	94.6	94.1	91.4	86.5
Death rate	5.6	5.6	6.3	6.4	6.4
Feed Supply					
Pasture (ha)	200	200	200	200	200
Hay made (bales)	2584	2639	3198	4367	3563
Hay fed per animal (bales)	0.6	0.7	0.8	1.1	1.0
Net Revenue[2]					
Total net revenue ($)	58800	62500	67100	70800	74800
Net revenue per hectare ($/ha)	294.0	312.5	335.5	354.0	374.0

[1] Stocking rate calculated assuming: 1 Coopworth ewe = 1.1 SU
1 Coopworth ewe hogget = 1.0 SU

[2] Net Revenue refers to Total Gross Margin. It only represents Direct Costs and Returns and no account has been made for Fixed Costs.

high cull ewe prices (the base run and runs 1 and 2) the move to a younger flock structure would meet with a smaller change in net revenue per unit of the activity than a move to an older flock structure. The converse is true for runs 3 and 4.

The replacement policy for the base run, and runs 1 and 2, is one of the replacements being bred from within the flock but this changes in runs 3 and 4. As the prime lamb price increases, and the cull ewe price decreases, a change of policy occurs, from one of breeding replacements within the flock, to purchasing two tooth replacements. The consequence of this change in policy is to release ewe lambs, held for replacements in previous runs, to be sold as prime lambs or as potential breeding stock. The shadow prices (Table 5.8) show that the replacement policy adopted in each of the runs is stable. In run 1 the activity with the lowest shadow price is the purchase of seven year old ewes. A similar situation occurs in run 4 but in this case the purchase of six year old ewes has the lowest shadow price. However, the shadow prices shown in each of the above cases are high. The results indicate, therefore, that the replacement policy adopted in each of the runs is stable but any change in policy would be to a policy of purchasing six (runs 3 and 4) or seven year old (runs 1 and 2, and the base run) ewes.

Analysis of the production data (Table 5.7) suggests that the change in policy to culling ewes after their sixth lambing gives a slight increase in the lambing percentage (1% increase) and a drop of 0.1 kg in average wool weight. This shows that the management system adjusts to the higher lamb returns by selecting a flock age structure which maximises lambing percentage. The production of lamb meat and wool per hectare are similar to those obtained at Winchmore Irrigation Research Station (see discussion of base run results).

TABLE 5.8

SHADOW PRICES OBTAINED FOR ACTIVITIES IN RESPONSE TO CHANGES IN THE PRIME LAMB AND CULL EWE PRICES (IRRIGATED MODEL)

Activity	Run 1	Run 2	Base	Run 3	Run 4
Change in prime lamb price (%)	-20	-10	0	+10	+20
Change in cull ewe price (%)	+20	+10	0	-10	-20
Purchasing					
Ewe hoggets	12.80	11.74	10.57	9.45	8.60
Two tooths	5.33	3.38	1.90	0.41*	2.56*
Five year olds	2.37	2.56	2.48	2.21	2.52
Six year olds	1.40	1.77	2.38	0.82	0.53
Seven year olds	0.35	1.57	2.20	1.80	1.72
Ewe Age Groups					
Six year olds	0.91	0.17	2.75*	0.96*	0.62*
Seven year olds	3.38	1.85	1.19	0.62	0.53
Eight year olds	4.80	5.29	1.23	5.77	4.73
Nine year olds	15.85	11.91	9.80	7.60	7.23
Culling Policies					
Ewe hoggets	0.04	0.06	0	0*	0*
Two tooths	0.57	0.94	0.70	2.66	2.56
Four year olds	0.14	0.86	1.72	2.90	3.29
Five year olds	0.27*	1.22*	0.37	1.00	1.21
Six year olds	1.03	0.19	2.21*	1.08*	0.70*
Seven year olds	3.98	2.18	1.40	0.73	0.63
Eight year olds	10.16	6.94	5.32	3.71	3.45
Nine year olds	24.38	18.32	15.08	11.69	11.12

*Indicates activity included in the basis.

The stocking rates adopted at optimality vary with the changes in lamb and cull ewe prices. As the lamb price is forced down and cull ewe price forced up (runs 1 and 2) the stocking rate decreased. It would be expected that the opposite would also be true but as the lamb return increased and the cull ewe return decreased, the stocking rate again decreased. A contributing factor to this decrease is that in run 3, and particularly run 4, excess ewe lambs are held over to be sold in the February ewe fairs as potential breeding stock. Holding these ewe lambs through to February influences potential winter feed and decreases the number of ewes wintered. The number of ewe lambs raised and sold in run 4 is very high and it would not be a very common practice to run this number of ewe lambs for selling as potential breeding stock.

All runs of the model adopted an all grass system in the optimal solution. This system was very stable and large changes in the establishment and maintenance costs associated with the other feed alternatives would be needed to alter the basis in each run. The only change to the feed supply profile in runs 1 to 4 is the amount of hay made and fed. This, as with the dryland model, is closely tied to the pressure put on the grazing system, in the late winter, by stock. This is illustrated by the increases in hay made as stocking rates increase and vice-versa.

The effect of the varying lamb and cull ewe prices on net revenue is demonstrated in Figure 5.6. The net revenue change between runs is relative to changes in the prime lamb price. There is not, however, a one for one relationship. A 20% increase in the lamb price (from the base run) only provided an 11.5% increase in the net revenue and a 20% decrease in the lamb price only caused a 12% drop in net revenue. The factor preventing full realisation of the change in lamb price appears to be the retention of ewe lambs until February which has had the effect of reducing ewe numbers.

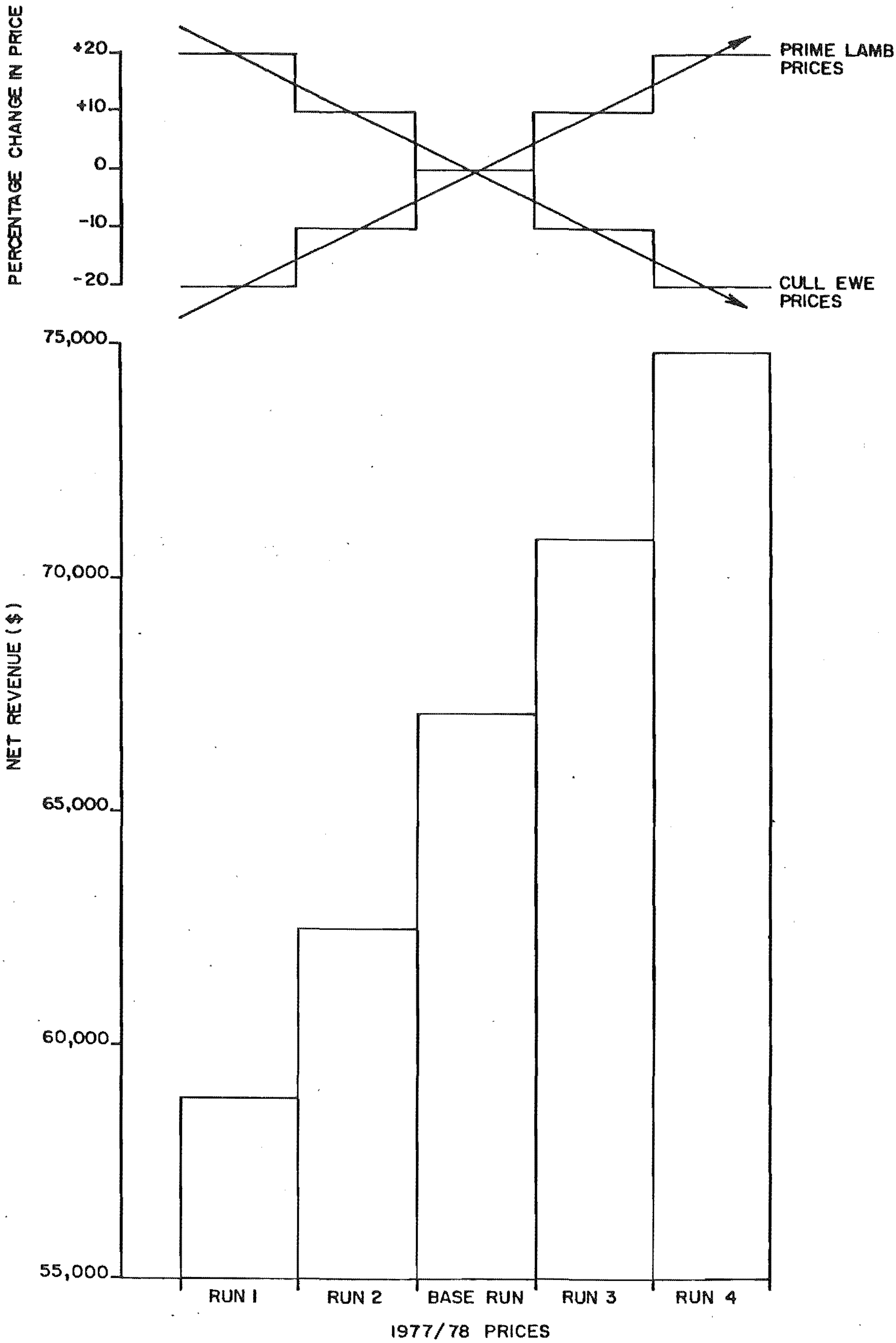

FIGURE 5.6 THE EFFECT ON NET REVENUE OF VARYING PRIME LAMB AND CULL EWE PRICE

In summary, it has been shown that with high lamb and low cull ewe prices that a policy of buying in two tooths for replacements and holding these for six years is optimal. A feature of the solutions under this price regime is the extent to which ewe lambs are sold as replacements at ewe fairs. This has the effect of lowering the stock numbers wintered. With low lamb and high cull ewe prices a policy of breeding the required ewe lambs from within the ewe flock and culling these after their fifth lambing was optimal. The feed supply profiles generated in all runs showed that an all grass system was optimal. Hay was required in each run but this was related to the number of stock to be fed. The net revenue moves relative to the lamb price. This is illustrated by the fact that a 20% rise in lamb price (from the base run) generated an 11.5% rise in the net revenue (run 4).

5.3.3 The Effect of Varying the Wool Price

A summary of the results of the parametric study with the irrigated models' wool prices are shown in Table 5.9. In all runs, except run 8, the optimal age at which ewes should be culled is after their sixth lambing. In run 8 the policy is one of culling ewes after their fifth lambing. It should be noted that it required a 40% increase in the wool price (from 1977/78 prices) to alter the flock structure. The shadow prices associated with the seven year old activity (Table 5.10) decreases as the wool price decreases and the shadow price in run 5 is low. This indicates that this activity is becoming more attractive and if the wool price is forced down still further the flock structure would alter. In run 8 the shadow price for the six year old ewe activity is low indicating that forcing this activity into the basis would only alter the net revenue by a small amount. The shadow prices for the culling of five year old ewes decrease with increasing wool price

TABLE 5.9

CHANGES IN THE LINEAR PROGRAMMING MODEL SOLUTIONS IN RESPONSE TO CHANGES IN THE WOOL PRICE (IRRIGATED MODEL)

Activity	Run 5	Run 6	Base	Run 7	Run 8
Change in wool price (%)	-40	-20	1977/78 prices	+20	+40
Stock					
Cull ewe lambs	438	447	-	-	-
Cull five year olds	-	-	-	-	543
Cull six year olds	395	403	410	417	-
Ewe hoggets	637	650	662	673	771
Two tooths	599	611	622	633	725
Four tooths	575	587	597	608	696
Six tooths	552	563	573	583	668
Four year olds	524	535	545	554	634
Five year olds	488	497	507	515	590
Six year olds (broken mouth)	449	458	466	474	-
Total breeding ewes	3824	3901	3972	4040	4084
Stocking rate (SU/ha)[1]	20.7	21.1	21.5	21.9	22.1
Stock production					
Lambs prime off mother	2150	2192	2231	2272	2216
Lambs fattened	1075	1096	1569	1599	1445
Replacement ewe lambs	637	650	662	673	771
Lambing percentage (total lambs sold/ewes mated)	135	135	135	135	134
Lamb meat per hectare	279.5	285.0	290.0	295.4	288.1
Average wool weight (kg)	4.7	4.7	4.7	4.7	4.8
kg Wool per hectare	90.6	92.4	94.1	95.7	97.94
Death rate (%)	6.3	6.3	6.3	6.3	5.6
Feed Supply					
Pasture (ha)	200	200	200	200	200
Hay made and fed (bales)	1910	2856	3198	4937	4643
Hay fed per animal (bales)	0.5	0.7	0.8	1.2	1.1
Net Revenue[2]					
Total net revenue ($)	52200	59300	67100	74000	81400
Net revenue per hectare ($/ha)	261.0	296.5	335.5	370.0	407.0

[1] Stocking rate calculated assuming: 1 Coopworth ewe = 1.1 SU
1 Coopworth ewe hogget = 1.0 SU

[2] Net Revenue refers to Total Gross Margin. It only represents Direct Costs and Returns and no account has been made for Fixed Costs.

