ALTERNATIVE MANAGEMENT STRATEGIES AND

DRAFTING POLICIES FOR

IRRIGATED CANTERBURY SHEEP FARMS

N.M. SHADBOLT

RESEARCH REPORT NO.133

NOVEMBER 1982

Agricultural Economics Research Unit

Lincoln College

Canterbury, New Zealand

ISSN 0069-3790

THE AGRICULTURAL ECONOMICS RESEARCH UNIT
Lincoln College, Canterbury, N.Z.

The Agricultural Economics Research Unit (AERU) was established in 1962 at Lincoln College, University of Canterbury. The aims of the Unit are to assist by way of economic research those groups involved in the many aspects of New Zealand primary production and product processing, distribution and marketing.

Major sources of funding have been annual grants from the Department of Scientific and Industrial Research and the College. However, a substantial proportion of the Unit's budget is derived from specific project research under contract to government departments, producer boards, farmer organisations and to commercial and industrial groups.

The Unit is involved in a wide spectrum of agricultural economics and management research, with some concentration on production economics, natural resource economics, marketing, processing and transportation. The results of research projects are published as Research Reports or Discussion Papers. (For further information regarding the Unit's publications see the inside back cover). The Unit also sponsors periodic conferences and seminars on topics of regional and national interest, often in conjunction with other organisations.

The AERU, the Department of Agricultural Economics and Marketing, and the Department of Farm Management and Rural Valuation maintain a close working relationship on research and associated matters. The Unit is situated on the 3rd floor of the Burns Wing at the College.

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PREFACE

The study reported in this publication is part of the A.E.R.U.'s continuing research effort into the seasonality of ruminant animal production in New Zealand. The philosophy behind the programme of research is that production, transport and killing and processing activities should be viewed as an integrated system in order to maximise the efficient use of resources.

Smoothing the existing seasonal peak flow of lambs should allow the downstream sectors to be more efficient resulting in lower charges to the producing sector. However, producing other than at the "peak" can be more costly at the farm level. The objective of the research programme is to estabish the relative costs and savings associated with changes in different parts of the production-processing system.

Other studies reported in this series include Research Report No.103 (A Study of Excess Livestock Transport Costs in the South Island of New Zealand by R.D. Innes and A.C. Zwart) and Research Report No.123 (Seasonality in the New Zealand Meat Processing Industry by R.L. Sheppard).

In the present study, Nicola Shadbolt (graduate research fellow in the A.E.R.U. from 1979 to 1981) reports on a simulation model that addresses the management potential for smoothing the peak production of lambs on irrigated Canterbury sheep farms.

This work was supported financially by the Ministry of Agriculture and Fisheries; this support is gratefully acknowledged by the A.E.R.U.

P.D. Chudleigh
Director

ACKNOWLEDGEMENTS

The author wishes to acknowledge the financial support of the Agricultural Research and Advisory Services Divisions of the Ministry of Agriculture and Fisheries for whom this study was undertaken.

Project supervision was provided by Professor J.B. Dent and Mr A.C. Beck of Lincoln College, and Mr I. Ritchie and Mr J. Hayman of the Ministry of Agriculture and Fisheries.

Essential data were provided by the scientists of both Winchmore and Templeton Research Stations and their assistance is gratefully acknowledged.

Finally, the helpful comments of Mr Shane Carroll, the editorial contribution of Mr Tony Beck, and the typing efforts of Mrs Rosalie Beck are also acknowledged.

SUMMARY

The purpose of this investigation was to study the economic implications to producers of altering the offtake patterns of lambs on irrigated farms. To permit such a study, a detailed analysis of both management and drafting strategies in the system under analysis was required. This was necessary because of the complexity of the lamb production system and also because it allowed an assessment and comparison to be made between traditional (dryland) practices and alternative production practices under irrigation.

A simulation model incorporating biological, physical and economic components of the lamb production system on an irrigated farm was constructed and was then used to experiment with alternative management and drafting strategies. These strategies were tested on a few different 'farms', that is, the growth rates of the 'modal' lamb to which all simulated lambs relate, were varied between 'farms'. By this method, some allowance was able to be made for the different abilities of farmers in practice to manage both stock and feed successfully.

Feed supply and demand were best equated when lambing percentage was highest and stocking rate lowest. Returns could be improved upon if the lambs grew at a rate that allowed as many as possible to be drafted as PM's by early March. Although high lambing percentages do not necessarily equate with high growth rates, this situation was improved by a delay in the mean drafting date which allowed more of the multiple birth lambs to benefit from compensatory growth.

The choice of an optimum management or drafting strategy ultimately depends on each decision maker's attitude to risk, and, in practice, the decision maker must assess the stocking rate and performance level at which he is most confident.

In conclusion, while irrigation increases feed supply, higher stocking rates and feed requirements associated with the rearing of replacements allow little scope to change lamb offtake times. However, a slight delay appears justified to permit a greater number of lambs to achieve the benchmark grade weight.

CHAPTER 1

INTRODUCTION

The objective of this study was to ascertain the costs and/or savings to producers of taking lambs off at times of the season which differ from those currently practised. That is, the aim was to estimate the potential for spreading the lamb kill by production methods.

Smoothing the flow of livestock from farms would benefit the off farm sector in a number of ways. Innes and Zwart (1979) state that over 25 percent of excess transport charges are caused by the seasonality of the lamb kill. They suggest that spreading supply by early slaughter or by withholding livestock will not only decrease collection costs but also ease the labour related costs and problems at the freezing works. The works will also benefit from more efficient use of equipment installed to cope with the kill quantity. The benefits to the farmer would be indirect but nonetheless important since a gain may be made via a higher schedule price due to less cartage costs deducted by works, or from a greater likelihood of being able to have livestock slaughtered when prime. However desirable nationally it may be to promote a greater spread of lamb kill, the broader question is whether the off farm savings will compensate for additional on-farm costs or other disincentives that may be caused by finishing lambs at times different from those considered traditional.

One method of reducing peak supplies, described by Martin (1979), involves the use of differential pricing based on a determination of the elasticity of demand at different times in the year: the commodity involved, wool, is more easily stored than livestock by both the farmer and the trader, but the same principle could apply. The price differential would have to compensate for the extra management and change in production systems.

Incentives for early lambs have been paid in the past by various freezing works (Innes et al, 1979) but, as with any change in production systems, there are often too many inter-relating aspects involved to allow the farmers to fill the demand. Herlihy (1970), in a thorough examination of Southland lamb rearing techniques, concluded that the limitations on early lamb production include inadequate spring feed supply and reduced lambing percentage due to earlier tupping date. Withholding lambs to heavier weights was, until 1981, an uneconomic proposition since the schedule price structure provides no incentive to do so (Shadbolt, 1980). Since 1981 the price for lean heavy weight lambs has improved considerably although fatter lambs at the same weight are still discounted.

Cullwick (1980) states that there is a global need for lean, well muscled carcasses of good conformation and urges re-assessment of lamb production practices to achieve such types. The New Zealand lamb production system deemed most suitable for assessment, because of its relatively reliable feed supply, is that practised on irrigated Canterbury farms. The feed flexibility made possible by irrigation provides the potential for changing off-take times of lambs. However, lamb production on irrigated Canterbury farms is still characterised by a degree of uncertainty, both economic and environmental.

The methodology used for the study was to build a computer based simulation model incorporating physical, biological and economic components of the lamb production system. This type of model is able to mimic complex, stochastic and dynamic situations and provide objective information for guiding decision making or extending the understanding of the system. That is, it can predict the output of the system from the 'inputs' given to its interacting sub-systems (Dent and Blackie, 1979).

The aim of the model is to provide some guidelines on possible management strategies given both environmental and economic constraints, with a view to assessing the possibility of spreading the kill.

The search for the particular data required for the model involved discussions with scientists, advisors and farmers. An hypothesis formulated as a result of these discussions, and from the review of literature, was that there is a production potential in irrigated systems that is not always realised by farmers since modifications of the traditional dry land practices do not occur. It was also hypothesised that the adoption of management strategies more appropriate to an irrigated system would allow the drafting period to be extended. This study therefore assesses both alternative and traditional production practices under irrigation, as well as alternative drafting strategies. The returns to the producer are evaluated in an effort to estimate his optimum and least risky drafting strategies.

CHAPTER 2

SYSTEMS ANALYSIS

2.1 Introduction

Canterbury lamb has traditionally been produced on the dryland farms of the Canterbury Plains. Low, unreliable rainfall in the summer months is characteristic of the area and management systems have been devised to optimize returns within these restrictions. Early lambing dates, early maturing sire breeds and the use of deep rooting summer legumes allow the production of finished lamb from dryland farms. Replacement ewes are often bought in and total ewe numbers are restricted due to the unreliability of summer pasture growth. This therefore limits the return per hectare from such management systems.

Typical offtake patterns on dryland Canterbury farms often involve drafting the majority of lambs at weaning or as soon as possible after that date. Where summer legumes are grown there is the opportunity to keep some lambs to a heavier weight and also to wean earlier and therefore avoid ewe competition for the limited feed available (Jagusch, Rattray, Winn and Scott, 1979).

The development of irrigation on farms provides the moisture required for summer pasture growth and has enabled an increase in stock numbers carried on farms during the low rainfall months. This has generally resulted in an increase in total ewe numbers maintained on the farm. The extent to which returns per hectare have improved as ewe numbers have increased has been governed by the rate of change by farmers, from dryland management practices, to those more suited to irrigated land. Stock performance has not automatically improved with irrigation; poor growth rates, poor lambing percentages and ill thrift in all classes of sheep were noted in the first five years of irrigation development on the Morven Glenavy Irrigation Scheme (Oliver, McKnight and Hay, 1980). It was found, however, that when farmers were given assistance and spent more time on stock management that well fed and properly managed sheep on irrigated pasture did grow and perform well.

While Batey (1980) states that irrigation development must involve a complete change in both farmers' management systems and way of life, there are a number of factors that will affect the rate at which such changes take place. Frengley (1980) outlined a set of factors endogenous to the on-farm irrigation system that alter both the adoption rate and the normative equilibrium state created by a farmer. He included:

(i) Technical constraints preventing the instantaneous transformation of farms to the irrigated state.

(ii) Pervasive farmer preferences.

(iii) The evolution of new technologies and their adoption rate.

(iv) The ubiquitous imperfections of the capital market.

The overriding factor in farm development, notwithstanding the technical and capital constraints, is farmer preference. As any decisions taken to increase future incomes may place present incomes at risk there is an unwillingness to sacrifice known management practices for the unknown area of irrigation. It might also involve a possible reduction in present income or an increase in present risk (Frengley, 1980).

Irrigation does remove a large factor of risk or uncertainty to farmers by reducing the seasonal variation of pasture production (Rickard and Radcliffe, 1976). In a survey of irrigation farmers, Frengley (1980) found that the greatest marginal return to them from investing in irrigation was from the removal of the summer drought risk. They were unwilling though to adopt any further technological advance once irrigation had been introduced.

Anderson (1974) states that "risk is often perceived by farmers as being more formidable in new technologies emanating from agricultural research than in more traditional practices. Consequently risk may tend to act as an impediment to adoption of improved practices as well as a general friction on the efficient use of resources". It is necessary therefore to state the degree of uncertainty inherent in varying management strategies so as to allow both expected return, and the variability in that return, to be taken into account by decision makers.

The increased stocking rates adopted by farmers to both utilize summer feed and generate extra income, can both create and exacerbate areas of uncertainty on an irrigation farm if advanced stock management and improved techniques are not adopted. The result is often a decrease in productivity and profitability and therefore lower financial returns for irrigation investment.

There are a number of areas of uncertainty inherent in the lamb production cycle that are applicable to both dryland and irrigated farms. While irrigation may not automatically improve stock performance in terms of lambing percentage and lamb carcass weights, practice has shown that correct management of irrigated pastures can prevent a reduction in productivity therefore allowing an increased stocking rate to provide increased returns per hectare. Both environmental and economic uncertainties, inherent in the system, must be fully examined before corrective management strategies can be outlined.

2.2 Environmental Variables

Environmental factors have been closely linked to annual fluctuations in agricultural output in New Zealand by a number of authors (Maunder, 1974; Thompson and Taylor, 1975; Rich and Taylor, 1977). Climatic conditions coupled with biological factors can be a major constraint on pasture productivity and, therefore, carrying capacity of farms (Woodford and Woods, 1978). The effect of environmental conditions is multiple as it can influence current period carrying capacity as well as future productivity, e.g., lambing percentages that result from feed intakes prior to and during conception, and lamb weights that are influenced by feed availability both before and during the lambing period. The environmental factors that cause annual variability in pasture productivity include both climatic and biological variables. The latter, involving, for example, changes in the severity of pests and diseases, can sometimes be attributed to the state of the former with respect to the prevailing rainfall, temperature, wind and sunlight. For example, the population of internal parasites in pastures increases significantly as the humidity of their environment is raised by either rainfall or irrigation. In the Morven-Glenavy irrigation scheme it was found that only those farmers drenching lambs regularly, as well as ensuring clean pastures for lambs, were able to ensure good stock health and growth rates (McKnight, Oliver and Gumbrell , 1978).

The environmental variable which has the most significant effect on pasture production and livestock carrying capacity is 'days of soil moisture deficit'. Soil moisture deficit is defined as the level of soil moisture at which there is no pasture growth (Walsh, 1980).

Rich and Taylor (1977) suggest that soil moisture conditions are the most important determinant of fluctuations in annual wool weights per head. Similarly the lambing percentage can be related to soil moisture conditions with regard to the ewe weight and her level of nutrition at tupping. It can also be related to the overall climatic conditions at lambing (Rich and Taylor, 1977).

One of the greatest factors of uncertainty for Canterbury dry land farmers is the high variability in pasture productivity both within and between seasons. Rickard and Radcliffe (1976) estimated the coefficient of variation of annual pasture yield from 13 years of data collected at Winchmore Research Station to be between 82 and 122 percent. With irrigation this variation was reduced to a 12-24 percent range during the same time interval.

Irrigation farmers, therefore, can reduce the effect of environmental factors by minimizing the days of soil moisture deficit. The variability of pasture production, however, can still be 12 to 24 percent of the expected mean (Rickard and Radcliffe, 1976) so deficits and surpluses can occur in the feed supply. There must be some flexibility in drafting strategies to allow for such variability.

Although irrigation farmers are relatively certain of feed availability, their decision to draft may be influenced by how the environment is affecting their dryland counterparts and therefore the availability and price of store lambs. Both store prices and the schedule price system for finished lambs will influence the extent to which lamb weights are increased before slaughter. Dryland conditions may also affect the number of ewe lambs retained on an irrigated farm to sell as breeding stock as also will the relativity between schedule and ewe lamb prices.

2.3 Economic Variables

While on-farm costs have risen steadily over the past decade, returns per kg of lamb meat have fluctuated considerably (Figure 1). This is due to the fact that the Meat Exporters' Schedule system varies both within and between seasons as it equates supply to international market demand for specific lamb carcass types. In 1976 the New Zealand Meat Producers' Board (NZMPB) brought a scheme into operation aimed at providing producers with protection against price fluctuations. The scheme consists of minimum and maximum (trigger) prices for representative "benchmark" grades of export meat. If Meat Exporters' Schedule prices are lower than the minimum, the NZMPB will either supplement payments from a buffer account or intervene in the market itself to ensure the producers receive at least the minimum price. When prices exceed the trigger price, deductions are made from producer returns and put into the buffer account (NZMPB, 1979). The "benchmark" grade for lamb is the PM carcass that forms the largest proportion of lamb exported.

In 1978 the Government implemented an additional supplementary minimum price scheme by which producers are assured of a guaranteed price should the market value of PM lambs be depressed. In this instance government funds provide the difference between the actual market price and the minimum and no levies are collected when prices are high.

Average carcass weights of export lambs slaughtered have gradually increased over the last three seasons as a result of favourable environmental conditions and also possibly due to an increase in farmer confidence as the above schemes have reduced price fluctuations. Unfortunately, there has been a gradual increase in overfat lambs as weights have risen (see Table 1).

TABLE 1

Export Lamb Weights and Overfat Percentages.

	Slaughter Seasons		
	1977/78	1978/79	1979/80
Av. Carcass Wt (kg)	12.9	13.3	13.6
% Overfat Lambs	0.48	1.11	1.25

Source: NZMPB (1980)

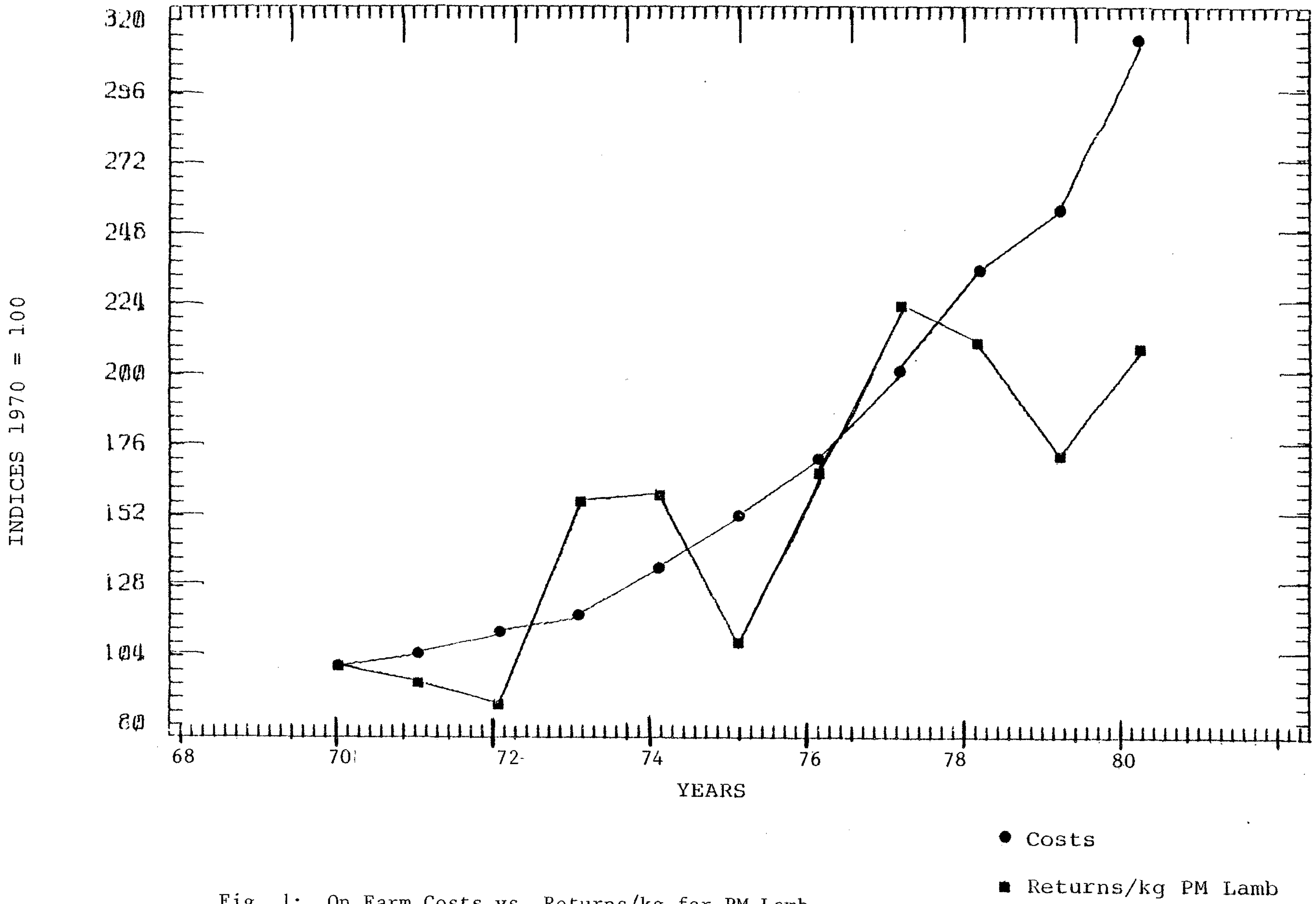


Fig. 1: On Farm Costs vs. Returns/kg for PM Lamb
(Appendix I)

However, the Meat Exporters' Schedule system for buying lambs can and has been criticized for a number of years because of its inability to provide financial incentive to producers to further increase their average lamb weight (Herlihy, 1970; Kirton, 1979; Cullwick, 1980). Although a number of alterations in both the calculation of costs and the carcass grades has occurred (NZMPB, 1979), the basic 'saw-tooth' structure of the system remains. The saw-tooth effect is the result of a reduced payment per kilogramme as lamb weights increase. It is an important aspect of the schedule system and its magnitude is a direct result of price relativity between grades.

A more detailed examination of the structure of the schedule price system plus an interpretation of the 'saw-tooth' effect on lamb carcass prices, and therefore its influence on producers' management decisions, is provided by Shadbolt (1980). In precis, the marginal return to producers for increasing lamb weights in the 1980/81 slaughter season decreased as the proportion of benchmark grade lambs in each draft decreased.

The price smoothing and supplementary minimum price schemes implemented by the NZMPB and Government respectively, to reduce price fluctuations, can also have an adverse effect on the pricing structure if they do not adequately represent forecast market demand. If the benchmark grade minimum price is set unrealistically high, export companies may be forced to market such carcasses at a loss to avoid intervention by the NZMPB. As a result the non-benchmark grades (nearly 70 percent of all export lambs) are priced to offset losses and thus price relativities between grades are distorted. It is not until the benchmark grade falls below the minimum that the NZMPB can control the prices of the other grades. It can, however, endeavour to persuade companies to alter the schedule when it sees fit and in the event of no response, advise producers of the position and note alternatives open to them (Frazer, pers comm.).

In conclusion, therefore, to reduce fluctuations in lamb returns, a producer should aim to slaughter only benchmark grade lambs. This is not always feasible, however, as most of the risk and uncertainty inherent in the production system involves aspects beyond the on-farm situation. The current practice of both drafting and grading mainly by eye creates a source of variation in the returns to the producer that can not be controlled. The probability of lambs being picked that are either unfinished or over-finished and graded as either too lean or fat, is a relatively unmeasured but extremely important factor. For those producers with the technical ability to increase lamb weights, the presence of such risks provides a disincentive to do so.

Another strategy for the producer aiming to avoid the distortions in per head value that result from the schedule system, is that of adopting alternative marketing options. These include co-operative and pooling systems and owner account schemes in which the producer does not receive all or some of the payment for his lambs until they are sold overseas in the hope that schedule price distortions will be removed on the world market. This, however, introduces a further aspect of uncertainty for the producer; the variability of international demand for lamb.

2.4 Production and Management

The management problems of irrigated pastures differ greatly from those of the dry land pastures (Hayman, 1978). Summer and autumn feed is as abundant and reliable as spring feed (Rickard, 1968) and therefore early lambing and drafting is not necessary. Cossens (1980) found the respective proportions of annual pasture production that occur in spring and in summer are 38 percent and 42 percent for irrigated pastures and 60 percent and 20 percent for dry lands.

Irrigation from May to October is seldom required and has little effect on pasture production (Figure 2). From November to April, however, irrigation trebles pasture production, increasing it from an average of 2,800 kg DM/ha. to 8,270 kg DM/ha. (Hayman, 1978). While dry land farmers are endeavouring to make as much hay as possible in spring (Cameron, 1968) the irrigation farmers' haymaking can be both delayed to summer and reduced because there are no drought conditions (Hayman, 1978). In addition, turnips are not necessary for winter feed as autumn grown pasture, which can be conserved, is guaranteed under irrigation.

The manager of irrigated pasture therefore can maximize productivity by converting the extra DM into saleable meat and wool while maintaining future productivity of both pasture and breeding stock by carefully planning feed use during the winter months.

A simple feed budgeting exercise can be used to identify the time periods at which feed might be a limiting factor on stocking rates and growth rates for various management strategies. The irrigated pasture production profile differs significantly from dry land pastures in both level and distribution of production (Hayman, 1978). Growth reaches a peak in late December and January, reflecting the seasonal growth pattern of the dominant legume *Trifolium repens* (white clover)(Rickard and Radcliffe, 1976). The metabolizable energy (ME) content of clover is greater than pasture at its post-anthesis stage of growth so the level of ME available to grazing livestock can be improved during December and January by irrigation (Figure 3). Higher intakes of clover than of ryegrass (Sinclair, Clarke and Filmer, 1956) and the more efficient utilization of ME from clover than from ryegrass (Joyce and Newth, 1967; Rattray and Joyce, 1974) should allow improved growth rates during this period.

2.4.1 Lambing date

By superimposing a ewe and lamb demand profile for 20 ewes per hectare on an available ME supply per hectare profile in which account is already taken of utilization rates, it is possible to illustrate the most likely periods of feed deficit. Figures 4 and 5 illustrate the demand and supply profiles for management strategies that involve lambing beginning pre and post mid September respectively. Early spring

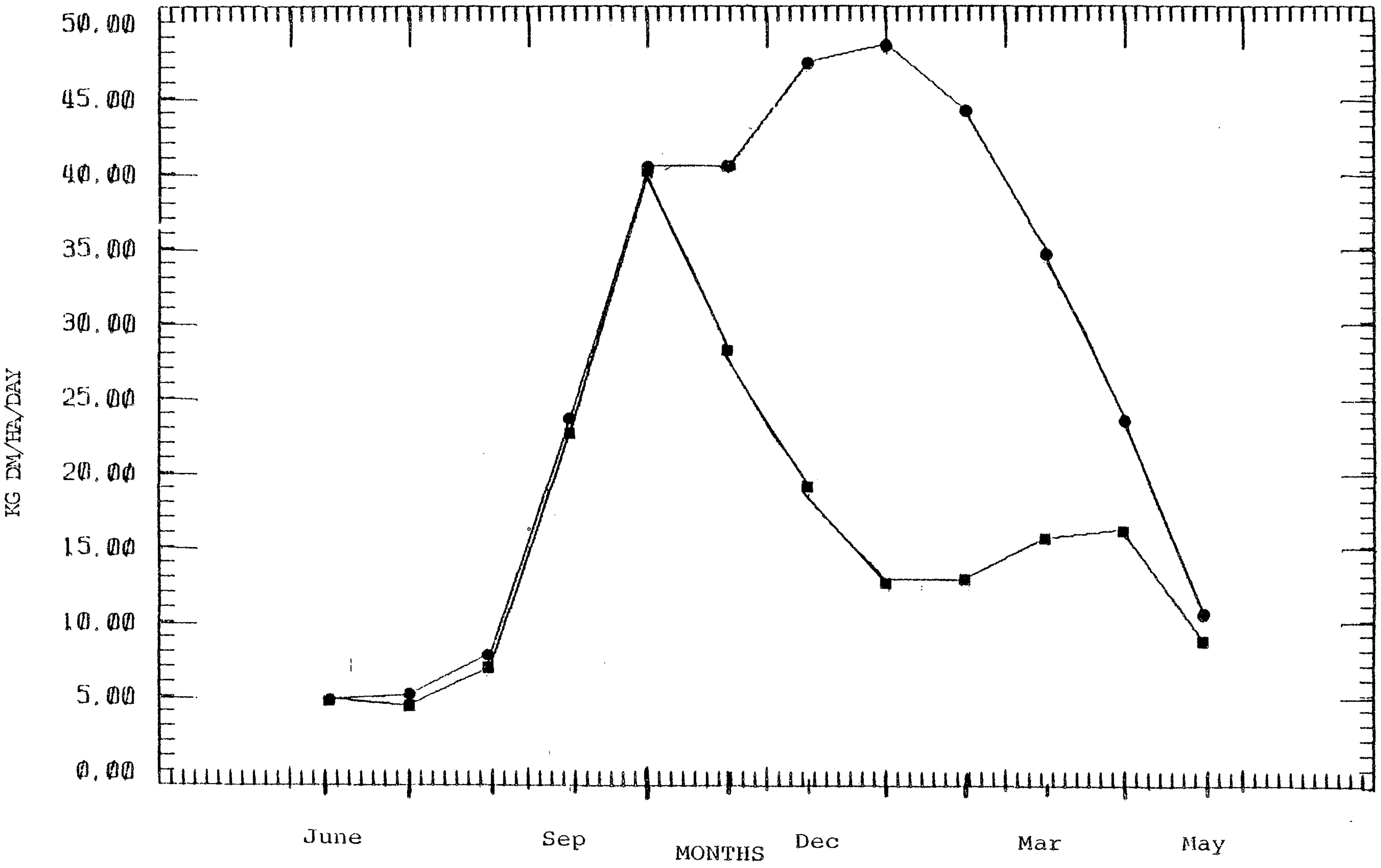


Fig. 2: Pasture Production at Winchmore Irrigation Research Station
● irrigated land
■ dry land
(Source: Rickard & Radcliffe (1976)).