TABLE 5.10

SHADOW PRICES OBTAINED FOR ACTIVITIES IN RESPONSE TO CHANGES IN THE WOOL PRICE (IRRIGATED MODEL)

Activity	Run 5	Run 6	Base	Run 7	Run 8
Change in wool price (%)	-40	-20	1977/78 prices	+20	+40
Purchasing					
Ewe lambs	7.01	8.77	10.57	12.35	12.96
Two tooths	0.17	0.62	1.90	2.32	2.64
Five year olds	0.90	1.55	2.48	3.16	3.57
Six year olds	0.36	0.80	2.38	1.84	1.99
Seven year olds	1.62	1.69	2.20	1.85	1.59
Ewe Age Groups					
Six year olds	0.42*	0.92*	2.75*	2.12*	0.35
Seven year olds	0.11	0.57	1.19	1.63	2.48
Eight year olds	1.23	1.20	1.23	1.24	1.27
Nine year olds	5.43	7.30	9.80	11.60	12.42
Culling Policies					
Ewe lambs	0.15*	0.54*	0	0.05	0.12
Two tooths	2.35	1.95	0.70	0.37	0.16
Four year olds	3.20	2.62	1.72	1.17	0.89
Five year olds	1.27	0.91	0.37	0.03	1.11*
Six year olds	0.47*	1.04*	2.21*	1.86*	0.39
Seven year olds	0.12	0.67	1.40	1.92	2.93
Eight year olds	2.16	3.51	5.32	6.62	6.93
Nine year olds	8.35	11.23	15.08	17.84	19.11

* Indicates activity included in the basis.

until the activity is included in the optimal solution in run 8. At low wool prices the shadow prices for the culling policies again indicate that a change to an older structured flock would have the least effect on net revenue.

Following Table 5.9 the optimum replacement policy in all runs (runs 5-8) is one of retaining ewe lambs produced by the flock for replacements. At low wool prices (run 5), ewe lambs excess to requirements are sold at ewe fairs as potential breeding stock while at high wool prices (run 8), excess ewe lambs are sold prime. At low wool prices (runs 5, 6 and the base run) the two tooth purchasing activity has the lowest shadow price (Table 5.10) whereas at high wool prices shown in runs 7 and 8 respectively the purchase of older ewes, six and seven year olds, have the lowest shadow prices. Overall, however, the breeding of replacements on the property is a stable policy.

The results indicate that as the wool price increases, the management system adopted adjusts in the following ways:

(i) increase in stock numbers (from 3824 to 4084 ewes), and

(ii) a change to a flock age structure which gives a higher average wool weight per head. This is obtained at the expense of a slight drop in average lambing percentage.

The lamb meat per hectare increases with increasing wool price as shown in runs 5-7 but in run 8 decreases. The decrease in run 8 reflects the 1% drop in lambing percentage associated with the change in flock structure. The wool weight per hectare increases with the wool price increase. In the early runs (runs 5-7) this is related to increases in ewe numbers but in run 8 the increased production per head, associated with the changed flock structure, plays a part.

The change in wool price has only a minimal effect on the feed supply. An all grass system has been adopted as the optimum solution in all runs and only the amount of hay made and fed changes between runs. The changes in hay made and fed occur in response to increases or decreases in stocking rate and also in run 8 to a change in the flock structure.

Changes in the total net revenue coincide with variations in the wool price (Figure 5.7). A 40% increase in the wool price has the effect of increasing the total net revenue 11% (run 8) and a 40% decrease in the wool price reduces the total net revenue 22% compared with the base run value. This would suggest, as with the dryland situation discussed earlier, that under irrigated conditions variations in wool price will have little effect on the total system compared with similar changes in the prime lamb and cull ewe prices.

To summarise, an increase in wool return leads to an increase in stocking rate and net revenue. When the increase in wool price is large, as in run 8, a change in the flock structure occurred from a flock with ewes being culled after their sixth lambing to a flock where ewes are culled after their fifth lambing. This alteration in flock structure had the effect of increasing the average wool weight per head while decreasing the lambing percentage. As wool returns fall, the stocking rate also fell but the replacement policy and age structure of the flock in each run remained the same. The only change in the feed profile as a result of wool price changes was the number of bales of hay made and fed.

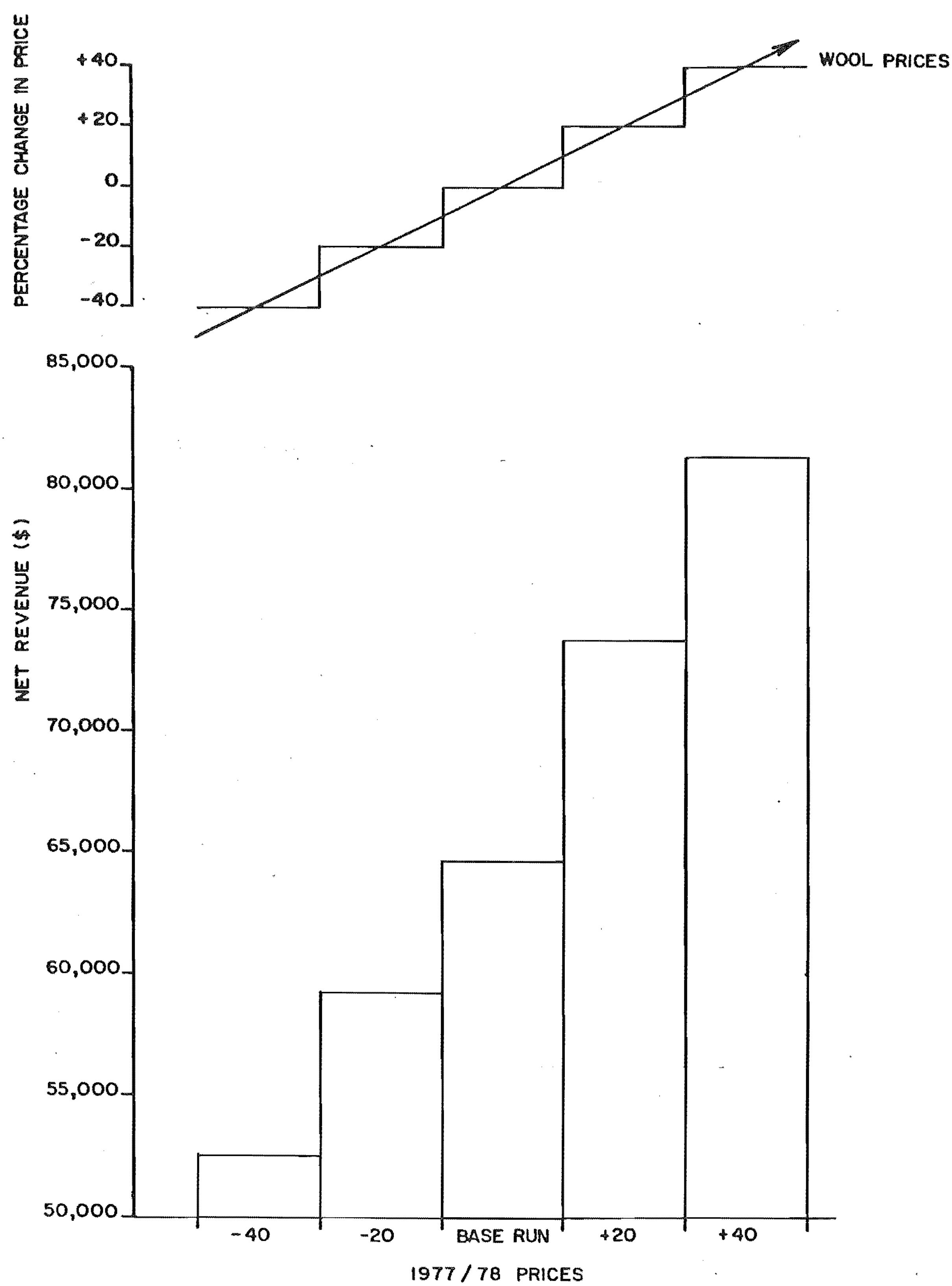

FIGURE 5.7 THE EFFECT ON NET REVENUE OF VARYING WOOL PRICE

5.4 DISCUSSION

An analysis of the effects of varying prices has been undertaken in the research but no investigation has been made of the likely effects of changes in the production of aged ewes as further parametric analysis would have confused the pricing analysis. An assessment, by gross margin analysis, of changes in death rates and lambing percentage within the gummy ewe group is shown in Figures 5.8 and 5.9. However, when both a low death rate and higher lambing percentage were adopted together the optimal replacement age was found to rise to nine years.

The base data used in developing both the models in this thesis reflect a somewhat conservative estimate of aged ewe performance. This approach has been adopted in the absence of sufficient data to suggest that higher performance figures should have been used. It should also be noted that the tendency of farmers to cull aged ewes from the breeding flock when their constitution is suspect has not been accounted for in the models. As a consequence the death rate may have been exaggerated. It is possible that the gross margin for aged ewes would rise by the extent of the difference between the level of deaths adopted and the real salvage value obtained by culling on constitution pre-tupping.

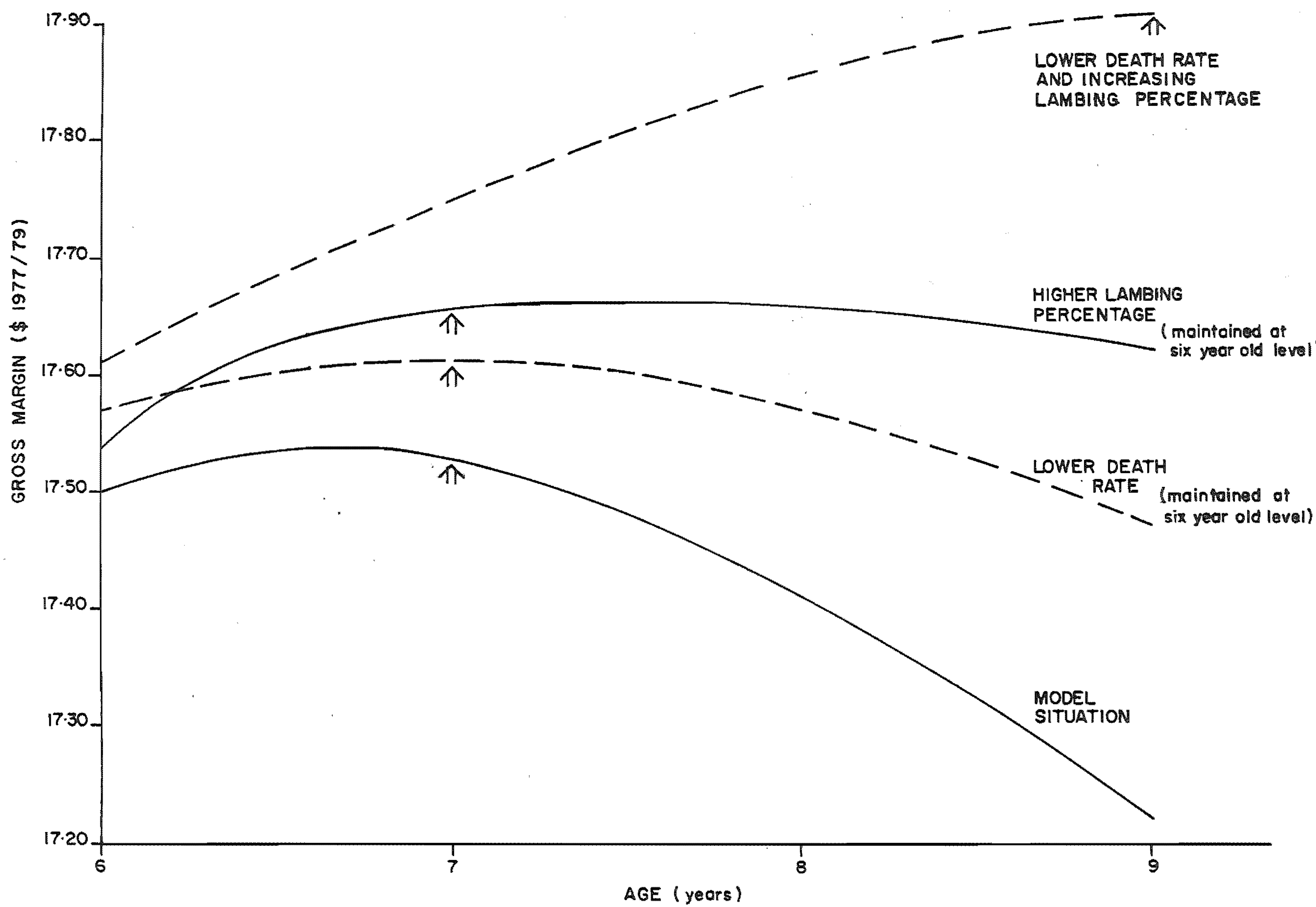

FIGURE 5.8 THE EFFECT OF VARYING PRODUCTION PARAMETERS (Dryland station)

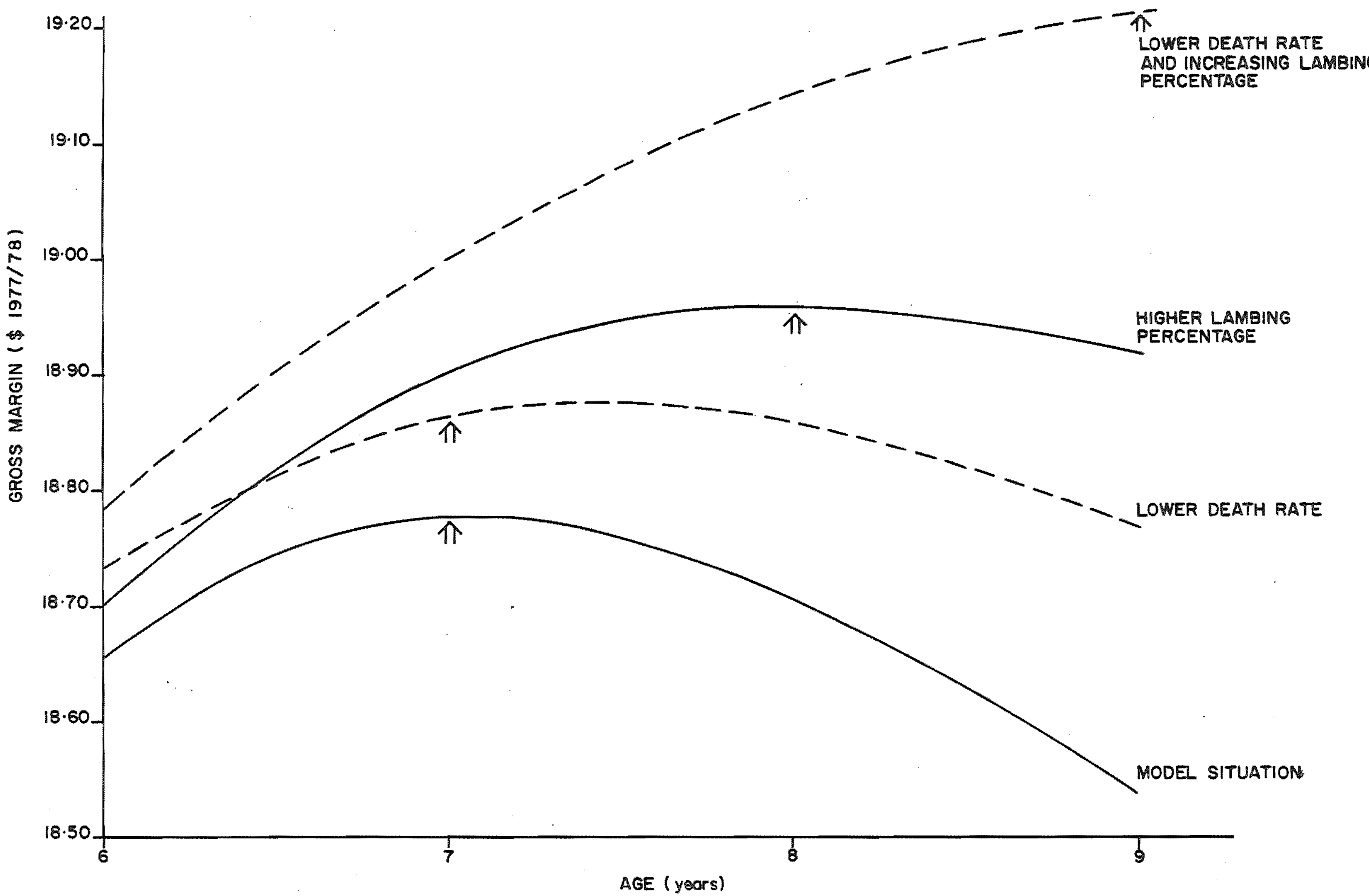

FIGURE 5.9 THE EFFECT OF VARYING PRODUCTION PARAMETERS (Irrigated station)

CHAPTER VI

CONCLUSIONS

6.1 A SUMMARY OF THE RESULTS

The survey of farmers running 'gummy' ewes (Section 3.1) showed that ewe mouths failed on average after five years. This varied according to the breed of sheep, area, climate and the amount and type of feed available. A large proportion of the farmers ran these ewes as a separate mob feeding them soft feeds. However, as the trial work (Section 3.2) showed that 'gummy' ewes can be fed turnips as long as they are not placed in competition with young ewes and an allowance is made for their slower eating. Both the survey and trial results suggest that aged ewes, particularly those with 'gummy' mouths, were susceptible to feed stress. It was noted that ewes placed under feed stress tended to lose condition and waste away before dying. This was found to account for the largest proportion of deaths among these ewes on the surveyed properties. The trials also showed that feed stress, particularly in mid or late pregnancy, led to high death rates caused by a progressive loss of condition. Another factor brought to light by both the survey and trial results was the high incidence of ewes losing lambs shortly after birth. It was evident from the results that the old, poor mouthed ewes were more likely to have bad udders or restricted milk supplies at lambing. Foster mothers were needed for the lambs produced by these ewes.

The survey results showed some clear production trends exist between 'gummy' and mixed aged ewes. The 'gummy' ewes had -

1. a 10-15% higher lambing percentage,
2. a 2-3% higher death rate, and
3. a 0.5-1.0 kg lower wool weight.

However, the trial results indicated some differences from the above trends. The lambing percentage in all but one trial was lower than the mixed aged ewes. The lower lambing percentage was caused by one of the following stresses;

1. Feed stress due to competition with younger, better mouthed ewes.
2. Stress provided by poor weather at lambing.
3. The contraction of disease (hairy shaker disease was evident in Trial 4).

These stresses, particularly the feed and weather stress, led to unusually high ewe and lamb deaths in some cases. The death rate of the ewes can be reduced by better feeding especially in the last six weeks of pregnancy but unless climatic and feed conditions are good the death rate of old and 'gummy' ewes will be significantly higher than that of mixed aged ewes. The reduced wool weight observed in the survey was similar in extent to the loss measured in the trials.

A study of the survey results, using gross margin analysis, showed that over the eight year period 1970-77 a policy of selling five year olds and retaining replacement ewe lambs was the most profitable (Figure 3.1). This was not so when the cull ewe price and lamb price received by the farmer differed significantly. In this case it was more profitable to have a system of buying 'gummy' ewes and running these for two years. This suggests that the decline associated with the ageing and loss of teeth of a ewe both in economic and production losses needed investigating.

The results of the experimentation with the linear programming models (Chapter V) showed that breeding ewes should be retained for at least five lambings and in some cases as long as seven lambings. The solutions obtained from each model when using 1977/78 prices showed that ewes should be culled after their sixth lambing (as six year olds). An increase in the lamb price of 20% and a corresponding decrease in the cull ewe price was needed to increase the age structure of the flock by one year in the Dryland Model. On the other hand, a similar decrease in lamb price and increase in cull ewe price had no effect on the flock's age structure. The change in flock structure, from culling as six year olds to culling as seven year olds, was associated with a 1% rise in lambing percentage and a 0.1 kg/head drop in average wool weight. The replacement policy adopted for all runs of the dryland management system was one of purchasing ewe lambs.

The flock structure in the Irrigated Model remained stable with ewes being retained until after lambing as a six year old following a 20% increase in the prime lamb price and a corresponding decrease in the cull ewe price. At the same time the replacement policy changed from one of replacements being bred within the flock to a policy of purchasing two tooths for replacements. This latter policy meant that half the ewe lambs produced could be sold as potential breeding stock in February. A 20% decrease in the lamb price and a corresponding increase in the cull ewe price led to the culling age dropping from six to five year olds, but the replacement policy remained the same. This change in age structure of the flock resulted in a 1% drop in lambing percentage and a 0.1 kg rise in the average wool weight per head.

The Dryland model adjusted to an increase in the wool price by an increase in the stock numbers but at the same time maintained the same replacement policy and flock age structure. Conversely a decrease in the wool price caused a decrease in stock numbers with an extension of the age structure of the flock by one year. This had the effect of slightly increasing lambing percentage and decreasing average wool weight per head.

The effects of an increase in the wool returns on the irrigated farm model were an increase in the stocking rate and a change in the flock structure from culling ewes after six lambings to a policy of culling ewes after five lambings. This change in policy is associated with a slight increase in average wool weight per head and a decrease in lambing percentage. As wool prices fell the stocking rate also fell but the replacement policy and age structure of the flock remained the same.

Table 6.1 summarises the linear programming solutions discussed above.

6.2 THE IMPLICATIONS OF THE RESULTS

It is clear from the above discussion that the age at which ewes are culled from the New Zealand ewe flock is too low and that it is physically possible and economically desirable to increase the average age. The implications to the nation of an increase in the average age of ewes in the national flock are;

1. An increase in the number of lambs available for export through fewer replacement ewe lambs being required to maintain the ewe flock and a slight increase in average lambing percentage as the percentage of older ewes increases.
2. A proportionate decrease in the number of cull ewes available for export as mutton. With more age groups in the ewe flock, ewes are retained in the flock longer.
3. Substitution of lamb meat for wool. Wool production from aged ewes is lower (and lamb production higher) meaning less wool is available for export.

The implications of a shift in the culling age of the ewe flock from 4.3 years (calculated in Chapter I) to 5.3, 6.0 and 6.6 years (calculated

TABLE 6.1

SUMMARY OF THE LINEAR PROGRAMMING SOLUTIONS

Farm Type	Representative Farm - Dryland						Representative Farm - Irrigated					
Product price effected	Wool			Lamb and Ewe			Wool			Lamb and Ewe		
Percentage change from 1977/78 prices	0	+40	-40	0	+20L[1] -20E[2]	-20L +20E	0	+40	-40	0	+20L -20E	-20L +20E
Replacement policy	Purchase ewe lambs			Purchase ewe lambs			Breed own replacements			Breed own replacements	Purchase two-tooths	Breed own replacements
Culling age (yrs)	6	6	7	6	7	6	6	5	6	6	6	5
Flock structure (%)												
Ewe hoggets	16.6	16.6	15.1	16.6	15.1	16.6	16.6	18.9	16.6	16.6	-	18.9
Two-tooths	15.7	15.7	14.2	15.7	14.2	15.7	15.7	17.7	15.7	15.7	18.8	17.7
Four-tooths	15.0	15.0	13.6	15.0	13.6	15.0	15.0	17.0	15.0	15.0	18.0	17.0
Six-tooths	14.4	14.4	13.1	14.4	13.1	14.4	14.4	16.4	14.4	14.4	17.3	16.4
Four year olds	13.7	13.7	12.4	13.7	12.4	13.7	13.7	15.5	13.7	13.7	16.5	15.5
Five year olds	12.8	12.7	11.6	12.8	11.6	12.8	12.8	14.5	12.8	12.8	15.3	14.5
Six year olds	11.7	11.7	10.6	11.7	10.6	11.7	11.7	-	11.7	11.7	14.1	-
Seven year olds	-	-	9.4	-	9.4	-	-	-	-	-	-	-
Stocking rate (SU/ha)	12.4	14.2	11.4	12.4	13.9	11.6	21.5	22.0	20.7	21.5	20.0	21.2
Lambing %	116	116	117	116	117	117	135	134	135	135	135	134
Lamb meat/ha (kg)	158	180	147	158	178	147	290	288	280	290	320	277
Wool weight (kg)	4.4	4.4	4.3	4.4	4.3	4.4	4.7	4.8	4.7	4.7	4.7	4.8
Wool/ha (kg)	46	53	42	46	51	43	94	98	91	94	87	94

[1] refers to lamb price.

[2] refers to cull ewe price.

in the same way as Chapter I but using the linear programming solutions) is studied. These represent 23.0, 39.5 and 53.5% increases in the age at which ewes are culled. In the 1977/78 export killing season 5.4 million ewes and 24.9 million lambs[1] were slaughtered in New Zealand freezing works. In the same period 192.1 million kg of wool[2] were produced on New Zealand sheep farms. The value of the changes in production described in the analysis, have been assessed from a national point of view using the F.O.B. product price assumptions for estimating the value of agricultural production to New Zealand by the Ministry of Agriculture and Fisheries. The results of this analysis are shown in Table 6.2.

It is clear from table 6.2 that even a small increase in the culling age of the New Zealand ewe flock is likely to have a large effect on export earnings. Although it would be more desirable for the culling age of the ewe flock to rise to between 6 and 7 years of age, the level of 5 to 6 years of age is perhaps a more realistic target. A change of this magnitude would be more prudent as it should be realised that farming conditions and practices vary throughout the country. There would also be problems in removing farmer barriers relating to traditional culling policies.

An increase in the age at which ewes are culled from the New Zealand flock has been shown to be a simple and efficient method of increasing New Zealand's overseas earnings. More research into the physical limitations of running 'failed mouth' and 'gummy' ewes under all New Zealand conditions should be carried out. The results of trials by various research stations could help allay farmer fears in this respect. The practice of holding ewes beyond 5 years of age has been shown to be a cheap and easily attained one with significant repercussions throughout the New Zealand sheep industry.

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[1] Source - The New Zealand Meat Producer, Volume 6, No.11.

[2] Source - Meat and Wool Boards Economic Service.

TABLE 6.2

THE VALUE TO THE NATION OF INCREASING THE AGE STRUCTURE OF THE NEW ZEALAND EWE FLOCK
(all values $\times 10^6$)

Age change (years)	Additional lambs killed A[1]	Value to Nation of lambs A×$14.40	Additional ewes retained B[2]	Loss to Nation of ewes B×$11.10	Drop in wool production C[3]	Loss to Nation of wool C×$2.02	Net change in export earnings
4.3-5.3	6.6	$95	1.2	-$13	2.7	-$5.5	+$76.5
4.3-6.0	11.0	$158	2.1	-$23	4.3	-$8.5	+$126.5
4.3-6.6	14.6	$210	2.8	-$31	5.8	-$11.5	+$167.5

[1] This value represents the additional lambs available for export. The source of these lambs is from the increased lambing percentage associated with the change in age structure.