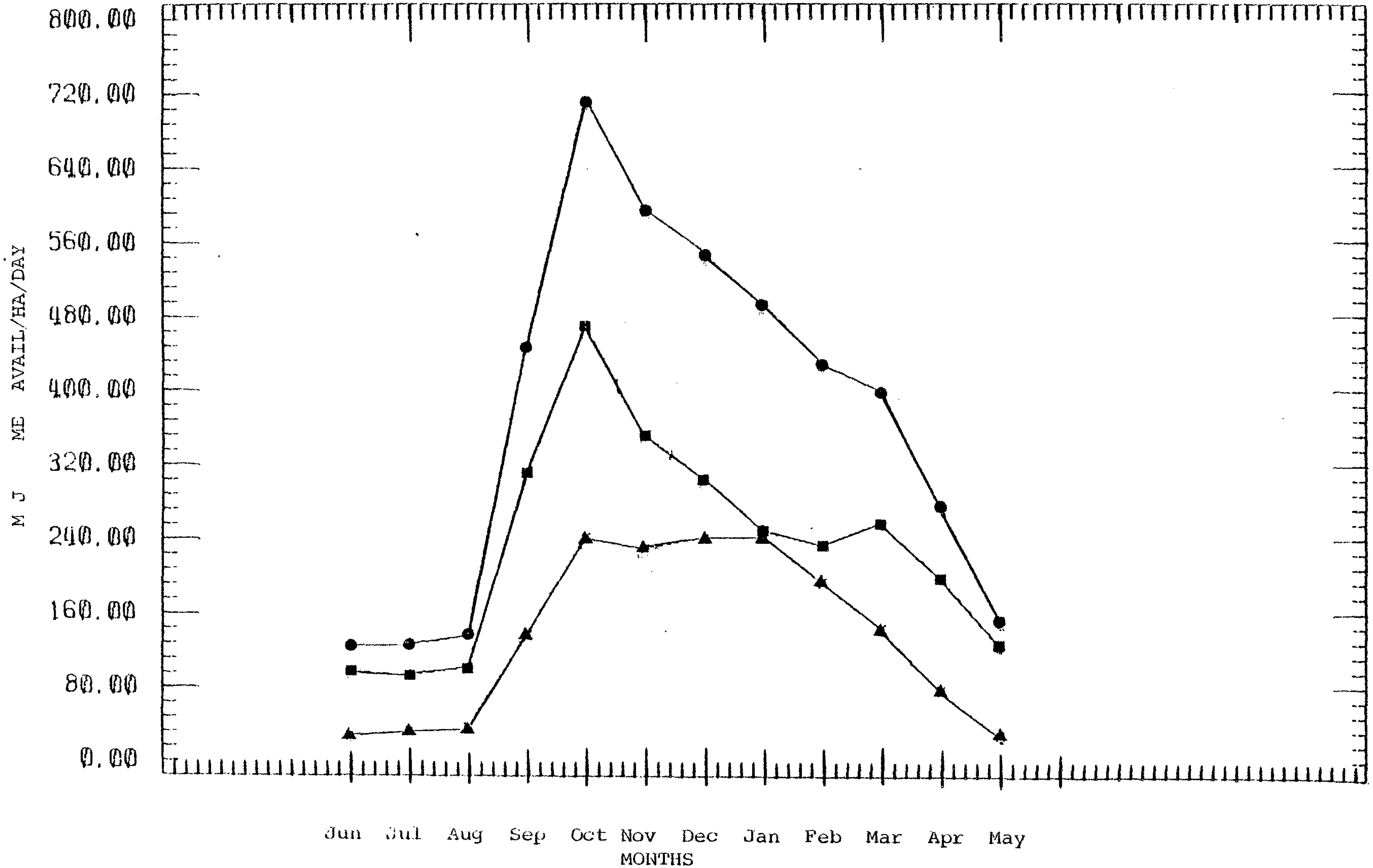


Fig. 3: Pasture and White Clover Growth Curves Under Irrigation.

● total pasture
■ grass
▲ white clover
(from Appendices II & III)

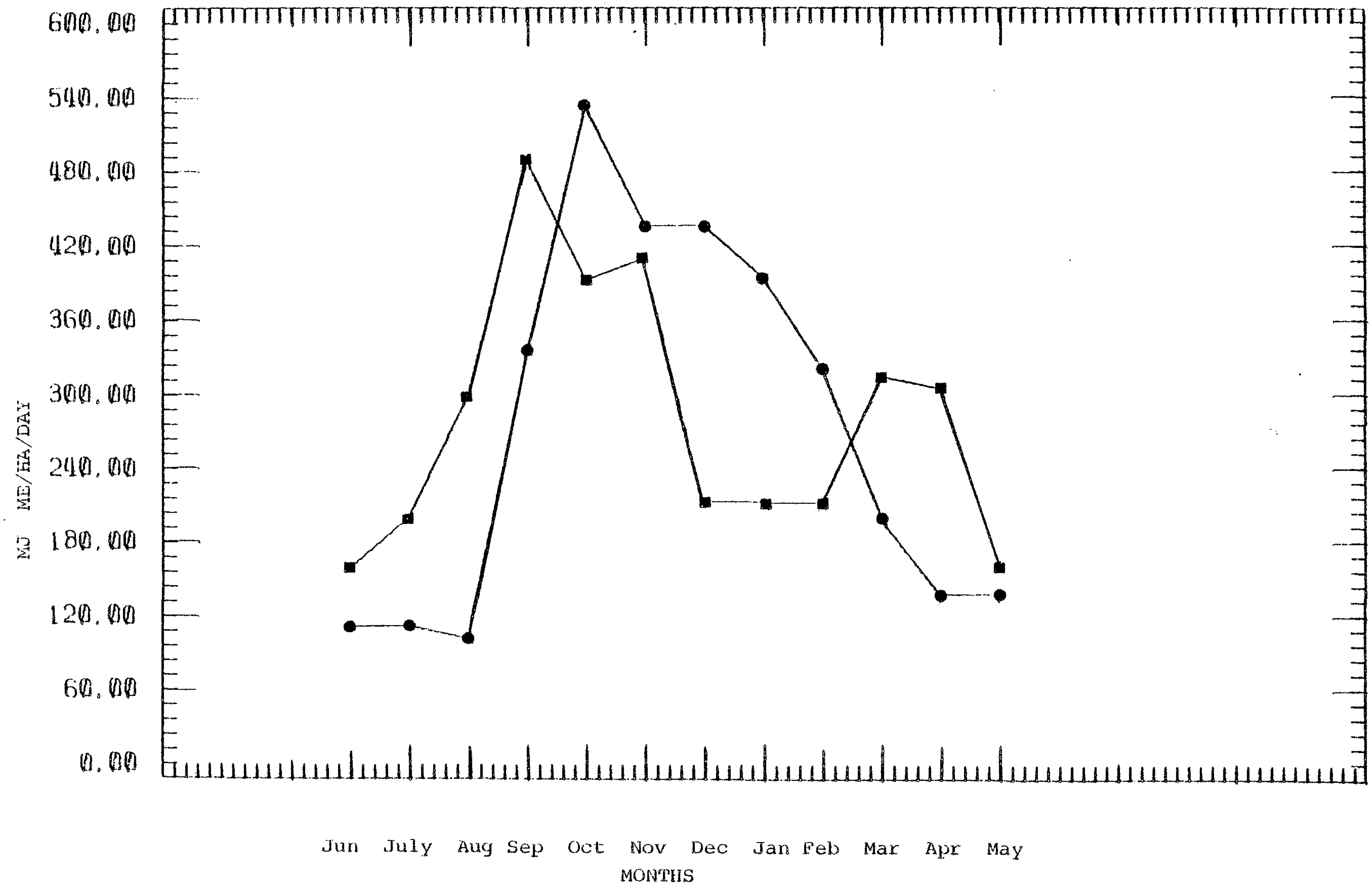


Fig. 4: ME Supply & Demand Profiles, Lambing before Mid-September.

● Supply/ha

■ Demand of 20 ewes/ha

(Appendix III & IV.

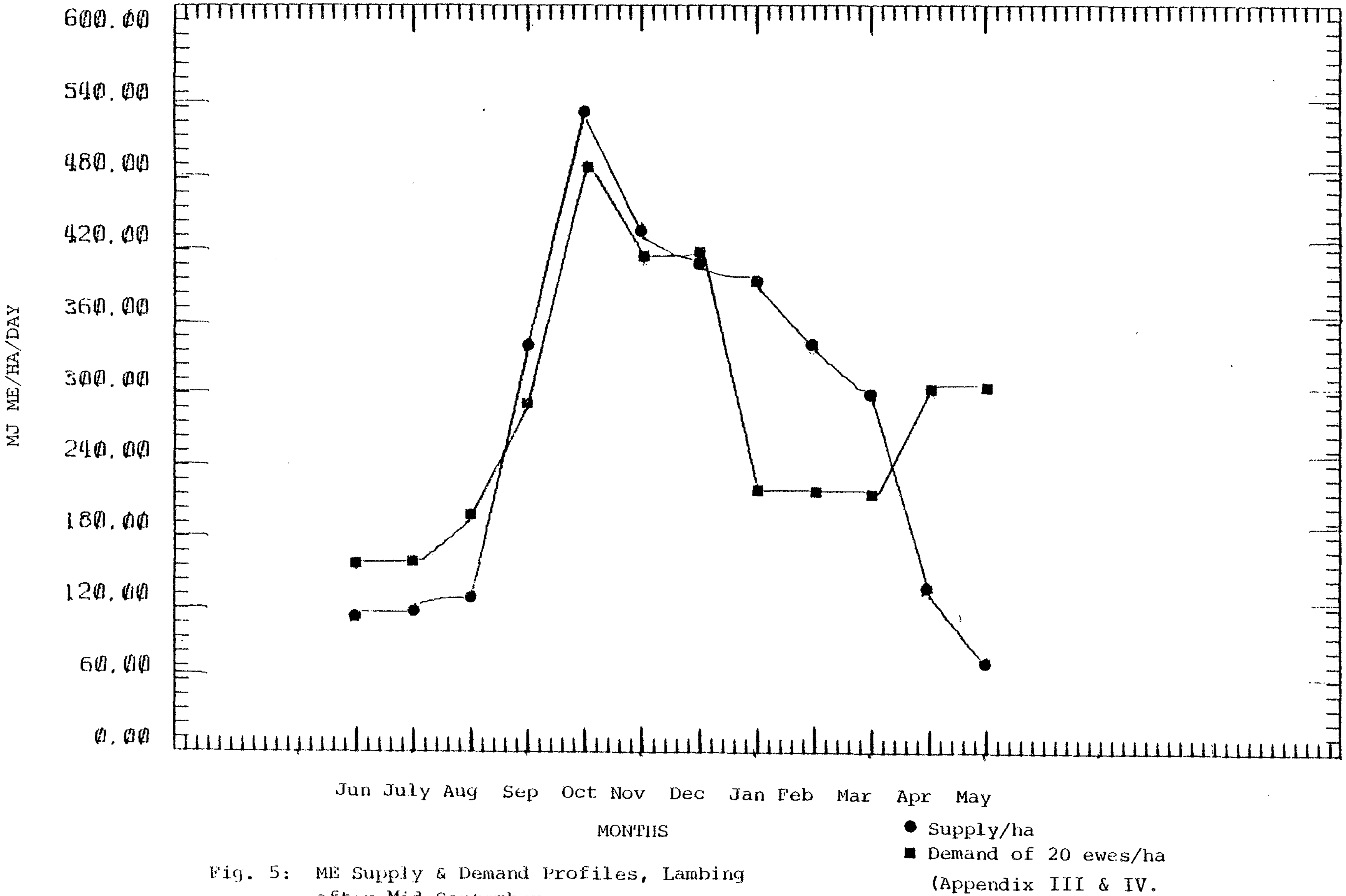


Fig. 5: ME Supply & Demand Profiles, Lambing after Mid-September.

growth, limited more often by temperature than lack of moisture, is unable to supply ewe demands when lambing dates are too early.

Inadequate supply of feed to lactating ewes directly affects pre-weaning lamb growth rates. Rattray, Morrison and Oliver (1975) note a 14g per day lower growth rate in the first four weeks of age of lambs born early. Geenty (1980) also recorded a disadvantage to early born lambs that were, on average, 14 percent lighter than later born lambs. Early born lambs did have a greater post-weaning growth rate but this was inadequate compensation. The advantages of later lambing are documented by Geenty (1980), and are due to:

(i) Heavier ewe liveweights at lambing.

(ii) Heavier lamb birthweights.

(iii) Higher early ewe milk production.

(iv) Availability of more pasture for lambs during lactation.

Dry land farmers are unable to co-ordinate peak demand with peak pasture production and still have lambs ready for slaughter before the summer drought. Thus they have to both supplement feed and operate at lower ewe numbers. Irrigation farmers, however, can delay lambing until mid-September or later. This allows a better match of feed supply and demand (Hayman, 1978) at the crucial lambing period, thus winter supplementation is not so heavily required.

The effect of grazing management on feed supply during lambing must also be understood. Hayman (1978) found that at high stocking rates, rotational grazing was able to make more efficient use of available feed than set stocking. The average pasture production profile from approximately monthly cuttings during the growing season differs from the profile for the two-weekly cuttings that simulate set stocking (Figure 6). The comparison shows that longer spells between grazing helps to provide more feed during the critical periods of stock demand.

Successful stock production from an irrigated system requires careful feed budgeting during the winter months and a later lambing date to ensure feed supply to the larger number of breeding stock carried relative to dry land properties. Partial adoption of such techniques is not sufficient unless costly feed supplements are provided to meet ewe demands during the crucial period. Hayman (1978) concludes that irrigated pastures have the potential for high production with low annual inputs if careful grazing management is adopted.

Farmers are not always keen to change certain management principles such as lambing date which, often as not, are a tradition on a farm and may also be chosen on the basis of unrelated factors such as the availability of family labour during school holidays.

2.4.2 Weaning date

Weaning dates also tend to be traditional and are often planned to

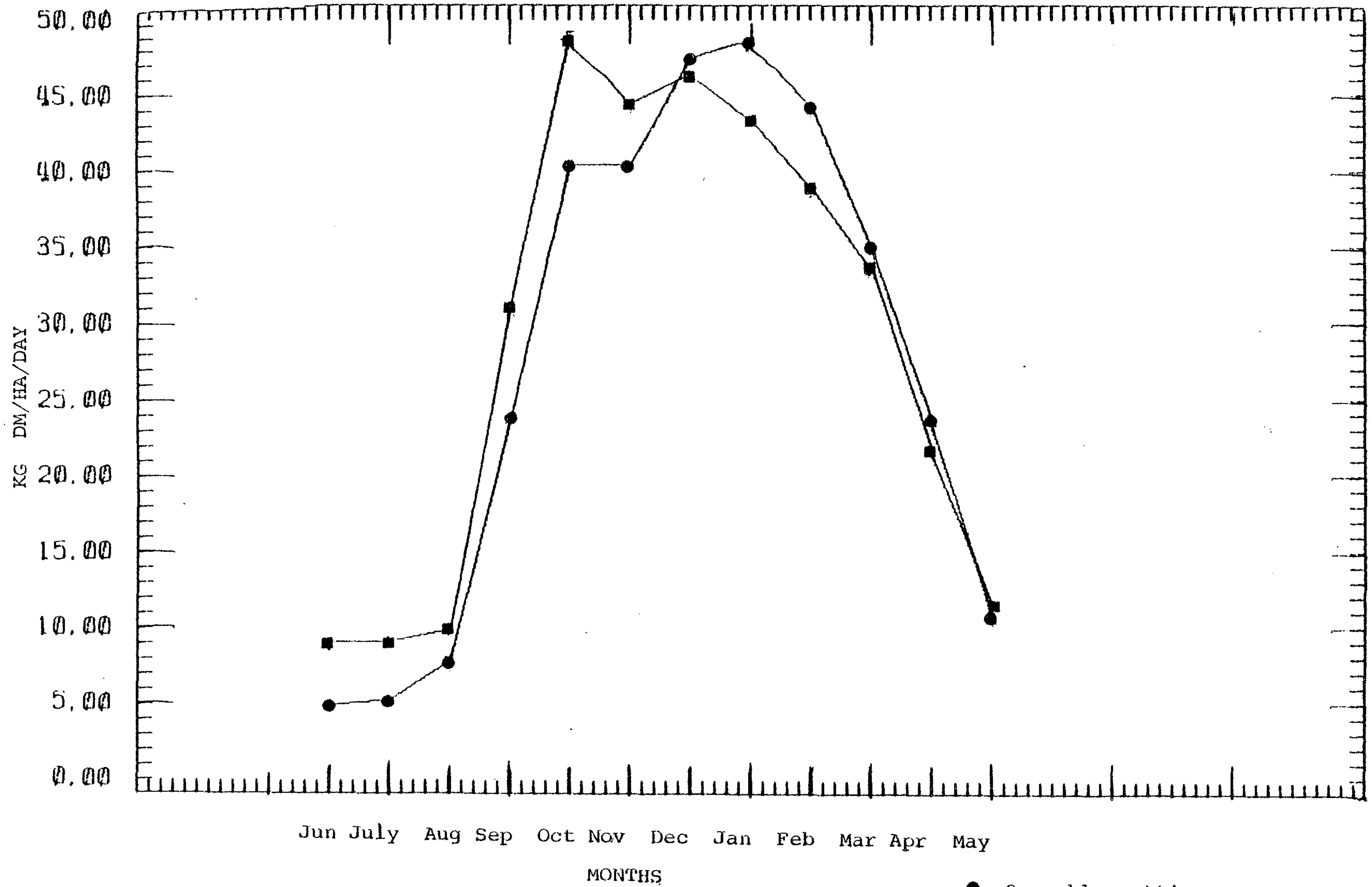


Fig. 6: Pasture Profiles from 2 & 4 Weekly Cuttings.

(Source: Rickard & Radcliffe (1976) & Rickard (pers comm) coincide with the first drafting-off of finished lambs. Geenty (1977) divided the pre-weaning growth period into stages (Figure 7). Stage I is from birth to four weeks of age when the lamb's diet consists mainly of milk. At Stage II there is a depression in growth rates as the lamb's digestive system adapts to the intake of pasture and in the final stage, growth rates are further reduced as the ewes begin to compete with the lambs for high quality pasture. Milk production has the most influence on lamb growth during the initial 6 weeks of life (Geenty, 1979). By weaning, at 8 to 9 weeks of age the third stage, of ewe competition, can be avoided but lamb growth rates can still decrease if high quality pasture is not made available to them. Rattray, Morrison and Farquhar (1976) recommend that when stocking rates are high and under highly intensive systems, it may be advantageous to wean early to lower overall feed requirements and aid farm management. Although early weaning lowers the requirement for high quality feed by the removal of the ewes, lamb growth rates are often depressed for 2 to 3 weeks as they adapt to a total pasture diet. Growth rates after this period, however, are more rapid than for later weaned lambs and can compensate weights quite satisfactorily (Geenty, 1980; Rattray et al., 1976). Drafting policies where early weaning is practised should therefore allow for the post weaning depression in growth rates if average slaughter weights are to be maintained. If lambs are weaned earlier still, that is on to pasture at 4 to 6 weeks, the risk of overfat lambs can be reduced (Jagusch and Rattray, 1979) but the post weaning check is still reflected in final weights as compensatory growth does not occur (Geenty, 1979).

2.4.3 Carcass composition

Features of major concern in the growth of the meat producing lamb are rate of muscle growth and the relative rates of fat deposition and bone growth. The growth of bone in relation to muscle varies appreciably between different genotypes but is little affected by sex or plane of nutrition (Prescott, 1979). The relative rate of deposition of fat on the other hand is markedly influenced by genotype, sex and, often, nutrition. Furthermore, since lambs are commonly selected for slaughter on the basis of fatness assessed by appraisal of subcutaneous fat cover (Russel et al., 1969), the relative development of fat on the surface of the carcass, between the muscles and within the body cavity, is also of practical importance (Prescott, 1979).

The risk of producing overfat lambs is a pertinent problem to farmers as overseas market demand and, therefore, price tends to favour leaner carcasses (Frazer, 1981). Although carcass fatness can be equated to carcass weight within a specific breed and sex of lambs, it would not always be sound economic policy to reduce carcass fatness by merely reducing slaughter weights of lambs (Kirton, 1980). Instead, management practices must be implemented that aim to reduce the possibility of producing overfat lambs.

Graham and Searle (1979) have defined four phases of fat deposition in ruminants:

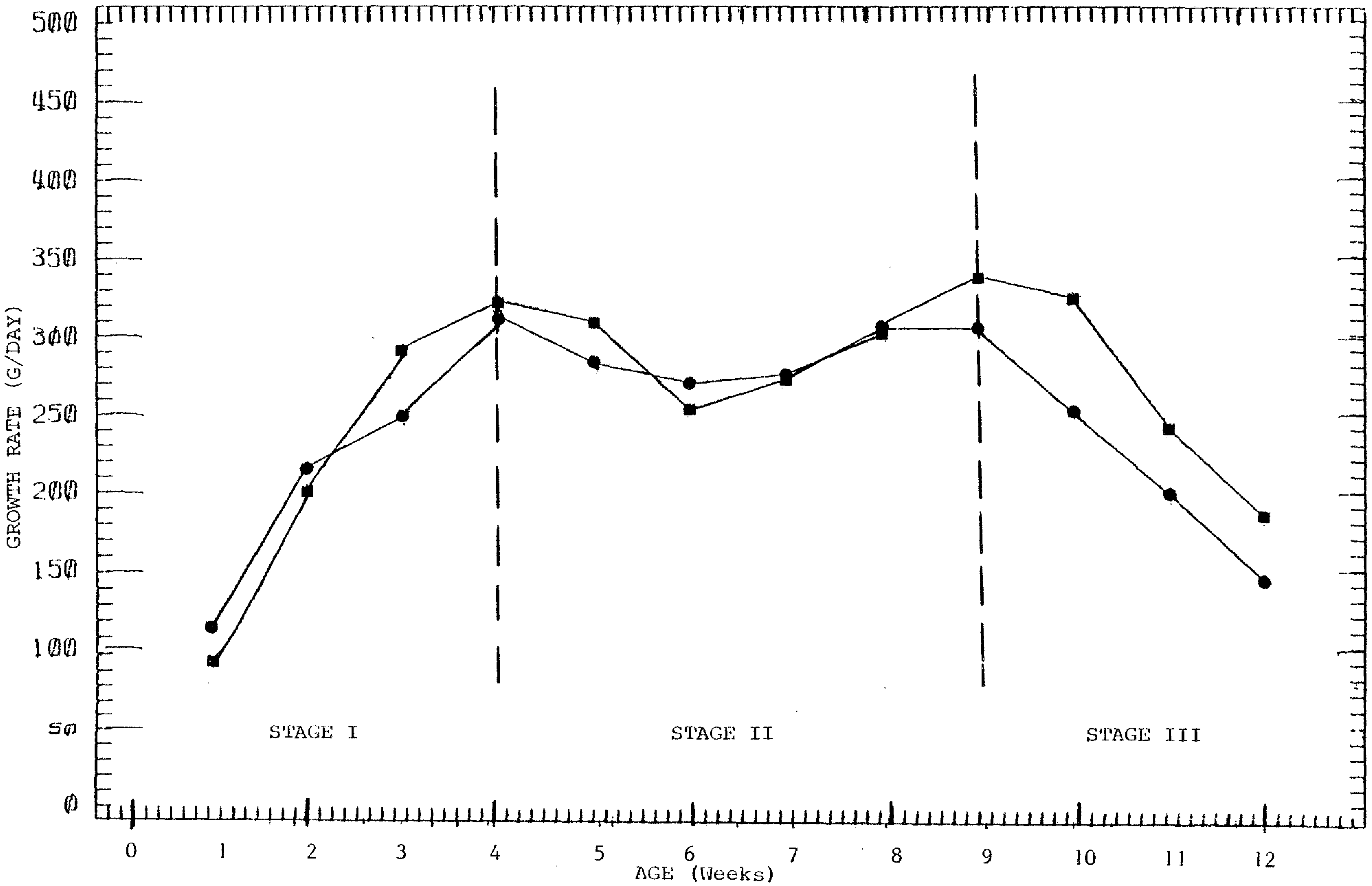


Fig. 7: Growth Rate Stages of Pre-Weaned Lamb.

● Romney
■ Corriedale
(Source: Geenty (1977))

(i) Milk feeding - fat representing 16 percent of liveweight gain.

(ii) Weaning (fat deposition
(rate related to
(iii) Pre-fattening (age at weaning and nutrition.

(iv) Fattening adult - fat representing 65 percent of liveweight gain.

In the first phase the proportions of fat and protein laid down are equal. The commencement of the fattening phase is related to weight which in turn is related to the final size of the animal concerned. Those animals from the smaller breeds will enter the fattening phase at lower weights than those of larger breeds. Once the fattening phase has been entered, the rate of fat accretion is constant, regardless of breed.

Searle and Griffiths (1976) have further proven that the body composition within breed and sex classes of sheep is similar at any specific weight regardless of early nutrition. They found that lambs fed well on milk regulated their fat level during the weaning and pre-fattening phases to be at a similar level to their contemporaries as they entered the final fattening phase. This is confirmed by Thornton and Hood (1979) who state that final carcass composition and meat quality depend more on an individual animal's weight at slaughter than on its nutritional history. Even though underfeeding influences body composition temporarily, the effects soon wear off once the feed supply resumes. However, when lambs are drafted at weaning, regulation of the fat level cannot occur and a wide range of fat levels is possible. Consequently, the number of lambs grading as overfats tends to increase (Kirton, pers comm.; Geenty, pers comm.).

The potential growth curve of the lamb under optimum environmental conditions is typically sigmoid (Prescott, 1979). Growth rate accelerates up to puberty and slows down progressively as maturity is approached. Searle and Griffiths (1976) equate the inflection point of a sigmoidal growth curve to that weight at which animals enter the post puberty fattening stage. The weight at the inflection point is, however, specific to both breed and sex. Although no significant differences have been found between the muscle proportion of carcass composition at similar weights (Jury et al., 1977; Kirton, 1979), smaller breeds reach their point of inflection at lighter weights than larger breeds so must be drafted sooner (Clarke and Geenty, 1979; Prescott, 1979).

Purchas (1978) noted that rams carried less fat at the same weight than castrates which in turn were leaner than female lambs. Fourie et al. (1970) found the proportionality of fat, lean and bone in the different carcasses reflected a relatively fatter female carcass at all weights. It would appear therefore that females reach the point of inflection at lighter weights than males and therefore should be drafted earlier if overfatness is to be avoided.

Although early work pointed to the effects of different levels of nutrition on carcass form and composition (Hammond, 1932; McMeekan, 1941; Pomeroy, 1941; Wallace, 1948), it has since been established that carcass composition is independent of nutritional environment and that in fact carcass weight is the prime determinant of fat and lean content (Jagusch and Rattray, 1979). The amount and timing of fat deposition varies with genotype, which determines the rate of maturing and the mature body size. The effect of nutrition is temporary and would merely represent a delay in reaching the inflection point.

2.4.4 Criteria for slaughter

Lambs approach the point of inflection at puberty. Searle and Griffiths (1976) quoted 30kg as being the weight at which Border Leicester X Merino lambs enter this phase. This represents approximately a 14 kg carcass. Any greater weight would involve a greater increase in carcass fat and therefore a less saleable product. An understanding of the relative inflection points of different breeds must be achieved for successful export lamb production as overfat carcasses are profitable to neither the farmer nor the exporting company.

The criteria for slaughter adopted for lambs of a specific genotype can include age, weight, fatness and percentage of mature weight.

(a) Age

When lambs are slaughtered at weaning they often have a high carcass fat content (Kirton, pers comm.). It is suggested that a change in traditional practices should occur to allow for regulation of the fat level (Geenty, pers comm.). Lambs could be weaned earlier and should not be slaughtered at weaning thereby reducing the risk of selling overfat carcasses.

(b) Weight, fatness and percentage of mature weight

Well grown lambs are typically slaughtered at about 50 percent of mature adult weight under U.K. conditions (UK/Meat and Livestock Commission 1975). The Meat and Livestock Commission recommend this figure as being an approximation of the inflection point on the sigmoidal growth curve. If lambs are slaughtered at or before this point, they have not yet entered the fattening phase so overfat carcasses can be avoided. They advise that estimated adult bodyweights used in the calculations should be based on weights which are attained under good conditions and are the average of male and female weights. Ewe lambs should be killed at 5 percent below the estimated average slaughter weight and wethers 10 percent above to attain the same amount of carcass fat.

In a survey of U.K. lamb carcasses in 1977, it was found that over 64 percent of lambs have a greater than 16kg carcass weight. The average carcass weight equalled 18.4 kg (Farmers Weekly, 1980). To achieve this, lambs would have to be killed at approximately 39 kg liveweight. The average adult weight therefore would be 78 kg, for example a 70 kg ewe put to an 86 kg ram.

The average slaughter weight of lambs killed in N.Z. in the 1979/80 season was 13.6 kg. By the same calculations, the average adult weight is 57.3 kg, for example a 50 kg ewe put to a 65 kg ram. Of those lambs slaughtered, nearly 39 percent were unfinished YL and YM grade carcasses. They possibly had not reached 50 percent of their mature weight at slaughter. From the estimated adult bodyweights for N.Z. bred sheep given in Table 2, it can be calculated that some carcass weights can still be increased 1 to 2 kg above the national average. It is suggested, therefore, that the MLC equation could be used by stock managers under N.Z. conditions to estimate the potential slaughter weights of lambs and to avoid the slaughter of both unfinished and overfat lambs.

A survey carried out by Taylor and Davison (1976) examined the drafts of nearly 260,000 lambs between November 1974 and January 1975 in the Whakatu area of the North Island. It noted that while 44 percent of the Southdown sired lambs drafted were graded as prime 8 to 12.5 kg carcasses, only 26-36 percent of the intermediate and 15-20 percent of the later maturing breeds were graded in the prime category. More than 20 percent of the two heavier breed groups were graded as YLs, light lambs with insufficient fat cover to grade as primes. These lambs could have been taken to heavier weights given that sufficient feed was available.