[2] This value represents the decrease in the number of ewes available for export due to ewes being retained in the flock longer.

[3] Represents the decrease in wool weight associated with the increased age structure.

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REFERENCES

Annon., 1977: Waihora Romneys.
New Zealand Farmer 98(22): 42.

BARNICOAT, C.R. 1957: Wear in sheep's teeth.
New Zealand Journal of Science and Technology: 38A.

BARTON, R.A. 1947: Fertility in the Romney ewe with particular reference to the two-tooth.
Sheepfarming Annual: 113.

BEETHAM, M.R. 1973: The use of arable by-products.
Annual Report (1972-73) Winchmore Irrigation Research Station: 10.

BENZIE, D.; CRESSWELL, E. 1962: Studies of the dentition of sheep IV Radiological studies from investigations into the shedding.
Research in Veterinary Science 3: 416-428.

BROWN, G.H.; TURNER, H.N.; YOUNG, S.S.Y.; DOLLING, C.H.S. 1966: Vital statistics of an experimental flock of Merino Sheep II. Factors affecting wool and body characteristics, including the effect of age of ewe and its possible interaction with method of selection.
Australian Journal of Agricultural Research 17: 557-581.

BRYNE, P.F. 1967: Optimal culling policy for breeding ewes.
Australian Journal of Agricultural Economics 11(2): 144-153.

BRYNE, P.F.; HEALY, A.T.A. 1969: A note on livestock breeding policies in stable and development situations.
Australian Journal of Agricultural Economics 13(2): 154-161.

CAIRNEY, J.M. 1967: Sheep's teeth.
New Zealand Meat 11(9): 40.

CAMPBELL, F.R. 1962: Influence of age and fertility of Rambouillet ewes on lamb and wool production. Miscellaneous Publication Texas Agricultural Experimental Station. No. M.P.-596: 6 pp.

COLLIN, F.H. 1966: Tangoio and Waerenga-O-Kuri stocking rate trials.
Journal of New Zealand Institute of Agricultural Science 1: 9-14.

COOP, I.E. 1973: Age and liveweight in sheep.
New Zealand Journal of Experimental Agriculture 1: 65-68.

COOP, I.E.; ABRAHAMSON, M. 1973: Effect of teeth condition on intake of grazing sheep.
New Zealand Journal of Experimental Agriculture 1: 58-64.

COOP, I.E.; CLARK, V.R. 1955: The influence of method of rearing as hoggets on the lifetime productivity of sheep.
New Zealand Journal of Science and Technology 37A: 214-228.

CROTTY, P. 1979: A comparison of stock wintering systems in Southland. Thesis, M.Agr.Sc. (unpubl.), Lincoln College, University of Canterbury, New Zealand.

CROUCHLEY, G.; BIRCHAM, J.S. 1971: Winter greenfeed production in Wairarapa.
New Zealand Journal of Agriculture 122(2): 36-40.

CUTTRESS, T.W.; HEALY, W.B. 1965: Wear of sheep's teeth 2. Effects of pasture juices on dentine.
New Zealand Journal of Agricultural Research 8: 753-762.

DICKERSON, G.E.; GLIMP, H.A. 1975: Breed and age effects on lamb production of ewes.
Journal of Animal Science 40(3): 397-408.

DUCKWORTH, J.; HILL, R.; BENZIE, D.; DALGARNO, A.L. 1962: Studies of the dentition of sheep I. Clinical observations from investigations into the shedding of permanent incisor teeth by hill sheep.
Research in Veterinary Science 3: 1-17.

EGAN, J.K.; BISHOP, A.H.; McLAUGHLIN, J.W. 1972: The influence of age and sex structure and of reproductive performance on the production from a self-replacing flock.
Proceedings of the Australian Society of Animal Production 9: 71.

FIELD, A.C.; SYKES, A.R.; GUNN, R.G. 1974: Effects of age and state of incisor dentition on faecal output of dry matter and on faecal and urinary output of nitrogen and minerals, of sheep grazing hill pastures.
Journal of Agricultural Science (Camb.) 83: 151-160.

FRANKLIN, M.C. 1950: Diet and dental development of sheep.
Commonwealth Scientific and Industrial Research Organisation, Melbourne, Bulletin 252.

GOOT, H. 1951: Studies on some New Zealand Romney Marsh stud flocks V. Losses in ewes and lambs.
New Zealand Journal of Science and Technology 33(2): 28-36.

GRANGER, W. 1944: Selection of breeding ewes - Dependence of practicable degree of selection of young ewes upon vital statistics.
The Australian Veterinary Journal 20: 253-260.

GREGORY, I.P.; ROBERTS, E.M.; JAMES, J.W. 1977: Genetic improvement of meat sheep. 4. Effect of age of dam on productivity of Dorset and Border Leicester sheep. Australian Journal of Experimental Agriculture and Animal Husbandry. 17: 735-740.

GUNN, R.G. 1970: A note on the effect of broken mouth on the performance of Scottish Blackface hill ewes.
Animal Production 12: 517-520.

HAYMAN, J.M. 1977: Irrigation-Management for sheep on light Canterbury soils.
Aglink FPP 79/7 3 pp.

HEALY, W.B. 1967: Ingestion of soil by sheep.
New Zealand Society of Animal Production Proceedings 27: 109-120.

HEALY, W.B.; CUTTRESS, T.W.; MICHIE, C. 1967: Wear of sheep's teeth. 4. Reduction of soil ingestion and tooth wear by supplementary feeding.
New Zealand Journal of Agricultural Research 10: 201-209.

HEALY, W.B.; LUDWIG, T.G. 1965: Wear of sheep's teeth. 1. The role of ingested soil.
New Zealand Journal of Agricultural Research 8: 737-752.

HICKEY, F. 1960: Death and reproductive rates of sheep in relation to flock culling and selection.
New Zealand Journal of Agricultural Research 3: 332-344.

HIGHT, G.K.; JURY, K.E. 1970: Hill country sheep production. I. The influence of age, flock, and year on some components of reproduction rate in Romney and Border Leicester x Romney ewes.
New Zealand Journal of Agricultural Research 13: 641-659.

HITCHIN, A.D.; WALKER-LOVE, J. 1959: Broken mouth in hill sheep.
Agriculture 66: 5-8.

JAGUSCH, K.T.; COOP, I.E. 1971: The nutritional requirements of grazing sheep.
Proceedings of the New Zealand Society of Animal Production 31: 224-234.

JARDINE, R.; MULLANEY, P.D.; TURNBULL, E.D.; EGAN, J.K. 1975: Effects of age, sex and fertility on the optimal structure of a static self-replacing ewe and wether flock.
Australian Journal of Experimental Agriculture and Animal Husbandry 15(76): 610-618.

JOHNS, M.A.; PEARSE, R.A. 1970: Towards optimal fat lamb mating strategies on the Northern Tablelands.
Review of marketing and Agricultural Economics 38(4): 114-214.

LUDWIG, T.G.; HEALY, W.B.; CUTTRESS, T.W. 1966: Wear of sheep's teeth. 3. Seasonal variation in wear and ingested soil.
New Zealand Journal of Agricultural Research 9: 157-164.

McARTHUR, A.T.G. 1973: Application of dynamic programming to the culling decision in dairy cattle.
Proceedings of the New Zealand Society of Animal Production 33: 141-147.

McGREGOR, M.J.; FRENGLEY, G.A.G. 1976: A survey of the economics and management of gummy ewes.
Lincoln College Department of Farm Management and Rural Valuation, Discussion Paper No.2: 63 pp.

McLEOD, C.C. 1974: A comparison of ryegrass cultivars in South Canterbury. 2. Annual cultivars.
Proceedings of the New Zealand Grasslands Association 35: 219-223.

MORTLOCK, C.T. 1975: An assess of some forage crops in South Canterbury. Proceedings of the Agronomy Society of New Zealand 5: 17-19.

MULLANEY, P.D.; BROWN, G.H. 1970: Some components of reproductive performance of sheep in Victoria. Australian Journal of Agricultural Research 21: 945-950.

MULLANEY, P.D.; BROWN, G.H.; YOUNG, S.S.Y.; HYLAND, P.G. 1969: Genetic and phenotypic parameters for wool characteristics in fine-wool Merino, Corriedale, and Polwarth sheep. I. Influence of various factors on production.
Australian Journal of Agricultural Research 20: 1161-1176.

NORBY, J.E.; TERRILL, C.E.; HAZEL, N.; STOEHR, J.A. 1945: from Barnicoat (1957).

POLÁCH, A. 1960: The relation between age and fertility in ewes. Animal Breeding Abstracts 28: 289, No.1409.

PORTER, W.L. 1970: Occurrence of Paradontal disease in sheep in relation to superphosphate topdressing, stocking rate and other related factors.
New Zealand Veterinary Journal 18: 21-27.

RATTRAY, P.V. 1977: Effect of lambing date on production from breeding ewes and on pasture allowance and intake.
Proceedings of the New Zealand Grassland Association 39(1): 98-107.

RATTRAY, P.V.; JAGUSCH, K.T. 1977: How much pasture should be offered to sheep.
Proceedings of the Ruakura Farmers Conference: 49-51.

RICKARD, D.S., RADCLIFFE, J.E. 1976: Seasonal distribution of pasture production in New Zealand. XII. Winchmore, Canterbury Plains dryland and irrigated pastures. New Zealand Journal of Experimental Agriculture 4: 329-335.

RITCHIE, I.J. 1978: Lucerne under irrigation on Canterbury and Otago soils. Aglink FPP85.

ROSE, M. 1972: Vital statistics for an experimental flock of Merino Sheep in North West Queensland.
Australian Society of Animal Production, Proceedings 9: 48-54.

ROSE, M. 1974: The effects of age, year and lambing performance on greasy wool production in Merino ewes in North-West Queensland.
Australian Society of Animal Production, Proceedings 10: 367-371.

SCOBIE, G.M. 1968: Economic aspects of replacement policies in Merino sheep flocks (a brief review).
Quarterly Review of Agricultural Economics 21: 126-139.

SIDWELL, G.M.; EVERSON, D.O.; TERRILL, C.E. 1962: Fertility, prolificacy and lamb livability of some pure breeds and their crosses.
Journal of Animal Science 21: 875-879.

SMETHAM, M.L. 1976: The influence of herbage utilisation on pasture production and animal performance.
New Zealand Grasslands Association, Proceedings 37(1): 91-103.

SYKES, A.R.; FIELD, A.C.; GUNN, R.G. 1974: Effects of age and state of incisor dentition on body composition and lamb production of sheep grazing hill pastures.
Journal of Agricultural Science (Camb.) 83: 135-144.

THOMSON, N.A. 1977: Factors affecting animal production intake and utilisation by ewes grazing grass/clover and lucerne pastures.
New Zealand Grasslands Association, Proceedings 39(1): 86-97.

THOMSON, R.T. 1974: An economic evaluation of alternative stock policies on a Canterbury arable farm.
Thesis, M.Agr.Sc. (unpubl.), Lincoln College, University of Canterbury, New Zealand: 250 pp.

THRIFT, F.A.; WHITEMAN, J.V. 1969: Wool production of Western and Dorset x Western ewes as influenced by certain environmental factors.
Journal of Animal Science 29: 869-873.

THROSBY, C.D. 1964: Some dynamic programming models for farm management research.
Journal of Agricultural Economics 16: 98-110.

TOWNSLEY, R.; SCHRODER, W.R. 1964: A note on breeding flock composition in relation to economic criteria.
Australian Journal of Agricultural Economics 8: 66-73.

TURNER, H.N.; BROWN, G.H.; FORD, G.H. 1968: The influence of age structure on total productivity in breeding flocks of Merino sheep. I. Flocks with a fixed number of breeding ewes, producing their own replacements.
Australian Journal of Agricultural Research 19: 443-475.

TURNER, H.N.; DOLLING, C.H.S. 1965: Vital statistics for an experimental flock of Merino sheep. II. The influence of age on reproductive performance.
Australian Journal of Agricultural Research 16: 699-712.

TURNER, H.N.; DOLLING, C.H.S.; SHEAFFE, P.H.G. 1959: Vital statistics for an experimental flock of Merino sheep. I. Death rates in adult sheep, in relation to method of selection, age and sex.
Australian Journal of Agricultural Research 10: 581-590.

VARTHA, E.W. 1971: Overdrilled winter-growing annual grass to supplement lucerne.
New Zealand Grassland Association, Proceedings 33: 115-123.

VARTHA, E.W.; BROWN, K.R. 1977: Christchurch Press, 10 December: 10.

VARTHA, E.W.; RAE, S.J. 1973: The growth of 'Grasslands Tama' Westerwolds ryegrass alone and in mixture with cereals. New Zealand Grasslands Association, Proceedings 34(2): 169-176.

VESELY, J.A.; PETERS, H.F. 1965: Fertility, prolificacy, weaned lamb production, and lamb survival ability in four range breeds of sheep. Canadian Journal of Animal Science 45: 75-78.