It can be seen in the yearly slaughter tallies of the N.Z. Meat Producers Board that the most common shift in proportions of lambs in respective export grades is between the YL and PM grades (Table 3). When both the seasonal and economic factors are beneficial to farmers, more of the medium to heavy weight breed lambs are taken to prime 13 to 16 kg carcasses (PMs). It might be presumed therefore that irrigation farmers with a certain feed supply should consistently be drafting PM weight lambs assuming they are able to achieve the desired lamb growth rates on the feed available.

Taylor and Davison (1976) noted the effect and importance of management decisions with respect to the grade of lambs slaughtered. When farmers instructed drafters to exclude overfats, the incidence of such carcasses was reduced from 0.52 percent to 0.42 percent. Also, understandably, by asking the drafters to take almost all lambs that would grade, there was a far greater proportion of light lambs (8 to 12.5 kg) than when the drafter was instructed to take only the tops from the line drafted. They emphasize the importance of "on farm" drafting decisions in relation to the losses associated with producing overfats. Specific breed, type of country farmed, feed supply, and availability of works killing space are all determinants in the decision to draft.

TABLE 2

Estimated Adult Bodyweights and Lamb Slaughter Weights of N.Z. Sheep.

Breed	Estimated Adult Bodyweight (kg)			Average Lamb Slaughter Weights (kg)	
	♀	♂	mean	Liveweight	Carcass Weight*
Southdown	45	60	57	28.5	13.5
Perendale	53	68	60.5	30.25	14.4
Romney	55	70	62.5	31.25	14.8
Coopworth	60	75	67.5	33.75	16.0
Suffolk	60	75	67.5	33.75	16.0

* Assumed dressing out percentage = 47.5 percent.

TABLE 3

The Percentage of the Total Lamb Kill in Respective Export Grades from 73/74 to 79/80.

Season	Grades (%)					Average Carcass Weight(kg)
	PL	YL	PM	YM	PH,YH/PH PX, PHH	
73/74	19.8	22.0	36.6	7.2	6.0	13.1
74/75	16.7	28.2	30.7	9.0	5.0	12.9
75/76	12.2	18.9	38.1	9.0	11.3	13.7
76/77	14.29	21.70	34.99	10.80	7.88	13.4
77/78	14.66	27.22	29.03	8.80	5.05	12.9
78/79	15.69	22.26	35.23	8.71	7.82	13.3
79/80	8.92	23.45	33.47	15.54	9.84	13.6

2.5 Summary

Traditional techniques of comparison between management strategies have tended to calculate optimal solutions from the average values of factors affecting output (Officer and Anderson, 1968). They have also judged optimum management systems as those in which average profit is maximized. This approach has assumed that farmers are both neutral to risk and entirely profit motivated, and therefore tends to provide results inconsistent with observed or plausible behaviour (Lin, Dean and Moore, 1974, Beck, 1981; Frengley, 1981).

Farmers are faced with risks and uncertainties in both technical and management aspects as well as from seasonal and economic factors. These lead to a high level of uncertainty with all farming operations, thereby affecting management strategies in both the short and long term (Barnard and Nix, 1973).

The problem faced by irrigation farmers is how to assess the value of alternative lamb production practices when faced with risk and uncertainty from both controllable and uncontrollable exogenous variables.

Controllable factors include ewe tupping weight and therefore lambing percentage, sire breed, lambing date, weaning date and docking policy which all affect lamb growth rate and 'finishing' weight. Sire and dam breed will also affect the wool weight and, therefore, the returns per lamb. The seasonal effect on ewe weight, lambing percentage and lamb growth rates must also be assessed to determine the uncontrollable variation in slaughter weights between years. The decision to draft will be the result of the management imposed and, therefore, the weight of lamb achieved, as well as the expected returns from the lamb schedule pricing system.

Finally, in some cases the uncertainty inherent in the system is aggravated by the increased stock numbers carried by irrigation farmers. The possibility that such uncertainty may be reduced by the adoption of irrigation based technology rather than dry land practices must be assessed. Therefore, before optimum policies can be decided upon, some understanding of the changed feed supply with respect to ewe numbers is required followed by an assessment of the economic worth of various management strategies.

CHAPTER 3

SYSTEMS SYNTHESIS

3.1 Introduction

The analysis of lamb production systems, described in Chapter 2, has made it possible to determine those factors most directly affecting lamb production on irrigated Canterbury farm land. The next stage in simulation modelling, systems synthesis, attempts to arrange those factors into a coherent and logical structure (Anderson, 1974).

In systems analysis it was found that certain exogenous variables, such as the environment, had an important impact on the growth rate of lambs. A number of management strategies were also isolated as factors most likely to affect both lamb growth and fat deposition rates. However, while both management strategies and environmental variables affected the rate at which the lambs approached a specified carcass type, the schedule pricing system most affected drafting decisions and, therefore, the conditions of the lamb at slaughter.

It was also found that a manager's interpretation of the situation and his attitude to risk could affect his decision to draft, thereby influencing his returns per lamb.

The inter-relationships between the salient features and components of the system are illustrated in Figure 8. While the computer model does not aim to analyse individual farmer attitudes to risk, it does aim to provide an indication of the variability of returns to the farmer, given specified management and drafting strategies.

In devising a model structure capable of evaluating a number of lamb production practices it was decided to begin with a norm. In other words a 'modal' lamb with specified birth weight, pre and post weaning growth rates, and fat deposition rate. Production factors most directly affecting the values of the variables specified were determined in system analysis as being a lamb's birthranking (i.e. whether it is a single, twin or triplet), its sex, sire breed, lambing date and weaning age. The 'modal' lamb, representing traditional farm practices, was specified as being a single, female lamb by a wool breed sire, born before mid-September and weaned after 12 weeks of age. Any lamb simulated in the model that met the criteria of the 'modal' lamb adopted its birth weight and was grown to slaughter at its specified growth rates. When either flock management or individual lamb criteria were not the same as those of the 'modal' lamb then birth weights, growth and fat deposition rates were adjusted accordingly.

The model structure was designed, therefore, to evaluate the effect of alternative management strategies on the rate at which lambs achieve specified carcass criteria. Where ewe lambs are being retained in the flock the model can also be used to evaluate the effect of alternative

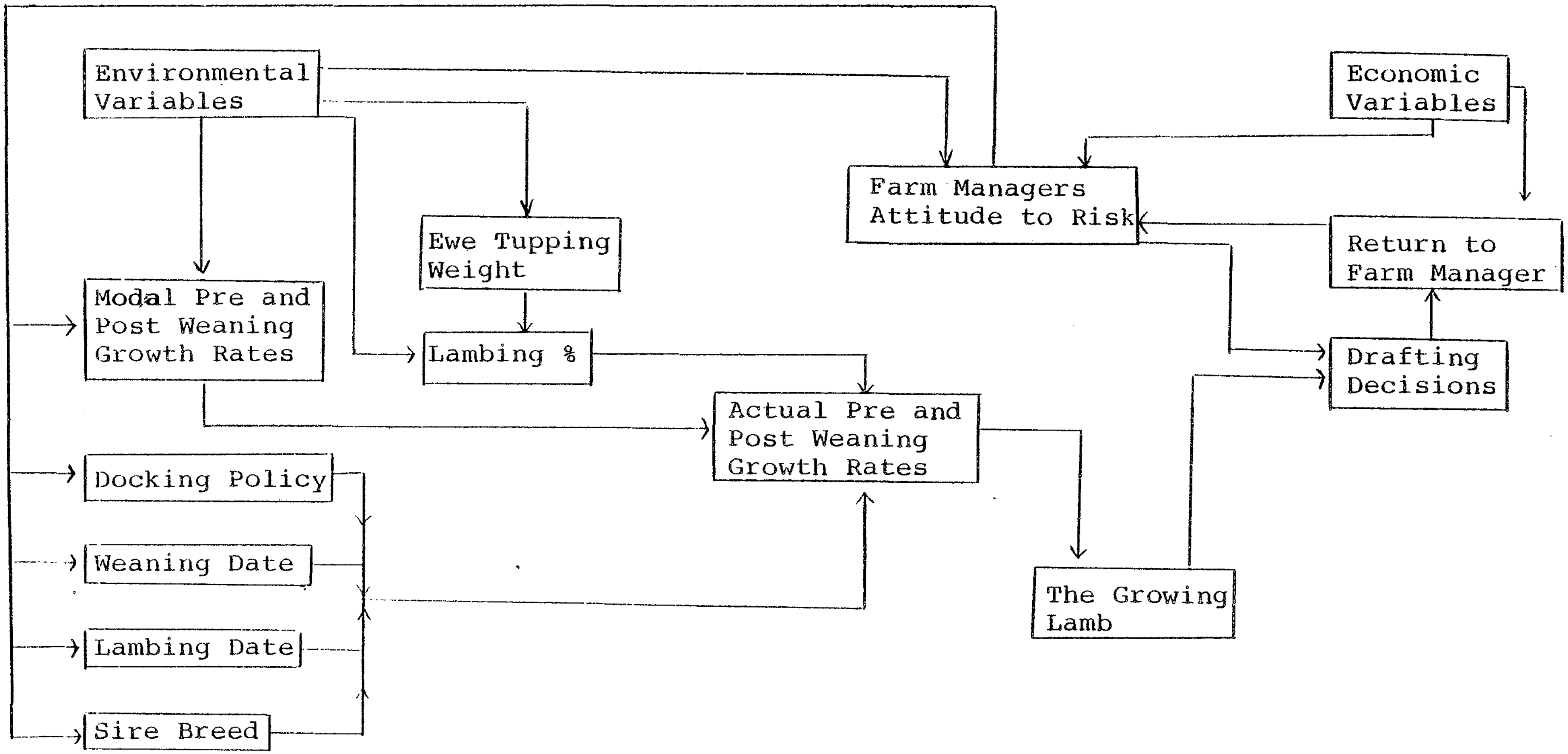


Fig. 8: Block Diagram of the Lamb Drafting Model

management strategies on the autumn live weight achieved by replacement stock.

3.2 Model Summary

There are a number of inputs required by the model before simulation of the lamb production cycle can begin.

The first set of inputs is the 'modal' lamb birth weight and pre and post weaning growth rates. In the assessment of these values it is assumed that all flocks are run under traditional farm practices. The values given therefore reflect an inherent productivity or base level of the flock under evaluation.

The second set of inputs specify the management controlled factors, that is, the sire breed, lambing date, weaning age and docking policy, that are currently adopted for the flock. Where these differ from traditional practices corrections are made to the 'modal' lamb data. At this stage the 'modal' data become specifically, the flock mean birth weight and growth rates for single, ewe lambs.

Thirdly, the model requires the expected price/kg for the benchmark grade (PM) lamb. As it is the structure of the schedule system that dictates the price relativity between benchmark and non-benchmark grades this also has to be specified to enable the calculation of the non-benchmark grade prices.

Fourthly, it is required that a preferable carcass type be specified. This is achieved by putting in a fat level above, and carcass weight below, which it is not desirable to draft.

Simulation of the flock at this stage would result in all lambs behaving in the same way as the flock mean for single, ewe lambs. In practice, it is improbable that all lambs will adhere totally to such specifications. The model is designed, therefore, to simulate both sexes of lambs, as well as alternative birthrankings per lamb, and to alter the single, ewe lamb birth weight and growth rates to suit other lamb types.

The probability of a ewe giving birth to a ram lamb is assumed to be about 50 percent. This is not influenced by any external factors so can be simulated within the model. However, the probability of that lamb being a single twin or triplet is more difficult to determine. The number of lambs a ewe produces has been shown to be a function of her weight at tupping (Coop, 1962; Rattray, 1980). Thus, the next input required by the model is the mean flock tupping weight. The mean flock lambing percentage is then calculated from a specified regression function. From the lambing percentage it is possible to calculate by matrix algebra a birth ranking probability distribution which, with the inclusion of specific death rates for each birth ranking, is used to determine appropriate proportions of single, twin, triplet and dead lambs and barren ewes within a flock.

Variations in flock tupping weights will alter the proportions of singles, twins, triplets and barren ewes within the flock. As the proportions vary, so too will the proportion of dead lambs because death rates vary between birth rankings.

Seasonal variations occur in both the mean flock tupping weights and lamb growth rates because they are influenced by the environmental conditions that determine feed availability. The model is designed to allow for this by varying the mean tupping weight and the mean growth rates of single, ewe lambs from year to year. Before simulation of the ewe flock begins the mean birth weights and growth rates of twin and triplet ewe lambs are calculated from the mean values for a single, ewe lamb.

As the flock is simulated, each ewe is randomly allocated her litter size from a cumulative probability distribution which is based on the flock lambing percentage and lamb death rates. If her lamb(s) is a live one it adopts the mean birth weight and growth rates of its birth ranking. The lamb is then randomly allocated a sex; if it is a ram lamb appropriate corrections are made to its birth weight. The docking policy adopted by management then dictates whether corrections to the lamb growth rates are those for castrate or for entire ram lambs. All entire ram lambs are also allocated an alternative fat deposition rate to that of the ewe and castrate ram lambs.

The actual birth weight and growth rates of each lamb are then randomly selected from the distribution about the mean values for its birthranking and sex. This allows for within flock variation between lambs of the same type (e.g. twin ram, single castrate or triplet ewe lambs).

Thus, each live lamb generated from the ewe flock is born at a prescribed weight, on a date randomly allocated from around the mean lambing date, and grown at prescribed rates till slaughter. Lambs are drafted according to carcass specifications, at two weekly intervals from weaning as long as there are sufficient numbers to draft. Lamb numbers are monitored to ensure that the majority are drafted by a specified period at which the ewes require feed for the pre-tupping period.

Each lamb's carcass weight, grade and returns are calculated and these are aggregated for the flock at the end of the year. Where replacement ewe lambs are retained these are allocated a value which is related to cull ewe lamb prices. Using the results from a number of years the model then calculates the expected mean and variance of the lamb carcass weight, the returns per lamb and the returns per ewe.

3.3 Conversion Factors

When the sex, birthranking or management of a lamb differs from that of the 'modal' lamb appropriate conversion factors are applied to the 'modal' lamb data.

The calculation of each conversion factor was based on available research results. In some cases, notably the research on varying lambing dates, there were few research results available for assessment so the conversion factors calculated may not be adequately representative of variations that occur in practice.

Similarly, because of the variation between research data in terms of location, breed of sheep and the number of sheep measured in each experiment, a conversion factor calculated as the mean value over all available data may appear too simplistic in that it gives each result an equal weighting. To give some of the results a stronger weighting would require a subjective selection of those results thought to be more accurate. Instead, it was decided to begin simulation by using a mean value for each conversion factor. The accuracy with which each value predicts output from alternative management strategies can then be tested during both the validation and the sensitivity analysis of the model.

The conversion factors used by the model reflect, either directly or indirectly, the management of the system. That is, while sire breed, lambing date, weaning age and docking policy are determined by the manager, the tupping weight and therefore, birthranking of the ewe's lamb(s) are not so easily controlled.

3.3.1 Sire breed

An extensive search of research data was carried out in which a number of papers were examined (Geenty, 1974; Jagusch et al., 1971; Geenty and Clarke, 1977; Meyer, Kirton, Dobbie and Harvey, 1978; Winchmore Exp. Farm, Ann. Report, 1976; Geenty, 1979; Carter, Kirton and Sinclair, 1974) in an attempt to calculate a mean breed effect on lamb performance. The most conclusive result was that Suffolk, Oxford, Dorset Down and Border Leicester rams all sire heavier, faster growing lambs than the Southdown. A comparison of alternative breeds to the Romney as a ewe resulted in faster growing lambs from Coopworth, Dorset Down and Corriedales and lower from Perendales. Both Perendale and Coopworth ewes bore lighter lambs while Corriedales were heavier at birth.

It should be noted however, that while interbreed comparisons with respect to growth rates and weight are an important tool in stock management there has been considerable evidence that intrabreed differences are often at least as variable as interbreed differences (Kirton, Carter, Clarke, Sinclair and Jury, 1974).

It was decided therefore to allow only for the effect of hybrid vigour on lamb weights and growth rates. Assuming the ewe flock is of a wool breed it was only by the use of a down breed sire that hybrid vigour was imposed on the 'modal' lamb birth weight and pre and post weaning growth rates. Data from Geenty (pers comm) and Fourie, Kirton and Jury (1970) enabled the calculation of conversion factors for cross breeding. Cross bred lambs were 5 percent heavier at birth and their pre and post weaning growth rates were 9 percent and 5 percent greater, respectively, than pure bred lambs.

3.3.2 Lambing date

While feed budgeting exercises can easily be used to illustrate the practicality of matching a period of high demand to that of high supply there are few research reports available that examine the effect of changing lambing dates on ewe and lamb performance. By delaying the lambing date it is possible to increase both birth weight and pre weaning growth rates through improved ewe nutrition.

However, both Geenty (pers comm) and Rattray (1978) noted this was followed by a six week reduction in the post-weaning growth rates from later lambing dates. This coincided with lower quality pasture being available for lamb growth. Rattray (1978) found that although later born lambs grew faster than early born lambs in the first four weeks after lambing, this was not maintained once the lambs began to consume grass.

Similarly, Geenty (pers comm) found a reduction in post-weaning growth rates due to lambs being weaned onto low quality pasture. Both experiments noted compensatory growth after a six week period and that the later lambing groups were as heavy or heavier by slaughter as the early lambers. (Table 4).

Later lambing in the model relates to a lambing date after mid-September with a mean on about 1st October. The six weeks of lower pasture quality on irrigated land were taken to be between December and January. Therefore, the conversion factors adopted (Table 4) allowed for increased birth weights (DATEWT) and pre-weaning growth rates (DATEGR) until 11 weeks from lambing. This is followed by a 6 week period of reduced growth rates (DATEPQ) then compensatory rates (DATEWG) until slaughter.

3.3.3 Weaning age

Although there has been some research on the effects of weaning age on lamb growth rates many of the comparisons have been between weaning ages that are seldom used in practice. The 'modal' lamb is presumed to be weaned at 12 weeks from the beginning of lambing. Mean conversion factors therefore relate to a 12 week norm (Table 5). The pre-weaning growth rate of the 'modal' lamb is the average of the three growth stages described by Geenty (1974). When a lamb is weaned early its average pre-weaning growth rate is higher since the final stage of decreasing growth rates, as the lamb competes with the ewe for food, has been removed.

During the time period from weaning until 12 weeks of age the growth rate of the early weaned lambs is generally less than those lambs still on their mothers. Growth rates after 12 weeks of age have been found to be greater for early weaned lambs. However, the compensatory growth recorded is variable and although this model used the mean conversion factor it is proposed that the extent of compensation is controlled by a number of factors which are beyond the scope of this model.

TABLE 4

The Effect of Lambing Date on Lamb Birth Weight and Pre-Weaning Growth Rate.

Source	Breed	Birth Weight (kg)		Wts. (kg)				Conversion Factors			
				Pre weaning		Post weaning		DATEWT Birth Weight	DATEGR Growth Rate Pre-weaning	DATEPQ Growth Rate 6 weeks	DATEWG Growth Rate Post-weaning
		E	L	E	L	E	L	E → L	E → L	E → L	E → L
Rattray, Morrison	Romney	4.225	4.375	19.1	19.8			}	}		
& Oliver (1975)		4.35	4.3	19.5	20.2			}1.012	}1.043		
Geenty	Mixed	4.0	5.2	24.0	29.4	36.8	35.9	1.3	1.21	0.51	
(pers comm)						42.3	47.8				2.16
Rattray		4.8	4.9	22.7	26.1	94	114	1.02	1.15		
(1978)				27.1	20.6					0.76	1.21
				MEAN CONVERSION FACTORS				1.111	1.134	0.635	1.69

E = early lambing
L = late lambing

TABLE 5

The Effect of Weaning Age on Lamb Pre-and Post-Weaning Growth Rates.

Source	Breed	Birth Wt(kg)	Weaning Wt.(kg) Early	Weaning Wt.(kg) Late	Post Weaning Wt.(kg) Early	Post Weaning Wt.(kg) Late	Conversion Factors Pre-weaning EARLGR	Conversion Factors Post-weaning EARLWG	Conversion Factors Post-weaning EARLWR
Geenty (pers comm)	Mixed	4.07	23.10 (9 wks)		26.8 (12 wks)	36.0 (18 wks)	1.067 (<12 wks)	0.622 (9-12 wks)	1.25 (12-18 wks)
		3.99		27.73 (12 wks)		35.1 (18 wks)			
Jagusch & Coop (1971)	Mixed	5.0	16.0 (5 wks)		24.0 (11 wks)		1.210 (< 11 wks)	0.733 (5-11 wks)	
		5.0		25.0 (11 wks)					
Rattray *et al* (1976)	Mixed	3.9	16.7 (6 wks)		19.1 (8 wks)	24.5 (12 wks)	1.10 (< 8 wks)	0.619 (6-8 wks)	0.982 (8-12 wks)
		4.1		19.6 (8 wks)		25.1 (12 wks)			
Geenty (1979)	Corriedale x Dorset	4.5	13.3 (5 wks)						
		4.5		20.0 (9 wks)			1.022 (< 9 wks)		
		4.5		33.1 (15 wks)			0.903 (< 15 wks)		
				MEAN CONVERSION FACTORS *			1.041 (<12 wks)	0.67 (<12-12wks)	1.12 (> 12 wks)

* Calculations assume a 12 week norm for weaning date although the research 'modals' vary from 8-15 weeks.

3.3.4 Docking policy

Although the 'modal' lamb is specified as a ewe lamb the fate of her male counterparts is controlled by management and this must be decided upon before simulation of the ewe flock occurs.

The choices offered to managers are to either castrate all ram lambs, to follow the guidelines of Kirton (pers comm) and keep all single ram lambs born in the first two weeks as entires or to keep all ram lambs as entires. During simulation when a male lamb is born it is allocated a ram lamb birthweight then either ram or castrate lamb growth and fat deposition rates depending on the docking policy chosen by the manager.

a) Birth weights and growth rates

A number of research trials have resulted in quite similar data for comparisons between ewe and ram lamb birth weights (Table 6). While wether lambs benefit from ram lamb birth weights they are not able to achieve the growth rate of ram lambs once they are castrated. From Jagusch and Coop (1971), Rattray et al (1976) and extensive data provided by Geenty (pers comm) it was calculated that both pre and post weaning growth rates of castrates are from 8-9 percent greater than those of ewe lambs.

As docking generally takes place before weaning, the conversion factor for castrate pre weaning growth rates (CASG) was set at 1.08 while the post weaning growth rate factor (CASWG) equalled 1.09. (i.e. 8 and 9 percent greater than ewe lamb pre and post weaning growth rates respectively). The degree to which docking stress affects lamb growth rates is dependent on both the lamb age and the environmental conditions at docking (Clarke and Kirton, 1976). As these will vary between both farms and seasons, the conversion factors used may not accurately reflect the actual effect of docking on castrates' growth rates.

The mean growth rate of ram lambs was found to be more than 13 percent greater than that of ewe lambs (Table 7), throughout their development.

b) Fat deposition rates

Since carcass weight is the prime determinant of fat and lean content of lamb carcasses (Jagusch and Rattray, 1979) it was decided to use regression equations at each draft to calculate the carcass fatness of each lamb with respect to its weight.

As interbreed comparisons, excluding the Southdown breed, are extremely variable and regression equations for them not readily available it was decided to differentiate only between the sex of the lamb when calculating carcass fatness. Linear equations provided by Kirton (pers comm) indicated a greater increase in carcass fatness for ewe and wether lambs than for ram lambs as carcass weight increased. (Table 8).

TABLE 6

The Effect of Sex on Lamb Birthweights.

Source	Breed	Birth Wt (kg) Ewe Lamb	Ram Lamb	Conversion Factor RAMWT Ewe - Ram
Hart (pers comm)	Dorset Down	4.793	5.03	1.049
Geenty (pers comm)	Mixed	4.055	4.255	1.049
Meyer & Clarke (1978)	Mixed	4.32	4.62	1.069
Winchmore Irrigation Res. Stat. (1975)	Suffolk & Southdown x Romney	4.7	4.9	1.043
MEAN CONVERSION FACTOR				1.053

TABLE 7

The Effect of Sex on Lamb Growth Rates.

Source	Breed	Weight (kg) or Growth Rate (kg/day) Ewe Lambs	Ram Lambs	Conversion Factors RAMGR pre-weaning Ewe -> Ram	RAMGR post-weaning Ewe -> Ram
Everitt & Jury (1966)	Sth Down x Romney	8.57	10.45		
		->24.34	->28.31	1.084	
		->26.86	->30.76		1.11
Argue (1980)	Dorset Down x Coopworth	2.66	.318	1.19	
Sheeplan	Meat Type	.15	.22	1.467	
		.13	.18		1.385
	Wool Type	.17	.17	1.0	
		.10	.10		1.0
Kirton (pers comm)	Mixed	.111	.119	1.072	
Rattray et al	Mixed	.207	.248	(1.198)	
Jury, Johnson & Clarke (1979)	Romney			(1.106)	
Winchmore Irrigation Res. Station (1975)	Suffolk & Southdown x Romney	.227	.259	(1.14)	
	MEAN CONVERSION FACTORS			1.135	1.143
	(OVERALL)			(1.148)	

TABLE 8

Linear Regression Equation Coefficients and Intercepts for Calculating Carcass Fatness from Carcass Weight.

Source	Regression Coefficient		Regression Intercept	
	Ewe & Castrate	Ram	Ewe & Castrate	Ram
Kirton & Johnson (1979)	1.266		-8.55	
	1.122		-6.64	
Kirton (pers comm)	1.04		-5.67	
	1.36		-6.64	
	0.79		-3.53	
	1.4		-7.7	
		0.56		-1.25
		0.46		-1.8
		0.6		-1.3
MEAN VALUES Ewe & Castrates	1.163 (FATRG)		-6.455 (FATINT)	
MEAN VALUES Rams		0.54 (SEXRG)		-1.45 (SEXINT)

During simulation, therefore, male lambs are allocated either the ram, or the castrate and ewe lamb, regression co-efficient and intercept for the calculation of their carcass fatness.

3.3.5 Birthranking

The effect of birth rank on lamb weights and growth rates has been well documented (Tables 9 and 10). While multiple birth lambs are lighter at birth and have a lower pre-weaning growth rate they have been shown to compensate during the post-weaning growth stage. The conversion factors used by the model are the mean of those calculated from each research report. A close similarity between the various reports can be observed.

Little data are available on triplet lamb birth weights and growth rates. The conversion factors used for growth rates between twin and triplet lambs therefore were taken to be the same as for those between singles and twins.

3.4 Simulation Procedure

Once the flock mean values for a single ewe lamb's birth weight and pre and post weaning growth rates, and the tupping weight of the ewes, have been established, simulation of the ewe flock can begin.

3.4.1 Environmental variation

Each year the model simulates varying ewe body weights and lamb growth rates to indirectly reflect the effect of the environment on pasture productivity.

The coefficient of variation of annual pasture growth for irrigated land at Winchmore Experimental Station was measured by Rickard and Radcliffe (1976) as being between 12 and 24 percent. Variation in pasture supply immediately prior to and post lambing affects a ewe's condition and, her lamb's pre weaning growth rate. Similarly, a lamb's post weaning growth rate will be affected by pasture supply, and ewe tupping weights will be affected by late summer and autumn growth.

In practice, there is some variation in the ability of farm managers to budget their feed supply to optimize production. Also, ewes have the ability to buffer the effects of feed shortages, particularly during lactation, by utilizing their body reserves (Geenty, 1981, pers comm.). It is pre-supposed therefore that some degree of both pasture management and ewe buffering will reduce the effect of variability measured in feed supply.

The period of greatest reliance on pasture growth is during late winter and early spring when ewe requirements are at a peak. Variation in pre-weaning growth rates will reflect environmental conditions more acutely than post-weaning growth rates and ewe tupping weights which are more easily controlled or manipulated by management.

TABLE 9

The Effect of Birth Rank on Lamb Birth Weights.

Source	Breed	Birth Weight (kg) S	TW	TR	Conversion Factors RANKWT S -> TW	RANKWT TW -> TR
Hart (pers comm)	Dorset Down	5.35	4.48		0.838	
Argue (1980)	Dorset Down x Coopworth	5.15	4.3	3.85	0.835	0.895
Joyce, Clarke	Mixed	4.81	4.05		0.842	
MacLean, Lynch	Romney	4.68	3.99		0.853	
& Cox (1975)	Coopworth	5.11	4.23		0.828	
	Perendale	4.79	3.94		0.823	
Geenty (pers comm)	Mixed	4.67	3.88		0.832	
		MEAN CONVERSION FACTOR				0.836

TABLE 10

The Effect of Birth Rank on Pre-& Post-Weaning Lamb Growth Rates.

Source	Breed	Weight (kg) or Growth Rate (kg/day) S	TW	TR	Conversion Factors RANKGR S->TW	TW->TR	RANKWG S->TW
Hart (pers comm)	Dorset Down	.3	.255		0.85		
Argue (1980)	Dorset Down x Coopworth	.373	.286	.218	0.767	0.762	
Geenty (pers comm)		24.42 29.36 29.35	20.92 24.10 24.3		0.849 0.829 0.889		
Jury et al (1979)	Romney				0.825		
Sheeplan	Mixed				0.875		
MAF	Mixed				0.826		
MEAN CONVERSION FACTOR FOR PRE-WEANING GROWTH RATES					0.839		
Geenty (pers comm)	Mixed	34.83 35.31 37.26	31.88 32.40 33.21				1.012 1.054 1.140
MAF	Mixed						1.157
MEAN CONVERSION FACTOR FOR POST-WEANING GROWTH RATES							1.091

After some discussion with Geenty (pers. comm.) it was decided to allow a 12 percent coefficient of variation about the mean pre-weaning growth rates and to reduce the environmental effect on post-weaning growth rates and tupping weights by allowing only a 5 percent coefficient of variation about flock means. Each year the pre and post weaning growth rates and flock tupping weights are determined by randomly selecting from assumed normal distributions with appropriate means and standard deviations. Absolute autocorrelation is assumed between pre and post weaning growth rates by using the same random number for the respective selections.