APPENDIX A

Activities Included in Models

A.1 Dryland Model

Activity Number	Description
	A. Purchase of Replacement Activities:
1 - 3	Purchase of ewe lambs (2 weights and 2 purchase dates).
4 - 7	Purchase of two-tooth, five year old, six year old and seven year old ewes.
	B. Ewe Activities:
8	Rear unmated ewe lambs.
9 - 10	Mated ewe lambs.
11 - 29	Mixed ages ewes including two-tooths to six year old ewes. Each age group has three possible lambing dates (a-c) and the six year old ewes have four possible lambing dates (a-d); (a) lambing 15 September. (b) lambing 1 September. (c) lambing 15 August. (d) lambing 1 August.
30 - 53	Aged ewes; seven, eight and nine year old ewes. These ewe activities have the same lambing dates as the mixed aged ewes, but there are two feed standards for each lambing date activity. (a) ewes receive a ten percent increase in feed six weeks prior to lambing.

(b) ewes receive normal feed for a ewe of that liveweight.

C. Selling Cull Ewe Activities:

54 - 64 The selling of cull ewe lambs, two-tooths and four to ten year old ewes.

D. Selling Lamb Activities:

65 - 68 Selling store lambs at weaning.

69 - 72 Fattening of lambs to a killing weight from weaning. These activities include the subsequent selling of the lambs fat at the freezing works.

73 Selling lambs fat off the mother.

E. Wool Selling Activities:

74 - 75 Selling wool. Two qualities are used.

(a) Wool from ewes up to five years of age which is assumed to be of a higher quality than,

(b) wool from ewes six to nine years of age.

F. Pasture and Lucerne Activities:

76 - 77 Pasture and lucerne.

G. Pasture and Lucerne Renewal Activities:

78 - 80 Renewal of pasture and lucerne out of feed crops. Lucerne renewal involves a transition activity which covers the land requirement from drilling in October until production in January.

H. Feed Crops:

81 - 89 Lucerne overdrilled with Tama ryegrass receiving 22.4 kg nitrogen per hectare mid-winter.

90 - 101 Lucerne overdrilled with Tama ryegrass. Overdrilled in early March.

102 - 113 Lucerne overdrilled with Tama ryegrass. Overdrilled in mid April.

114 - 124 Tama ryegrass receiving 33.6 kg nitrogen per hectare mid-winter.

125 - 132 Tama ryegrass drilled in early March with ground receiving no summer fallow.

133 - 147 Tama ryegrass drilled in early March after ground has received a summer fallow.

148 - 157 Paroa ryegrass.

158 - 162 Tama ryegrass, ryecorn mix.

163 - 167 Tama ryegrass, Amuri oats mix.

168 - 172 Turnips drilled in December.

173 - 177 Turnips drilled in January.

178 - 180 Rape drilled early October.

181 - 183 Rape drilled late October.

184 - 187 Rape drilled mid-December.

K. Feed Transfer and Quality Substitution Activities:

188 - 202 High quality feed transfer between periods.

203 - 217 Medium quality feed transfer between periods.

218 - 232 Low quality feed transfer between periods.

233 - 248 High to medium quality feed substitution.

249 - 264 Medium to low quality feed substitution.

L. Make Hay Activities:

265 - 271 Make medium quality hay.

272 - 276 Make low quality hay.

M. Feed Hay Activities:

277 - 292 Feed medium quality hay.

293 - 308 Feed low quality hay.

N. Buy Hay Activities:

309 - 310 Buy medium and low quality hay.

A.2 Irrigated Model

Activity Number	Description
	A. Purchase of Replacement Ewes Activities:
1 - 5	Purchase of ewe lambs, two-tooths, five year old, six year old and seven year old ewes.
	B. Ewe Activities:
6 - 9	Rear replacement ewe lambs.
10 - 28	Mixed aged ewes, i.e. two-tooths to six year old ewes inclusive. Each age group has three possible lambing dates (a-c) and the six year old ewes have four possible lambing dates (a-d); (a) lambing 15 September. (b) lambing 1 September. (c) lambing 15 August. (d) lambing 1 August.
29 - 52	Aged ewes, i.e. seven, eight and nine year old ewes. These ewe activities have the same lambing dates as the mixed aged ewes, but there are two feed standards for each lambing date activity. (a) Ewes receive a ten percent increase in feed six weeks prior to lambing. (b) Ewes receive normal feed for a ewe of that liveweight.
	C. Selling Cull Ewe Activities:
53 - 69	The selling of cull ewe lambs, two-tooths and four to ten year old ewes.

D. Selling Lamb Activities:

70 - 77 Selling store lambs at weaning.

78 - 85 Fattening of lambs to a killing weight from weaning. These activities include the subsequent selling of the lambs fat at the freezing works.

86 - 90 Selling lambs fat off the mother.

E. Wool Selling Activities:

91 - 92 Selling wool. Two qualities are used;

(a) wool of higher quality from ewes aged up to and including five years.

(b) wool of a lower quality from ewes six to nine years of age.

F. Pasture and Lucerne Activities:

93 - 96 Irrigated and dryland pasture and lucerne.

G. Pasture and Lucerne Activities:

97 - 100 Renewal activities for the above pasture and lucerne activities.

K. Feed Transfer and Quality Substitution Activities:

101 - 115 High quality feed transfer between periods.

116 - 130 Medium quality feed transfer between periods.

131 - 145 Low quality feed transfer between periods.

146 - 161 High to medium quality feed substitution.

162 - 177 Medium to low quality feed substitution.

L. Make Hay Activities:

178 - 182 Make medium quality hay.

183 - 187 Make low quality hay.

M. Feed Hay Activities:

188 - 196 Feed medium quality hay.

197 - 205 Feed low quality hay.

N. Buy Hay Activities:

206 - 207 Buy medium and low quality hay.

APPENDIX B

Gross Margins

B.1 Dryland Model

Buy Ewe Lamb (light)	$
Cost of ewe lamb	13.00
Plus cartage (48 km)	0.36
	-$13.36

Buy Ewe Lamb (heavy)	
Cost of ewe lamb	14.50
Plus cartage (48 km)	0.36
	-$14.86

Buy Two-tooth Ewe	
Cost of two-tooth	19.00
Plus cartage (48 km)	0.47
	-$19.47

Buy Five Year Old Ewe	
Cost of five year old	11.00
Plus cartage (48 km)	0.47
	-$11.47

Buy Six Year Old Ewe	
Cost of six year old	8.50
Plus cartage (48 km)	0.50
	-$9.00

Buy Seven Year Old Ewe		$
Cost of seven year old		8.50
Plus cartage (48 km)		0.50
		-$9.00

Rear Replacement Ewe Lamb (unmated)		
Shearing	- 1.0 @ $32/100	0.32
Crutching	- 0.99 @ $15/100	0.15
Drenching	- 4 drenches @ $0.07/dose	0.28
Vaccination	- 1.0 triple vaccine @ $0.064/dose	0.06
Dipping	- 1.0 @ $0.13/lamb	0.13
Woolshed expenses	- 4.6 kg wool @ $0.02/kg	0.09
Cartage	- 4.6 kg wool @ $0.009/kg	0.04
Eartags, footrot and docking		0.07
		-$1.14

Rear Replacement Ewe Lamb (mated)		
Shearing	- 1.0 @ $32/100	0.32
Crutching	- 0.99 @ $15/100	0.15
Drench	- 4 drenches @ $0.09/dose	0.36
Vaccination	- 1.0 triple vaccine @ $0.064/dose	0.06
Dipping	- 1.0 @ $0.13/lamb	0.13
Ram cost	- 2 rams per 100 ewes, assume a four year life	
	0.005 rams @ $75	0.37
Woolshed expenses	- 4.6 kg wool @ $0.02/kg	0.09
Cartage	- 4.6 kg wool @ $0.009/kg	0.04
Eartags, footrot and docking		0.10
		-$1.62

Ewe

The gross margin calculated for a ewe is common for all ewes included in this model except for the woolshed expenses and wool cartage values which vary according to the wool weight of each age group. Below is the gross margin common to all of the ewe activities using the two-tooth ewe values for the variables.

		$
Shearing	- 1.0 ewe @ $32/100	0.32
Tup crutch	- 0.99 ewes @ $11/100	0.11
Main crutch	- 0.99 ewes @ $15/100	0.15
Drench	- 2 (one pre-tup and one pre-lamb)	
	2 drenches @ $0.097/dose for 0.99 ewes	0.19
Vaccination	- 0.98 ewes @ $0.064/dose	0.06
Dipping	- 1.0 ewe @ $0.14/ewe	0.14
Ram cost	- 2 rams per 100 ewes, assume a four year life.	
	0.005 rams @ $75	0.37
Woolshed expenses	- 4.8 kg wool @ $0.02/kg	0.10
Cartage	- 4.8 kg wool @ $0.009/kg	0.04
Eartags, footrot and docking		0.11
		-$1.59

Selling Cull Ewe Lambs

Price received for ewe lamb		13.00

Minus

Commission	- $13.00 @ 3.5%	0.45
Dipping	- 1.0 lamb @ $0.13/lamb	0.13
Drench	- 1.0 lamb 2 drenches @ $0.05/dose	0.10
Eartags and footrot		0.07
Cartage	- 1.0 cull ewe lamb (48 km)	0.36

Selling Cull Two-tooths		$
Price received for two-tooth		19.00
Minus		
Commission	- $18.00 @ 3.5%	0.67
Drench	- 1.0 2T, 1 drench @ $0.07/dose	0.07
Vaccination	- 1.0 2T, triple vaccine @ $0.06/dose	0.06
Dipping	- 1.0 2T @ $0.14/ewe	0.14
Cartage	- 1.0 cull 2T (48 km)	0.47
		$17.59

Selling Cull Ewes

All cull five, six and seven year old ewes are sold to the freezing works. One price has been assumed for all cull ewe activities. This assumes that once a ewe is classed as a works ewe its age has no effect on the price received.

		$
Price received for cull ewe		
25 kg carcase @ 33.8c/kg, plus		
0.5 kg woolpull @ $3.04/kg (less 12% for downgrading)		8.77
Minus		
M.A.F. inspection	- 1.0 ewe @ $0.24/head	0.24
Cartage		0.28
		$8.25

Selling Store Lambs

Price received for store lamb		8.50
Minus		
Commission	- $8.50 @ 3.5%	0.30
Drench	- 1 drench @ $0.04/dose	0.04
Cartage	- 1 store lamb (48 km)	0.29
		$7.87

Fattening Lambs to Killing Weight From Weaning		$
Price received for prime lamb:		
13 kg carcase @ 62c/kg, plus		
0.90 kg woolpull @ $3.15		11.21
Minus		
M.A.F. inspection	- 1.0 lamb @ $0.24/head	0.24
Drench	- 70% two drenches and 30% three drenches - 2.3 doses @ $0.04/dose	0.09
Cartage	- 1 prime lamb	0.23
		$10.65

Lambs Sold Fat Off Mother		$
Price received for prime lamb:		
13 kg carcase @ 67c/kg, plus		
0.76 kg woolpull @ $2.92		11.63
Minus		
M.A.F. inspection	- 1.0 lamb @ $0.24/head	0.24
Drench	- 1 drench @ $0.04/dose	0.04
Cartage	- 1 prime lamb	0.23
		$11.12

Selling Wool (Quality A)		$
Price received per kilogram of wool		1.95
Minus		
Brokers charges		0.05
Wool Board levy	- 3% of Gross Proceeds	0.06
Stabilisation levy	- 3% of Gross Proceeds	0.06
		$1.78

Selling Wool (Quality B)	$
Price received per kilogram of wool	1.90
Minus	
Brokers charges	0.05
Wool Board levy - 3% of Gross Proceeds	0.06
Stabilisation levy - 3% of Gross Proceeds	0.06
	$1.73

New Pasture		$
Cultivation	- 9.0 hours @ $6.61/hour[1]	59.49
Seed	- 22 kg Nui ryegrass @ $1.15/kg	25.30
	4.5 kg subterranean clover @ $2.10/kg	9.45
Fertilizer	- 250 kg superphosphate @ $57.95/tonne	14.49
	spreading @ $2.00/ha.	2.00
		-$110.73

Pasture		
Fertiliser	- 250 kg superphosphate every second year @ $57.95/tonne	7.25
	Spreading @ $1.00/ha.	1.00
		-$8.25

New Lucerne		
Cultivation	- 11.0 hours @ $6.61/hour	72.71
Seed	- 11.0 kg Wairau lucerne @ $3.75/kg	41.25
Innoculation		7.11
Lime	- 2.5 tonnes @ $9.30/tonne, applied	23.25
Fertilizer	- 300 kg lucerne sowing @ $59.75	17.93
	Spreading @ $2.00/ha.	2.00
		-$164.25

1 Tractor running costs obtained from Crotty (1979).

Lucerne		$
Rolling	- 0.6 hours @ $6.61/hour	3.97
Fertilizer	- 300 kg superphosphate @ $65.15/tonne	16.28
	Spreading @ $2.00/ha.	2.00
Weedspray	-	20.17
		-$42.42

Lucerne Overdrilled with Tama Ryegrass (Receiving 22.4 kg N/ha mid-winter)

Cultivation	- 3.0 hours @ $6.61/hour	19.83
Seed	- 22.4 kg Tama ryegrass @ $1.10/kg	24.66
Fertilizer	- 200 kg Superphosphate @ $57.95/kg	11.59
	100 kg Ammonium Sulphate @ $99.81/tonne	9.98
	Spreading @ $4.00/ha	4.00
		-$70.06

Lucerne Overdrilled with Tama Ryegrass (Drilled early March and mid April)

Cultivation	- 3.0 hours @ $6.61/hour	19.83
Seed	- 22.4 kg Tama ryegrass @ $1.10/kg	24.66
Fertilizer	- 200 kg Superphosphate @ $57.95/kg	11.59
	Spreading @ $2.00/ha.	2.00
		-$58.08