By this method, the effect of the environment can be imposed on the model, albeit in an indirect manner.

3.4.2 Birthranking

Once the mean birth weight and growth rates for a single, ewe lamb have been established birthranking conversion factors are used to calculate the values for twin and triplet ewe lambs.

The next step is to determine, from the flock tupping weight, the proportion of single, twin and triplet lambs and barren ewes within the flock.

a) Flock lambing percentage

The flock tupping weight is used to calculate a lambing percentage from a simplified equation:

$$LP = TUPRG * EWEWT$$

where LP = Lambing percentage

TUPRG = Regression coefficient

EWEWT = Flock tupping weight

The relationship between lambing percentage and ewe liveweight at tupping has been reported in a number of papers (Table 11). Most report a relationship between ovulation rate, lambs born per ewe lambing or lambs born per ewe mated and ewe tupping weight. To calculate a coefficient relating the number of lambs born to the ewe weight at mating it was necessary to assume that the number of lambs born per ewe lambing is 72 percent of her ovulation rate (Kelly & Knight, 1979) and that 4 percent of all ewes mated are barren. For example Joyce et al (1975) found that ovulation rate could be calculated as being equal to 3.2 times ewe tupping weight (kg). From the above assumptions the number of lambs born per ewe lambing equals 2.3 times ewe tupping weight and the number of lambs born per ewe mated is equal to 2.2 times ewe tupping weight. This compares favourably with the relationships defined by Parker (1974), Kelly & Knight (1979) and Rattray et al. (1976). These have, generally, been reported as the percentage increase in

TABLE 11

Regression Coefficients Relating Ewe Weight at Tupping to Lambs Born/Ewe Mated.

Source	Regression Coefficients Relating to Ewe Weight at Tupping		
	Ovulation rate / fertile ewe	Lambs Born /ewes lambing	Lambs Born /ewes mated
Parker (1974)			2.2
Kelly & Knight (1979)	3.3	(2.4)	(2.3)*
Joyce *et al* (1975)	3.2	(2.3)	(2.2)*
Rattray, Jagusch, Smith & Tervit (1978)	3.94	(2.84)	(2.7)*
Rattray *et al* (1976)		2.34	(2.25)*
		MEAN TUPRG	2.33

*( ) indicates an estimate based on the assumptions:

LB/EL = 72% of ovulation rate (Kelly & Knight, 1979)
LB/EM = 96% of LB/EL i.e. 4% barrenness.

ovulation rate or lambing percentage for each kilogramme increase in ewe tupping weight and have not had defined constant or error terms to be used in a regression equation. The regression equation used by the model, therefore, is simplistic in that it has no constant associated with it ant it assumes an intercept of zero. The equation is only realistic however, for 'normal New Zealand' ewe tupping weights; while it can be calculated that a 20 kg ewe could have a lambing percentage of 46, it is more likely that she would not be alive at that weight.

To allow for an error term, that is, for factors other than flock mean tupping weight, that affect flock lambing percentage a coefficient of variation of 5 percent (Geenty, pers. comm.) was applied to the calculated lambing percentage.

b) Birthranking probability distribution

The probable proportion of single, twin and triplet lambs and barren ewes in the flock is calculated from the flock mean lambing percentage, and is illustrated in Figure 9.

The relationship between the mean lambing percentage and the birthrank probabilities can be expressed in three simultaneous equations:

$$\text{(i)} \quad u = 0(P_1) + 1(P_2) + 2(P_3) + 3(1-P_1-P_2-P_3)$$

$$\text{(ii)} \quad \sigma^2 = (0-u)^2(P_1) + (1-u)^2(P_2) + (2-u)^2(P_3) + (3-u)^2(1-P_1-P_2-P_3)$$

$$\text{(iii)} \quad 0 = (0-u)^3(P_1) + (1-u)^3(P_2)+2-u)^3(P_3) +(3-u)^3(1-P_1-P_2-P_3)$$

where u = mean lambing percentage

σ^2 = variation about the mean (u)

P_1 = probability of ewe barrenness

P_2 = " " " bearing a single

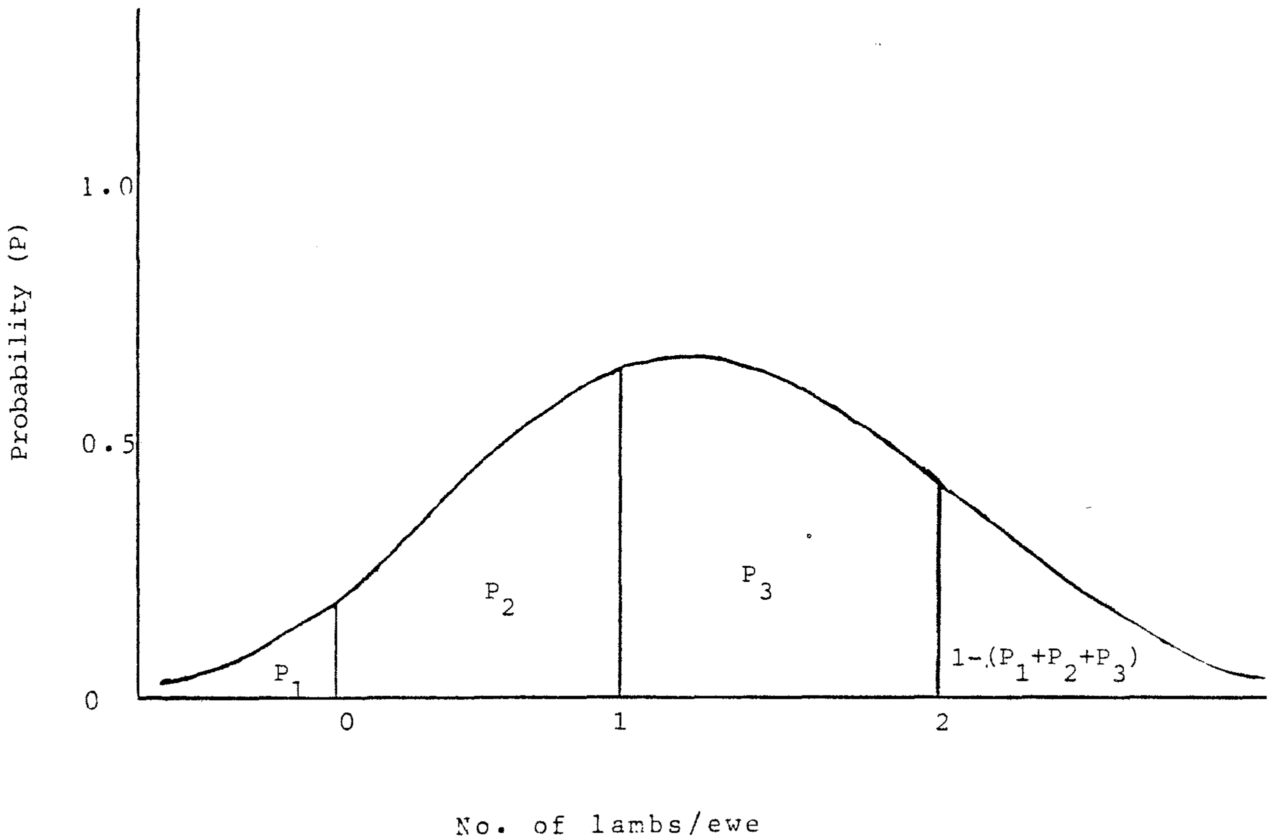
P_3 = " " " bearing twins

$1-P_1-P_2-P_3$ = " " " bearing triplets

(Source: McArthur, pers. comm)

By assuming a within flock coefficient of variation of 43 percent (McArthur, 1981, pers. comm.) about the known mean it is possible to solve the equation by matrix arithmetic. As a certain percentage of

FIGURE 9: Probability Distribution of Barren Ewes (P_1), Singles (P_2), Twins (P_3) and Triplets ($1-(P_1+P_2+P_3)$) about a Flock mean Lambing Percentage (u)



lambs in each birthranking do not survive lambing the death rate percentage is taken off each birthranking probability then accumulated to create a further probability, that of producing dead lambs.

The probable proportions of ewes bearing single, twin, triplet and dead lambs and being barren within the flock are then summated to form a cumulative probability distribution with five possible outcomes.

During simulation of the flock each ewe is randomly allocated her productive performance from the cumulative probability distribution. By this method a ewe can only produce either live or dead lambs or be barren. Although this may not simulate reality exactly it does allow, on a flock basis, representation of the number of singles, twins, triplets, dead lambs and barren ewes that relate to a specific lambing percentage and lamb death rate.

3.4.3 Within flock variation

Once it has been determined that a ewe has produced a live lamb, the lamb(s) is randomly allocated a sex, a birth date, a birth weight and pre and post weaning growth rates from within flock distributions about the flock means.

Approximately 50 percent of the lambs will be male and they are allocated either castrate or ram lamb growth rates depending on the docking policy adopted by management.

The distribution of lamb birth dates within South Island ewe flocks is assumed to be lognormal. Kelly and Knight (1979) recorded lamb births over three reproductive cycles and noted that 80.6 percent of the lambs were born in the first cycle (17 days) and by the end of the second cycle 94.7 percent of the lambs had been born with the remainder in the third cycle and later. These data were interpolated to calculate a mean lambing date and the variation about that mean for a South Island ewe flock. It can be seen in Figure 10 that the frequency distribution noted by Kelly and Knight (1979) can be approximated by the curve of a lognormal distribution. The lambing date is generated from the lognormal distribution (f(x)) by drawing observations of the underlying normal distribution (f(y)), where $y = \log_e(x)$ and then taking the antilog of the observation generated to give an observation from the lognormal (McArthur, 1979).

Using a within-flock coefficient of variation of 12 percent (Jagusch and Rattray, 1980, pers. comm.), the birth weight and pre and post weaning growth rates of each lamb are selected from distributions appropriate to its birth ranking and sex. For example, given a mean birth weight and growth rates for twin ram lambs, each twin ram lamb is given values from the probability distribution about each mean.

Each lamb, therefore, is born at a randomly selected weight and grown at randomly selected rates both before and after weaning until it is drafted.

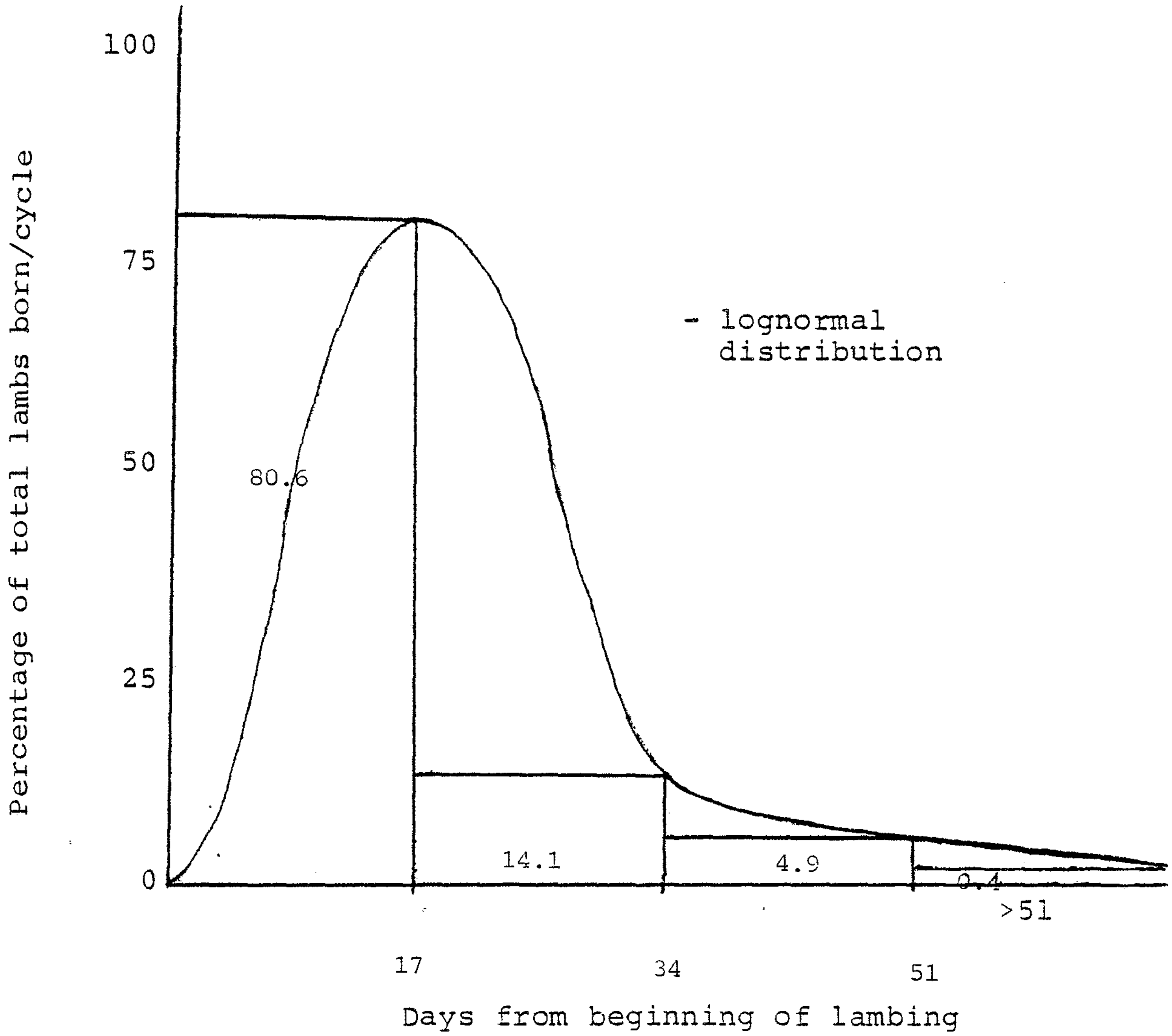


Fig. 10: Lognormal Distribution of Within Flock Lambing Dates

3.4.4 Drafting strategies

Before simulation began the model required maximum and minimum values for carcass fatness and weight respectively to be specified as well as the length of the drafting season. Where the drafting season length is not specified the default values used by the model are 26 weeks when lambing begins before mid-September and 24 weeks when it begins after that date. Later lambing ewes require tupping feed at a time of decreasing grass growth rates so there is some reliance on saved feed and lambs must be drafted earlier to allow feed to be saved.

From weaning the model proceeds in fortnightly steps with drafting possible at each step. Each fortnight all the lambs are first checked for fatness, then weight, then age. If they are equal to or greater than the values specified for fatness and weight or if they have reached the end of the season they are drafted.