Tama Ryegrass (Receives 33.6 kg N/ha Mid-Winter)

Cultivation	- 9.5 hours @ $6.61/hour	62.80
Seed	- 33.6 kg Tama ryegrass @ $1.10/kg	36.96
Fertilizer	- 200 kg Superphosphate @ $57.95/tonne	11.59
	160 kg Ammonium Sulphate @ $99.81/tonne	15.97
	Spreading @ $4.00/ha.	4.00
		-$131.32

		$
Tama Ryegrass (Receiving No Summer Fallow and Summer Fallow Activities)		
Cultivation	- 9.5 hours @ $6.61/hour	62.80
Seed	- 33.6 kg Tama ryegrass @ $1.10/kg	36.96
Fertilizer	- 200 kg Superphosphate @ $57.95/tonne	11.59
	Spreading @ $2.00/ha.	2.00
		-$113.35

Paroa Ryegrass (Reveives 22.5 kg N/ha Mid-Winter)		
Cultivation	- 9.5 hours @ $6.61/hour	62.80
Seed	- 33.6 kg Paroa ryegrass @ $1.00/kg	33.60
Fertilizer	- 125 kg Reverted Superphosphate @ $53.98/tonne	6.75
	100 kg Ammonium Sulphate @ $99.81/tonne	9.98
	Spreading @ $4.00/ha.	4.00
		-$117.13

Tama Ryegrass - Ryecorn Mix		
Cultivation	- 10.0 hours @ $6.61/hour	66.10
Seed	- 22.4 kg Tama ryegrass @ $1.10/kg	24.64
	112 kg C.R.D. ryecorn @ $185/tonne	20.72
Fertilizer	- 200 kg Superphosphate @ $57.95/tonne	11.59
	Spreading @ $2.00/ha.	2.00
		-$125.05

Tama Ryegrass - Amuri Oats Mix		
Cultivation	- 10.0 hours @ $6.61/hour	66.10
Seed	- 22.4 kg Tama ryegrass @ $1.10/kg	24.64
	112 kg Amuri Oats @ $145/tonne	16.24
Fertilizer	- 200 kg Superphosphate @ $57.95/tonne	11.59
	Spreading @ $2.00/ha.	2.00
		-$120.57

Turnips		$
Cultivation	- 9.7 hours @ $6.61/hour	64.12
Seed	- 500 gms York Globe turnips @ $2.40/kg	1.20
Fertilizer	- 125 kg Reverted Superphosphate @ $53.98/tonne	6.75
	Spreading @ $2.00/ha.	2.00
		-$74.07

Rape		
Cultivation	- 9.7 hours @ $6.61/hour	64.12
Seed	- 2.8 kg Rangi rape @ $1.30/kg	3.64
Fertilizer	- 125 kg Reverted Superphosphate @ $53.98/tonne	6.75
	Spreading @ $2.00/ha.	2.00
		-$76.51

Hay Making Costs		
Mowing and tedding	- 3.0 hours @ $6.61/hour	19.83
Baling	- 1.5 hours @ $7.11/hour (includes baler running costs)	10.66
		-$30.49

Total Variable Costs Per Hectare $30.49.

Twine, cartage to stack (contract) and repairs and maintenance on hay making equipment = 61c per bale.

Bales Per Hectare	Variable Costs Per Bale ($)	Other Costs Per Bale ($)	Total Cost Per Bale ($)
150	0.20	0.61	0.81
135	0.23	0.61	0.84
120	0.25	0.61	0.86
105	0.29	0.61	0.90
90	0.34	0.61	0.95

	$
<u>Feeding Hay</u>	
Tractor time - 2.0 hours per 100 bales	
therefore 0.02 hours per bale @ $6.61/hour	0.13
	-$0.13

<u>Buy Hay</u>

1. <u>Medium Quality Hay</u>

Purchase price of bale of hay	1.75
Plus	
Cartage - 1 bale of hay (32 km)	0.27
	-$2.02

2. <u>Low Quality Hay</u>

Purchase price of bale of hay	1.35
Plus	
Cartage - 1 bale of hay (32 km)	0.27
	-$1.62

B.2 Irrigated Model

	$
Buy Ewe Lamb	
Cost of ewe lamb	12.60
plus cartage (48 km)	0.36
	-$12.96
Buy Two-tooth Ewe	
Cost of two-tooth	18.00
plus cartage (48 km)	0.47
	-$18.47
Buy Five-year Old Ewe	
Cost of five-year old ewe	11.00
plus cartage (48 km)	0.47
	-$11.47
Buy Six-year Old Ewe	
Cost of six-year old ewe	8.50
plus cartage (48 km)	0.50
	-$9.00
Buy Seven-year Old Ewe	
Cost of seven-year old ewe	8.50
plus cartage (48 km)	0.50
	-$9.00

<u>Rear Replacement Ewe Lamb</u>

	$
Shearing: 1.0 @ $32/100	0.32
Crutching: 0.99 @ $15/100	0.15
Drenching: 4 drenches @ $0.07/dose	0.28
Vaccination: 1.0 triple vaccine @ $0.064/dose	0.06
Dipping: 1.0 @ $0.13/lamb	0.13
Woolshed expenses: 4.7 kg wool @ $0.02/kg	0.09
Cartage: 4.7 kg wool @ $0.009/kg	0.04
Eartags, footrot and docking	0.10
	-$1.17

<u>Ewe</u>

The gross margin calculated for a ewe is common for all ewes included in the model, but the woolshed expenses and wool cartage values vary according to the wool weight of each age group. Below is the gross margin common to all of the ewe activities using the two-tooth values for the variables.

	$
Shearing: 1.0 ewe @ $32/100	0.32
Tup crutch: 0.99 ewes @ $11/100	0.11
Main crutch: 0.99 ewes @ $15/100	0.15
Drench: 2 (one pre-tup and one pre-lamb) 2 drenches @ $0.097/dose for 0.99 ewes	0.19
Vaccination: 0.98 ewes @ $0.064/dose	0.06
Eartags, footrot and docking:	0.11
Dipping: 1.0 ewe @ $0.14/ewe	0.14
Ram cost: 2 rams per 100 ewes, assume a four year life 0.005 rams $ $100	0.50
Woolshed expenses: 5.2 kg wool @ $0.02/kg	0.11
Cartage: 5.2 kg wool @ $0.009/kg	0.05
	-$1.74

<u>Selling Cull Ewe Lambs</u>	$
Price received for ewe lamb	12.60
<u>Minus</u>	
Commission: $12.60 @ 3.5%	0.44
Drench: 1.0 lamb, 3 drenches @ $0.04/dose	0.12
Vaccination: 1.0 lamb, triple vaccine @ $0.06/dose	0.06
Dipping: 1.0 lamb @ $0.13/lamb	0.13
Eartags and footrot	0.07
Cartage: 1.0 cull ewe lamb (48 km)	0.36
	$11.42

<u>Selling Cull Two-tooths</u>	
Price received for two-tooth	18.00
<u>Minus</u>	
Commission: $18.00 @ 3.5%	0.63
Drench: 1.0 2T, 1 drench @ $0.07/dose	0.07
Vaccination: 1.0 2T, triple vaccine @ $0.06/dose	0.06
Dipping: 1.0 2T, @ $0.14/ewe	0.14
Cartage: 1.0 cull 2T (48 km)	0.47
	$16.63

<u>Selling Cull Ewes</u>

All cull five-, six- and seven-year old ewes are sold to the freezing works. One price has been assumed for all cull ewe activities. This assumes that once a ewe is classed as a works ewe its age has no effect on the price received.

	$
Price received for cull ewe:	
25 kg carcase @ 33.8 c/kg, plus	
0.5 kg woolpull @ $3.04/kg	
(less 12% for downgrading)	8.77
Minus	
M.A.F. inspection: 1.0 ewe @ $0.24/head	0.24
Cartage:	0.28
	$8.25

Selling Store Lambs

Price received for store lambs	8.50
Minus	
Commission: $8.50 @ 3.5%	0.30
Drench: 1 drench @ $0.04/dose	0.04
Cartage: (48 km)	0.29
	$7.87

Fattening Lambs to Killing Weight from Weaning

Price received for prime lamb	
13 kg carcase @ 62 c/kg plus	
1.10 kg woolpull @ $3.47	11.53
Minus	
M.A.F. inspection: 1.0 lamb @ $0.24/head	0.24
Drench: 70% two drenches and 30% three drenches - 2.3 doses @ $0.04/dose	0.09
Cartage:	0.23
	$10.97

Lambs Sold Fat Off Mother	$
Price received for prime lamb:	
13 kg carcase @ 67 c/kg, plus	
0.85 kg woolpull @ $3.07	11.78
Minus	
M.A.F. inspection: 1.0 lamb @ $0.24/head	0.24
Drench: one drench @ $0.04/dose	0.04
Cartage:	0.23
	$11.27

Selling Wool (Quality A)	
Price received per kilogram of wool	2.05
Minus	
Brokers charges	0.05
Wool Board levy: 3% of Gross Proceeds	0.06
Stabilisation levy: 3% of Gross Proceeds	0.06
	$1.88

Selling Wool (Quality B)	
Price received per kilogram of wool	1.95
Minus	
Brokers charges	0.05
Wool Board levy: 3% of Gross Proceeds	0.06
Stabilisation levy: 3% of Gross Proceeds	0.06
	$1.78

New Pasture (Irrigated)		$
Cultivation:	9.0 hours @ $7.33/hour	65.97
Seed:	22 kg Nui ryegrass @ $1.15/kg	25.30
	4.5 kg Huia white clover @ $2.25/kg	10.13
Fertilizer:	300 kg nitrogen super @ $66.59/tonne	19.98
	200 kg superphosphate @ $57.95/tonne	11.59
	Spreading @ $3.20/ha	3.20
		-$136.17

New Pasture (Dryland)		
Cultivation:	9.0 hours @ $7.33/hour	65.97
Seed:	22 kg Nui ryegrass @ $1.15/kg	25.30
	4.5 kg subterranean clover @ $2.10/kg	9.45
Fertilizer:	250 kg superphosphate @ $57.95/tonne	14.49
	Spreading @ $2.00/ha	2.00
		-$117.21

Pasture (Irrigated)		
Fertilizer:	250 kg superphosphate @ $57.95/tonne	14.49
	Spreading @ $2.00/ha	2.00
		-$16.49

Pasture (Dryland)		
Fertilizer:	250 kg superphosphate every second year @ $57.95/tonne	7.25
	Spreading @ $1.00/ha	1.00
		-$8.25

New Lucerne (Irrigated)		$
Cultivation:	11.0 hours @ $7.33/hour	80.63
Seed:	11.0 kg Saranac lucerne @ $3.90/kg	42.90
Innoculation:		7.11
Lime:	2.5 tonnes @ $9.30/tonne, applied	23.25
Fertilizer:	300 kg lucerne sowing @ $59.75/tonne	17.93
	Spreading @ $2.00/ha	2.00
		-$173.82

New Lucerne (Dryland)		
Cultivation:	11.0 hours @ $7.33/hour	80.63
Seed:	11.0 kg Wairau lucerne @ $3.75/kg	41.25
Innoculation:		7.11
Lime:	2.5 tonnes @ $9.30/tonne, applied	23.25
Fertilizer:	300 kg lucerne sowing @ $59.75/tonne	17.93
	Spreading @ $2.00/ha	2.00
		-$172.17

Lucerne (Irrigated)		
Rolling:	0.6 hours @ $7.33/hour	4.40
Fertilizer:	800 kg 30% Potash super @ $72.10/tonne	57.68
	Spreading @ $3.20/ha	3.20
		-$65.28

Lucerne (Dryland)		
Rolling:	0.6 hours @ $7.33/hour	4.40
Fertilizer:	300 kg superphosphate @ $65.15/tonne	16.28
	Spreading @ $2.00/ha	2.00
Weedspray:	@ $20.17/ha	20.17
		-$42.85

Hay Making Costs	$
Mowing and tedding: 3.0 hours @ $7.33/hour	21.99
Baling: 1.5 hours @ $7.83/hour (includes baler running costs)	11.75
	$33.74

TOTAL VARIABLE COSTS PER HECTARE $33.74

Twine, cartage to stack (contract) and repairs and maintenance on hay making equipment = $0.61/bale

Bales per hectare	Variable Costs per bale ($)	Other costs per bale ($)	Total Cost per bale ($)
200	0.17	0.61	0.78
175	0.19	0.61	0.80
150	0.22	0.61	0.83
125	0.27	0.61	0.88
100	0.34	0.61	0.95

Feeding Hay

Tractor time: 2.0 hours per 100 bales therefore: 0.02 hours per bale @ $7.33/hour	0.15
	-$0.15

Buy Hay

1. Medium Quality Hay

Purchase price of bale of hay	1.75
Plus Cartage: 1 bale of hay (32 km)	0.27
	-$2.02

2. Low Quality Hay

Purchase price of bale of hay	1.35
Plus Cartage: 1 bale of hay (32 km)	0.27
	-$1.62

B.3 Values Used in the Parametric Analysis

Prime Lamb Prices Used

Run	Change from base run (%)	Price received for lambs prime off mother (c/kg)	Price received for lambs fattened (c/kg)
1	-20	53.6	49.6
2	-10	60.3	55.8
Base (1977/78 prices)	0	67.0	62.0
3	+10	73.7	68.2
4	+20	80.4	74.4

Cull Ewe Prices Used

Run	Change from base run (%)	Price received (c/kg)
1	+20	40.6
2	+10	37.2
Base (1977/78 prices)	0	33.8
3	-10	30.4
4	-20	27.0

Wool Price Used (Dryland Model)

Run	Change from base run (%)	Price received for	
		Quality A (c/kg)	Quality B (c/kg)
5	-40	117	114
6	-20	156	152
Base (1977/78 prices)	0	195	190
7	+20	234	228
8	+40	273	266

Wool Price Used (Irrigated Model)

Run	Change from base run (%)	Price received for	
		Quality A (c/kg)	Quality B (c/kg)
5	-40	123	117
6	-20	164	156
Base (1977/78 prices)	0	205	195
7	+20	246	234
8	+40	287	273

APPENDIX C

Physical Data : Animal Feed Requirements

C.1 Replacement Stock

Table C1 Ewe lamb liveweight, liveweight gain and feed quality requirements (born 1st August)

Period	Liveweight (kg)	Liveweight gain (gm/day)	Food quality (MJME/kg DM)
Start-November	20		
		82	12.5
Start-January	25		
		92	12.5
Start-May	36		
		13	10.9
Start-October	38		
		129	12.5
Start-January	50		

Table C2 Ewe lamb liveweight, liveweight gain and feed quality requirements (born 16th August and 1st September)

Period	Liveweight (kg)	Liveweight gain (gm/day)	Food quality (MJME/kg DM)
Mid-November	20		
		109	12.5
Start-January	25		
		92	12.5
Start-May	36		
		13	10.9
Start-October	38		
		129	12.5
Start-January	50		

Table C3 Ewe lamb liveweight, liveweight gain and feed quality requirements (born 16th September)

Period	Liveweight (kg)	Liveweight gain (gm/day)	Food quality (MJME/kg DM)
End-November	20		
		97	12.5
Start-January	23		
		100	12.5
Start-May	35		
		13	10.9
Start-October	37		
		129	12.5
Start-January	49		

Table C4 Ewe lamb liveweight, liveweight gain and feed quality requirements (purchased 1st February)

Period	Liveweight (kg)	Liveweight gain (gm/day)	Food quality (MJME/kg DM)
Start-February	28		
		92	10.9
Start-May	36		
		13	10.9
Start-October	38		
		129	12.5
Start-January	50		

The following table shows the metabolisable energy requirements of weaned lambs.

Table C5 Metabolisable energy requirement (MJ/day) of weaned lambs

Liveweight (kg)	ME conc. (MJ/kg DM)	Daily liveweight gain (gm/day)				
		0	50	100	200	300
20	10.9	5.0	7.1	9.2	14.6	-
	12.5	4.6	6.7	8.4	12.5	18.4
30	10.9	6.7	8.8	11.3	17.1	-
	12.5	6.3	8.4	10.5	15.0	20.9
40	10.9	7.9	10.5	13.0	19.2	-
	12.5	7.5	9.6	12.1	16.7	23.0

(Source - Jagusch and Coop (1971)).

The following is an example of the calculations required to find the feed requirements (per period) of a replacement ewe lamb born on the 1st September.

Table C6 Calculation of the annual feed demand of a ewe lamb born 1st September.

Period	Liveweight gain (gm/day)	Food Quality (MJME/kg DM)	ME Requirement (MJ/day)	ME Requirement (MJ/period)
November	82	12.5	9.2	138
December				285
January	92	10.9	10.16	315
February				284
March				315
April				305
May	13	10.9	8.18	254
June				245
July A				123
July B				131
August A				123
August B				131
September A				123
September B				123
October A	129	12.5	13.6	204
October B				218
November				408
December				422

C.2 Ewes

Table C7 Profile of Feed Demand for A Ewe Lambing 1st August

Period	Physiological State	Food Quality (MJME/kg DM)
January	1.3 Maintenance	10.9
February	1.5 Maintenance	10.9
March	0.8 Maintenance	6.7
April	0.8 Maintenance	6.7
May	1.3 Maintenance	10.9
June	1.4 Maintenance	10.9
July 1[1]	1.5 Maintenance	10.9
July 2[2]	1.8 Maintenance	10.9
August 1	3.0 Maintenance	10.9
August 2	2.8 Maintenance	10.9
September 1	2.6 Maintenance	10.9
September 2	2.4 Maintenance	12.5
October 1	2.0 Maintenance	10.9
October 2	1.5 Maintenance	10.9
November	Maintenance	7.5
December	Maintenance	7.5

Table C8 Profile of Feed Demand for a Ewe Lambing 16th August

Period	Physiological State	Food Quality (MJME/kg DM)
January	Maintenance	7.5
February	1.3 Maintenance	10.9
March	1.5 Maintenance	10.9
April	0.8 Maintenance	6.7
May	0.8 Maintenance	6.7
June	1.3 Maintenance	10.9
July 1	1.4 Maintenance	10.9
July 2	1.5 Maintenance	10.9
August 1	1.8 Maintenance	10.9
August 2	3.0 Maintenance	10.9
September 1	2.8 Maintenance	10.9
September 2	2.6 Maintenance	12.5
October 1	2.4 Maintenance	12.5
October 2	2.0 Maintenance	10.9
November	1.5 Maintenance	10.9
December	Maintenance	7.5

[1] refers to first two weeks of the month.

[2] refers to second two weeks of the month.

Table C9 Profile of Feed Demand for a Ewe Lambing 1st September

Period	Physiological State	Food Quality (MJME/kg DM)
January	Maintenance	7.5
February	Maintenance	7.5
March	1.3 Maintenance	10.9
April	1.5 Maintenance	10.9
May	0.8 Maintenance	6.7
June	0.8 Maintenance	6.7
July 1	1.3 Maintenance	10.9
July 2	1.4 Maintenance	10.9
August 1	1.5 Maintenance	10.9
August 2	1.8 Maintenance	10.9
September 1	3.0 Maintenance	10.9
September 2	2.8 Maintenance	12.5
October 1	2.6 Maintenance	12.5
October 2	2.4 Maintenance	12.5
November	2.0 Maintenance	10.9
December	Maintenance	7.5

Table C10 Profile of the Feed Demand for a Ewe Lambing 16th September

Period	Physiological State	Food Quality (MJME/kg DM)
January	Maintenance	7.5
February	Maintenance	7.5
March	Maintenance	7.5
April	1.3 Maintenance	10.9
May	1.5 Maintenance	10.9
June	0.8 Maintenance	6.7
July 1	0.8 Maintenance	6.7
July 2	1.3 Maintenance	10.9
August 1	1.4 Maintenance	10.9
August 2	1.5 Maintenance	10.9
September 1	1.8 Maintenance	10.9
September 2	3.0 Maintenance	12.5
October 1	2.8 Maintenance	12.5
October 2	2.6 Maintenance	12.5
November	2.2 Maintenance	10.9
December	1.5 Maintenance	10.9

The above tables show the feed demand profiles for ewes lambing 1st August, 16th August, 1st September and 16th September. When the above values are tied with the following tables, table C11 and table C12, the feed requirement of a ewe for a period can be calculated.

Table C11 Metabolisable energy requirement (MJ/day) for maintenance of adult sheep.

Liveweight (kg)	ME concentration (MJ/kg DM)				
	6.7	7.5	9.2	10.9	12.5
50	10.1	9.6	9.2	8.8	8.4
55	10.5	10.0	9.6	9.2	8.8
60	10.8	10.3	9.9	9.5	9.1
65	11.1	10.6	10.2	9.8	9.4
70	11.4	10.9	10.4	10.0	9.6

(Source - Jagusch and Coop (1971))

Table C12 Liveweight of ewes by age group for Dryland and Irrigated models.

Age Group	Dryland model ewe liveweight (kg)	Irrigated model ewe liveweight (kg)
Two-tooth	55	56
Four-tooth	60	57
Six-tooth	62	57
Four year old	64	61
Five year old	65	64
Six year old	66	64
Seven year old	63	62
Eight year old	60	59
Nine year old	58	57

The following is an example of the calculations required to determine the feed requirements per period, of a 55 kg ewe lambing on 1st September.

Table C13 Calculation of the annual feed demand of a 55 kg ewe lambing 1st September.

Period	Physiological state	Food quality (MJME/kg DM)	ME requirements (MJ/day)	ME requirement (MJ/period)
January	Maintenance	7.5	10.00	310
February	Maintenance	7.5	10.00	280
March	1.3 Maintenance	10.9	11.96	371
April	1.5 Maintenance	10.9	13.80	414
May	0.8 Maintenance	6.7	8.40	260
June	0.8 Maintenance	6.7	8.40	252
July 1	1.3 Maintenance	10.9	11.96	179
July 2	1.4 Maintenance	10.9	12.88	207
August 1	1.5 Maintenance	10.9	13.80	207
August 2	1.8 Maintenance	10.9	16.56	265
September 1	3.0 Maintenance	10.9	27.60	414
September 2	2.8 Maintenance	12.5	24.64	370
October 1	2.6 Maintenance	12.5	22.88	343
October 2	2.4 Maintenance	12.5	21.12	338
November	2.0 Maintenance	10.9	18.40	552
December	Maintenance	7.5	10.00	310

Seven, eight and nine year old ewes have an extra ewe activity for each lambing date. This activity has a different feed requirement to those shown above. The difference is that the ewes represented by these activities have a ten percent higher feed requirement for the six week period prior to parturition.

C.3 Cull Stock

1. Ewe Lambs

The feed requirements of the cull ewe lambs are the same as the ewe lambs used for replacements up until the end-January. The cull ewe lambs are culled in mid-February so they only require half the feed requirements of the replacement ewe lambs in this period.

2. Two-tooths

The feed requirements of the cull two-tooths is the same as the two-tooth activities for January and February but the February value is halved to allow for the two-tooths being sold in mid-February.

3. Ewes sold to freezing works

These ewes are fed a maintenance ration for January and February with the level of feeding depending on the ewe liveweight. The ewe liveweight is assumed to be the same as the ewe liveweight in the supply activity.

4. Ewes sold in the saleyards

These ewes are fed a maintenance ration for January and 1.5 times maintenance ration for the first two weeks of February.

C.4 Lamb Fattening

Table C14 Calculation of the feed demand of a wether lamb, born 1st August, from weaning (end-October) to attainment of prime condition.

Period (Days in brackets)	To fatten (%)	Feed quality (MJME/kg DM)	ME requirement (MJ/day)	ME requirement (MJ/period)
November (30)	70	12.5	10.23	215
November (30)	30	12.5	10.55	95
December (15)	70	12.5	10.23	107
December (31)	30	12.5	10.55	98

Table C15 Calculation of the feed demand of a wether lamb, born 16th August or 1st September, from weaning (mid-November) to attainment of prime condition.

Period (Days in brackets)	To fatten (%)	Feed quality (MJME/kg DM)	ME requirement (MJ/day)	ME requirement (MJ/period)
November (15)	70	12.5	10.23	107
November (15)	30		10.55	47
December (31)	70		10.23	222
December (31)	30		10.55	98
January (15)	70		10.23	47

Table C16 Calculation of the feed demand of a wether lamb, born 16th September, from weaning (end-November) to attainment of prime condition.

Period (Days in brackets)	To fatten (%)	Feed quality (MJME/kg DM)	ME requirement (MJ/day)	ME requirement (MJ/period)
December (31)	70	12.5	10.23	222
December (31)	30		10.55	98
January (15)	70		10.23	107
January (31)	30		10.55	98

APPENDIX D

Physical Data : Animal Production

D.1 Ewe Death Rates (Dryland and Irrigated)

Table D1 Ewe Death Rates

Age group	Ewe death rate (%)
Ewe lamb	6
Two-tooth	4
Four-tooth	4
Six-tooth	5
Four-year old	7
Five-year old	8
Six-year old	12
Seven-year old A[1]	15
Seven-year old B[2]	18
Eight-year old A	23
Eight-year old B	27
Nine-year old A	35
Nine-year old B	40

[1] A refers to the ewe activity receiving a ten percent increase in feed six weeks prior to parturition.

[2] B refers to the ewe activity receiving normal feeding.

D.2 Lambing Percentage

Table D2 Lambing percentages by age groups

Age group	Lambing percentage	
	Dryland (%)	Irrigated (%)
Ewe lamb	70	Not mated
Two-tooth	115	125
Four-tooth	120	130
Six-tooth	126	136
Four-year old	127	137
Five-year old	133	143
Six-year old	132	142
Seven-year old A[1]	126	136
Seven-year old B[2]	116	126
Eight-year old A	118	128
Eight-year old B	108	118
Nine-year old A	110	120
Nine-year old B	100	110

[1] A refers to the ewe activity receiving a ten percent increase in feed six weeks prior to parturition.

[2] B refers to the ewe activity receiving normal feeding prior to parturition.

D.3 Wool Weight

Table D3 Wool weight by age groups

Age group	Wool weight	
	Dryland (kg)	Irrigated (kg)
Ewe lamb	4.6	4.7
Two-tooth	4.8	5.2
Four-tooth	4.6	5.0
Six-tooth	4.4	4.8
Four-year old	4.2	4.6
Five-year old	4.0	4.4
Six-year old	3.9	4.3
Seven-year old A[1]	3.8	4.1
Seven-year old B[2]	3.7	4.0
Eight-year old A	3.7	3.9
Eight-year old B	3.6	3.8
Nine-year old A	3.6	3.7
Nine-year old B	3.5	3.6

[1] A refers to the ewe activity receiving a ten percent increase in feed six weeks prior to parturition.

[2] B refers to the ewe activity receiving normal feeding prior to parturition.

APPENDIX E

Physical Data : Pastures and Forage Crops

E.1 Pasture Production, Utilisation Rates and Quality

Table E1 Non-irrigated and irrigated pasture under grazing

Period	Non-irrigated		Irrigated		
	Mean daily growth rate (kg DM/ha/day)	Metabolisable energy content (MJME/kg DM)	Mean daily growth rate (kg DM/ha/day)	Metabolisable energy content (MJME/kg DM)	Utili-sation rate (%)
January	18.0	8.5	65.0	12.0	80
February	14.0	8.5	57.0	12.0	80
March	17.0	11.2	46.0	11.5	75
April	20.0	10.8	32.0	11.0	75
May	13.0	10.5	17.0	10.8	80
June	11.5	10.5	11.5	10.8	85
July A	9.0	10.5	9.0	10.8	85
July B	9.5	10.5	9.5	10.8	85
August A	12.0	10.8	12.0	10.8	85
August B	14.6	10.8	14.6	10.8	85
September A	30.5	11.5	35.0	11.5	80
September B	45.0	11.5	49.6	11.5	75
October A	51.0	12.0	56.0	12.0	80
October B	47.5	12.0	56.5	12.0	80
November	38.0	10.9	60.5	12.0	80
December	25.5	8.7	64.5	12.0	80

Table E2 Non-irrigated and irrigated new pasture under grazing

Period	Non-irrigated		Irrigated		
	Mean daily growth rate (kg DM/ha/day)	Metabolisable energy content (MJME/kg DM)	Mean daily growth rate (kg DM/ha/day)	Metabolisable energy content (MJME/kg DM)	Utili-sation rate (%)
January	-	-	-	-	-
February	Drilled	-	Drilled	-	-
March	-	-	-	-	-
April	12.4	10.8	14.6	10.8	50
May	10.1	10.8	10.1	10.8	50
June	10.0	10.8	11.2	10.8	50
July A	8.3	10.8	9.9	10.8	50
July B	8.9	10.8	11.0	10.8	65
August A	9.3	10.8	11.3	10.8	70
August B	10.8	10.8	11.5	10.8	85
September A	30.5	11.5	35.0	11.5	75
September B	45.0	11.5	49.6	11.5	75
October A	51.0	12.0	56.0	12.0	80
October B	47.5	12.0	56.5	12.0	80
November	38.0	10.9	60.5	12.0	80
December	25.5	8.7	64.5	12.0	80

E.2 Lucerne Production, Utilisation and Quality

Table E3 Non-irrigated and irrigated lucerne under grazing

	Non-irrigated		Irrigated		
Period	Mean daily growth rate (kg DM/ha/day)	Metabolisable energy content (MJME/kg DM)	Mean daily growth rate (kg DM/ha/day)	Metabolisable energy content (MJME/kg DM)	Utilisation rate (%)
January	18.2	11.0	78.5	11.0	80
February	31.3	11.0	61.1	11.0	80
March	31.3	10.9	36.4	10.9	70
April	20.4	10.2	20.4	10.2	70
May	8.0	9.0	8.0	9.0	70
June	1.4	9.0	1.4	9.0	70
July A	3.3	9.0	3.3	9.0	70
July B	5.4	9.0	5.4	9.0	70
August A	6.7	11.0	6.7	11.0	75
August B	10.6	11.0	10.6	11.0	75
September A	33.0	11.0	33.0	11.0	80
September B	39.7	11.0	39.7	11.0	80
October A	44.7	11.0	54.0	11.0	80
October B	51.1	11.0	65.0	11.0	80
November	55.3	11.0	72.7	11.0	80
December	37.8	11.0	78.54	11.0	80

Table E4 Non-irrigated and irrigated new lucerne under grazing

	Non-irrigated		Irrigated		
Period	Mean daily growth rate (kg DM/ha/day	Metabolisable energy content (MJME/kg DM)	Mean daily growth rate (kg DM/ha/day)	Metabolisable energy content (MJME/kg DM	Utilisation rate (%)
December	15.15	11.0	31.5	11.0	65
January	13.7	11.0	59.1	11.0	70
February	28.6	11.0	56.0	11.0	70
March	26.6	10.9	30.9	10.9	70
April	18.3	10.2	18.3	10.2	70
May	7.6	9.0	7.6	9.0	70
June	1.4	9.0	1.4	9.0	70
July A	3.3	9.0	3.3	9.0	70
July B	5.4	9.0	5.4	9.0	70
August A	6.7	11.0	6.7	11.0	75
August B	10.6	11.0	10.6	11.0	75
September A	33.0	11.0	33.0	11.0	80
September B	39.7	11.0	39.7	11.0	80
October A	44.7	11.0	54.0	11.0	80
October B	51.1	11.0	65.0	11.0	80
November	55.3	11.0	72.7	11.0	80
December	37.8	11.0	78.54	11.0	80

Table E5 Turnip Data

Period	January Sown Feed available in period (kg DM/ha)					February Sown Feed available in period (kg DM/ha)					Metabolisable energy content (MJME/kg DM)	Utilisation rate (%)
June	3085					2645					12.0	90
July A		3435					2865				12.0	90
July B			3670					3100			12.0	85
August A				3870					3315		11.5	85
August B					3950					3550	11.5	85

Table E6 Data for Lucerne Overdrilled with Tama Ryegrass Activities (receiving 22.4 kg N/ha Mid-Winter)

Period	Feed available in period (kg DM/ha)									Metabolisable energy content (MJME/kg DM)	Utilisation rate (%)
	1	2	3	4	5	6	7	8	9		
January	564	564	564	564	564	564	564	564	564	11.0	80
February	876	876	876	876	876	876	876	876	876	11.0	80
March	970	970	970	970	970	970	970	970	970	10.9	70
April											
May											
June											
July A											
July B	2600	2600								12.0	60
August A			3100	3100	3100					12.0	60
August B						4000	4000			12.0	60
September A	2900	2900	2400					5500	5500	11.8	55
September B				3400	3400	2500				11.8	55
October A		2000					3500		2000	11.5	50
October B	3100		3100		2100	2100		3100		11.5	50
November	2600	3000		3000	2600	2600	3000	2600	3000	11.5	50
December	1172	1172	1172	1172	1172	1172	1172	1172	1172	11.0	80

Table E7 Data for Lucerne Overdrilled with Tama Ryegrass Activities (overdrilled Early March)

Period	Feed available in period (kg DM/ha)												Metabolisable energy content (MJME/kg DM)	Utilisation rate (%)
	1	2	3	4	5	6	7	8	9	10	11	12		
January	564	564	564	564	564	564	564	564	564	564	564	564	11.0	80
February	876	876	876	876	876	876	876	876	876	876	876	876	11.0	80
March	970	970	970	970	970	970	970	970	970	970	970	970	10.9	70
April														
May														
June														
July A														
July B	2400	2400	2400										12.0	60
August A				3000	3000	3000	3000						12.0	60
August B								3400	3400	3400			12.0	60
September A	1800	1800		1200							4200	4200	11.8	55
September B			2800		2200	2200		1800					11.8	55
October A		1800					3000		2600		1800		11.5	50
October B	3000		2000	3000		2000		2000		3500		3000	11.5	50
November	1800	2500	1800	1800	3000	1800	2500	1800	2500	1800	2500	1800	11.5	50
December	1172	1172	1172	1172	1172	1172	1172	1172	1172	1172	1172	1172	11.0	80

Table E8 Data for Lucerne Overdrilled with Tama Ryegrass Activities (overdrilled Mid-April)

Period	Feed available in period (kg DM/ha)												Metabolisable energy content (MJME/kg DM)	Utilisation rate (%)
	1	2	3	4	5	6	7	8	9	10	11	12		
January	564	564	564	564	564	564	564	564	564	564	564	564	11.0	80
February	876	876	876	876	876	876	876	876	876	876	876	876	11.0	80
March	970	970	970	970	970	970	970	970	970	970	970	970	10.9	70
April	306	306	306	306	306	306	306	306	306	306	306	306	10.2	70
May														
June														
July A														
July B	1700	1700	1700										12.0	60
August A				2000	2000	2000	2000						12.0	60
August B								2400	2400	2400			12.0	60
September A	1200	1200		900							2900	2900	11.8	55
September B			1800		1500	1500		1100					11.8	55
October A	1300						2200		1800		1300		11.5	50
October B		2300	1700	2300	1700			1700		2800		2300	11.5	50
November	2200	1200	1200	1200	1200	2900	2200	1200	2200	1200	2200	1200	11.5	50
December	1172	1172	1172	1172	1172	1172	1172	1172	1172	1172	1172	1172	11.0	80

Table E9 Data for Tama Ryegrass Activities (receiving 33.6 kg N/ha Mid-winter)

Period	Feed available in period (kg DM/ha)										Metabolisable energy content (MJME/kg DM)	Utilisation rate (%)
	1	2	3	4	5	6	7	8	9	10		
July A	1500	1500									12.0	70
July B			2000	2000							12.0	70
August A					2550	2550					12.0	70
August B	1700						3200	3200	3200		12.0	70
September A		2500	2000	2000						4000	11.8	65
September B					2350	2350	1700	1700			11.8	65
October A	2300		1500						2300	1500	11.5	60
October B		1800		1800		900	900				11.5	60
November								1000			11.5	60

Table E10 Data for Tama Ryegrass Activities (Land summer fallowed)

Period	Feed available in period (kg DM/ha)															Metabolisable energy content (MJME/kg DM)	Utilisation rate (%)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
May	620	620	620													12.0	50
June				1050	1050											12.0	50
July A						1550	1550	1550	1550							12.0	70
July B	1330									1950	1950	1950				12.0	70
August A		1680			1250								2300			12.0	70
August B							1200	1200								12.0	70
September A	1550		2880		1200				1950	1550		1550		3500	3500	11.8	65
September B		1800		3050		2550		1350			2150		1800			11.8	65
October A	1200				1200		1950							1200		11.5	60
October B		950	1550					950				1550	950		1550	11.5	60

Table E11 Data for Tama Ryegrass Activities (Land receives no summer fallow)

Period	Feed available in period (kg DM/ha)								Metabolisable energy content (MJME/kg DM)	Utilisation rate (%)
	1	2	3	4	5	6	7	8		
August A	1100	1100	1100						12.0	70
August B				1350	1350	1350			12.0	70
September A							1800		11.8	65
September B	1400		1400		1150	1150		2500	11.8	65
October A		2350		2100			1650		11.5	60
October B			1500		1500			1500	11.5	60
November						1900			11.5	60

Table E12 Data for Paroa Ryegrass Activities

Period	Feed available in period (kg DM/ha)										Metabolisable energy content (MJME/kg DM)	Utilisation rate (%)
	1	2	3	4	5	6	7	8	9	10		
June	800										12.0	50
July A		1100									12.0	60
July B			1350	1350							12.0	70
August A	900				1700	1700					12.0	70
August B		1000					2100	2100			12.0	70
September A			1350	1350					2700	2700	11.8	65
September B	1500				1500	1500					11.8	65
October A		1750	1150				1750	1750	1150		11.5	60
October B	1100			1600		1100				1600	11.5	60
November								900			11.5	60

Table E13 Data for Tama-Oat and Tama-Ryecorn Activities

Period	Tama-Oat: Feed available in period (kg DM/ha)					Tama-Ryecorn: Feed available in period (kg DM/ha)					Metabolisable energy content (MJME/kg DM)	Utilisation rate (%)
	1	2	3	4	5	1	2	3	4	5		
July B	2400					1700					12.0	70
August A		2900	2900	2900			2250	2250			12.0	70
August B					3450				2850		12.0	70
September A	1950	1450				1900	1350			3600	11.8	65
September B			2000		1450			2250	1650		11.8	65
October A	800			2250		1200				1200	11.5	60

Table E14 Data for Rape Activities

Period	Sown early-October: Feed available in period (kg DM/ha)			Sown late-October: Feed available in period (kg DM/ha)			Sown mid-December: Feed available in period (kg DM/ha)				Metabolisable energy content (MJME/kg DM)	Utilisation rate (%)
	1	2	3	1	2	3	1	2	3	4		
December	3100			2000							12.5	65
January		5200			4300		1400				12.5	65
February			5600			5900		3400			11.5	60
March									4800		11.5	60
April										5675	10.0	55

E.8 Hay

1. Medium Quality Hay

Average bale weight	= 26 kg
Average D.M. percentage	= 90
Average quality	= 8.4 MJME/kg DM
Total M.E. per bale	= 26 × 0.90 × 8.4
	= 196 MJME
Stack and feeding losses (percent)	= 30
Feed available from one bale	= 196-(196×0.30)
	= 137 MJME/bale

2. Low Quality Hay

Average bale weight	= 23 kg
Average D.M. percentage	= 85
Average quality	= 7.5 MJME/kg DM
Total M.E. per bale	= 23 × 0.85 × 7.5
	= 147 MJME
Making to feeding losses (percent)	= 30
Feed available from one bale	= 147-(147×0.30)
	= 104 MJME/bale