To permit the creation of a more realistic drafting schedule the number of lambs in each draft is counted and, if it is below a specified minimum, the lambs are grown on to the next draft. As it is common on irrigation farms for ewe lambs to be maintained for replacement stock (Binnie,1981, pers. comm.) the model allows the number of lambs remaining on the farm at the end of the drafting season to be up to 25 percent of the total ewe number.

If the sire breed is a wool type and replacement ewe lambs are to be retained all ewe lambs are grown until the final draft date when selection takes place and all cull ewe lambs slaughtered. Binnie (1981, pers. comm.) recommended that a random selection of, for example, 100 out of the heaviest 150 ewe lambs, would allow for farmer preferences for criteria other than weight, such as the birth ranking or wool weight. The model sorts the lambs by weight and randomly selects a specified amount (25 percent of the ewe numbers) from a group of the heaviest lambs. Those lambs retained as replacement are given monetary values above those of their culled counterparts.

When ewe lambs are not retained, either by choice or because a down breed sire has been used, lambs are drafted throughout the season. At the final draft the lambs are sorted by weight and the lightest lambs, no more than 25 percent of the ewe number in total, are retained on the farm. These, also, are given specified values above those of their drafted counterparts as it is presumed they will be drafted at heavier weights in due course.

All lambs drafted, including the cull ewe lambs, are graded by weight and fatness. A survey by the N.Z. Meat and Wool Boards' Economic Service (1976b) measured the carcass fatness of the respective lamb grades. The mean GR measurements for YL, YM, PL, PM, A, O and F grades were 9.6, 10.9, 11.8, 14.0, 5.7, 14.0 and 23.4 respectively. These values are used by the model to provide some indication of the difference between prime and second grade lamb carcasses.

3.4.5 Economic variation

Before simulation began the required carcass type was defined and the expected price for each lamb carcass grade was stated. The definition of the required carcass type (and, therefore, the drafting criteria) is influenced by the prices expected for the various export lamb grades. For example, where the expected price of all lambs with a greater than 15 mm GR measurement and weighing more than 16.5 kg, is less than that expected for leaner, lighter lambs, then the latter type would probably be the defined carcass type.

The only price the model requires is that of the benchmark grade (PM) lamb which is covered by the supplementary minimum price schemes. Specification of other grade prices is not necessary, instead a definition of the schedule price structure, which dictates the price relativity between the benchmark and non-benchmark grades, is required.

There are three schedule price structures offered (Table 12). The first was obtained from the slaughter seasons of 1978/79 and 1979/80. There was little variation in the November to March price structures between seasons. The second structure is hypothetical and provides more incentive to slaughter light lambs and the third, also hypothetical, reduces the 'saw-tooth' effect on heavy lamb prices.

By this method it is possible to assess the effect of varying price relativities on lamb values as well as to calculate the relative marginal returns of increasing average carcass weights under each schedule price structure.

During the 1980/81 season the value of pelts and, to a certain extent, slipe wool decreased and it would appear that market prospects in the near future are poor. Predicting market values for wool and pelts is outside the scope of this model. However, the difference between price/carcass and price/head which includes the skin payment can be an important determinant in a farmer's choice of sire breed. Similarly, if net shorn wool prices are higher than slipe wool then the use of a wool breed sire allows some flexibility for farm management. However, shearing will cause an immediate reduction in growth rates which must be taken into account in drafting strategies.

It was decided therefore to note the benefits of a wool breed sire with respect to the wool weights achieved but not to attempt to simulate the growth of wool by either wool or down breeds or to calculate the pelt and wool returns of the lambs.

3.4.6 Expected risks and returns

From the farmers point of view increased expected returns may not be enough if a new technology or strategy is risky and there is a possibility that, at times, the farmer may be worse off than he would have been under the old system (Beck, Harrison and Johnston, 1981). Therefore, the model was designed to estimate both the expected (mean) return (E) and the expected variance (V) (or standard deviation) of returns for specified management strategies and schedule price

TABLE 12

Three Price Structures Arranged to Illustrate Changing Demand Patterns for Export Lamb Grades.

	Non-benchmark grade prices with respect to the benchmark (PM) price per kilogramme						
	PM	PL	PX	PH	PHH	YL	YM
Nov - Mar '79*	1.0	0.96	0.87	0.81	0.80	0.94	0.98
Nov - Mar '80*	1.0	0.97	0.88	0.83	0.78	0.94	0.98
Structure 1	1.0	0.965	0.875	0.82	0.79	0.94	0.98
Structure 2	1.0	0.99	0.82	0.78	0.77	0.98	0.96
Structure 3	1.0	0.93	0.94	0.87	0.81	0.88	0.91

(* Source: NZMPB 1980)

structure. This was achieved by replicating the lamb growth procedure a number of times, each time with a different random number seed, to simulate the random effects of environment and other factors on the system.

Using the E,V criterion it is possible to determine a set of alternative risk efficient strategies for the decision maker's reference (Beck et al., 1981). (In an E,V sense treatment X will dominate treatment Y if X has the same expected return as Y but a smaller variance, or if X has the same variance as Y but a greater expected value). The E,V, method therefore does not attempt to identify a single maximum utility strategy since that is dependent on a specification of the decision makers preferences.

The main advantage of the E,V method, identified as an efficiency analysis method by Anderson (1976), is its simplicity in many applications. It should be noted however, that it deals only with risk and not with other attributes that may also differentiate between strategies.

Frengley (1981) points out that the best valued farm programmes are measured on some personal scale not directly related to money. The happiness of farmers with their farming systems and way of life is not satisfactorily reflected by their incomes.

The results produced by the model therefore provide only the financial assessment of a farming programme and as such are just reference points from which a decision maker can work.

3.5 The Computer Program

The program was written in the FORTRAN IV language for a VAX computer. It was designed to be run in an iterative fashion so as to ease both manipulation and understanding of the system by the simulator. At this stage the design does not include error trapping, nor prompts for data entry, so is not recommended for general use.

Time is simulated in the model both sequentially and by steps for, although days pass between tupping and lambing, these are not simulated. Instead within each year only the days from the start of lambing to slaughter are simulated, the lambing percentage being related to the tupping weight of the ewe earlier in the year.

```
i.e.  DO 10    J = 1, NYEAR
            .
            .
            .                       yearly steps
            .
            .
      DO 20    K = 1, WDAY-BDAY
            .
            .                       daily steps
20    CONTINUE
```

```
         .
         .
      DO 30    L = 1,SDAY - WDAY
         .
         .                         daily steps
30    CONTINUE
         .
         .

         .
         .
10    CONTINUE
```

where NYEAR = no. of years

BDAY = birth day of individual lamb

WDAY = weaning day of flock

SDAY = slaughter day of individual lamb

The main variables used in the model are listed in Table 13 and these are used in the flow diagram of the system (Figure 11). A listing of the program can be obtained from the author (C/- Ministry of Agriculture and Fisheries, Private Bag, Christchurch, New Zealand).

3.6 Verification

At various stages in model construction it was necessary to compare the model's response with that which would be anticipated to appear if the model's structure was programmed as intended. Verification therefore is a continuous phase of checking for logical consistency (Dent and Blackie, 1979), removing logical faults and thereby establishing the rectitude of the model (Mihram, 1972). It is also the stage at which the occurrence of faults can be prevented (antibugging) and as such is concurrent with model synthesis.

Random generation of values from specified distributions was simulated in a number of places in the model (e.g. ewe tupping weight between seasons). Tests were applied to ensure that the generated data came from the specified distribution and that the overall flock or seasonal mean produced by the model was that specified. By doing this during model synthesis it was also possible to establish the minimum number of replications and flock ewes required to allow adequate handling of stochastic variables. For example, to ensure adequate numbers of twins and triplets for assessment when ewe tupping weights are low a larger size flock is required. It was found that fifty replications were required of the model to allow sufficiently for environmental variation.

Verification of the model involved the use of WRITE statements for a number of variables throughout each replication. It also involved some manual calculations of how the model should alter mean live weights

TABLE 13

List of Variables of Lamb Drafting Model.

	Variable	Meaning	Units
Flock:	BRD	breed of ram	no.
	DATE	lambing date	no.
	WDAY	weaning age	weeks
	BALLS	docking policy	no.
	IREP	replacement policy	no.
	MINM	price of PM grade lamb	c/kg
	SWT	required sale weight of lamb	kg
	SGR	required GR (fatness) of lamb	mm
	SDAY	required sale date of lamb	weeks
	EWEWT	mean tupping weight	kg
	LP	mean lambing percentage	%
	AV	lambing percentage	%
	S	probability of single lambs	no.
	T	probability of twin lambs	no.
	TR	probability of triplet lambs	no.
	BARR	probability of barren ewes	no.
	NDRAFTS	weekly draft no.	no.
Modal	WTS	birth weight	kg
Lamb:	GRS	pre-weaning growth rate	g/day
	WGRS	post-weaning growth rate	g/day
Individual	K	birth ranking of lamb	no.1-5
Lambs:	MF	sex of lamb	no.
	BDAY	birth date of lamb	days

WT	weight of lamb (from birth to slaughter)	kg
GR	pre-weaning growth rate	kg/day
WGR	post-weaning growth rate	kg/day
REAR	regression coefficient for carcass weight & fatness	
SDF	standard deviation for carcass weight & fatness	
WEIGHT	carcass weight of lamb	kg
GRM	GR measurement of carcass	mm
INUM	slaughter age of lamb	days
NLAMBS	number of lambs to be drafted	no.
NREP	number of ewe lambs	no.

and growth rates and comparisons of these with the model output.

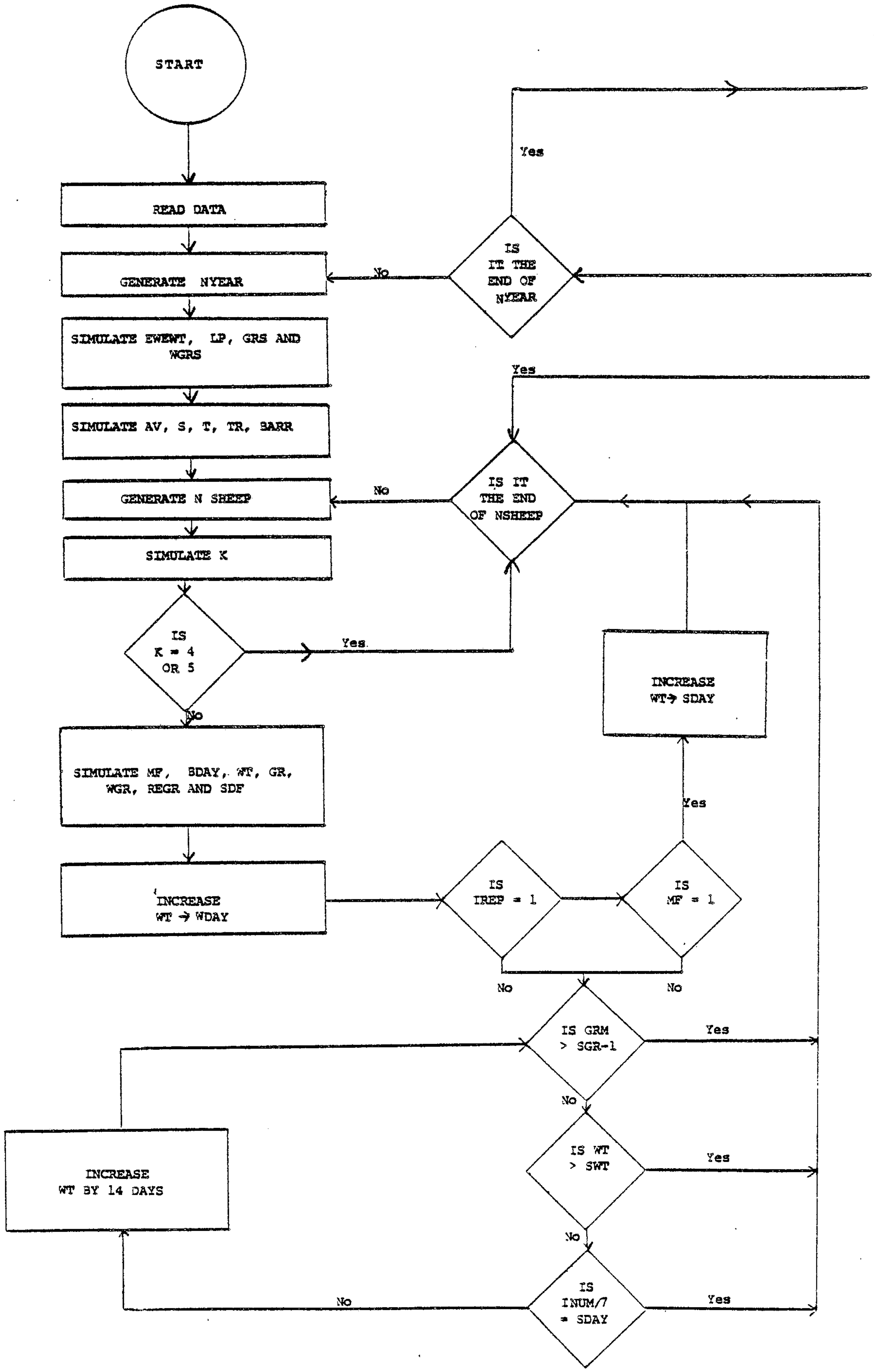
The simulation of lambing percentage and calculation of the probabilities of singles, twins, triplets, dead lambs and barren ewes deserved particular verification. It was important that as lambing percentage rose, the proportion of barren ewes fell and twins and triplets increased. The results of simulation from eight different flock lambing percentages are illustrated in Table 14.

The returns per draft were able to be verified for the simulated weights, carcass grades and specified schedule prices.

TABLE 14

Percentage of Ewes Bearing Singles, Twins, Triplets, or Being Barren, per Flock Lambing Percentage .

Lambing %	Barren Ewes	Singles	Twins	Triplets	Total Ewes
100	9.3	81.5	9.2	-	100
110	7.0	74.85	18.15	-	100
120	5.7	67.6	26.7	-	100
130	5.0	60.2	34.7	0.1	100
140	4.5	52.7	41.2	1.6	100
150	4.2	45.9	45.9	4.0	100
160	3.9	40.1	48.3	7.7	100
170	3.5	35.8	48.0	12.7	100


START
READ DATA
GENERATE NYEAR
SIMULATE EWEWT, LP, GRS AND WGRS
SIMULATE AV, S, T, TR, BARR
GENERATE N SHEEP
SIMULATE K
IS K = 4 OR 5
SIMULATE MF, BDAY, WT, GR, WGR, REGR AND SDF
INCREASE WT → WDAY
IS IT THE END OF NYEAR
IS IT THE END OF NSHEEP
INCREASE WT→ SDAY
IS IREP = 1
IS MF = 1
IS GRM > SGR-1
IS WT > SWT
IS INUM/7 = SDAY
INCREASE WT BY 14 DAYS
Yes
No

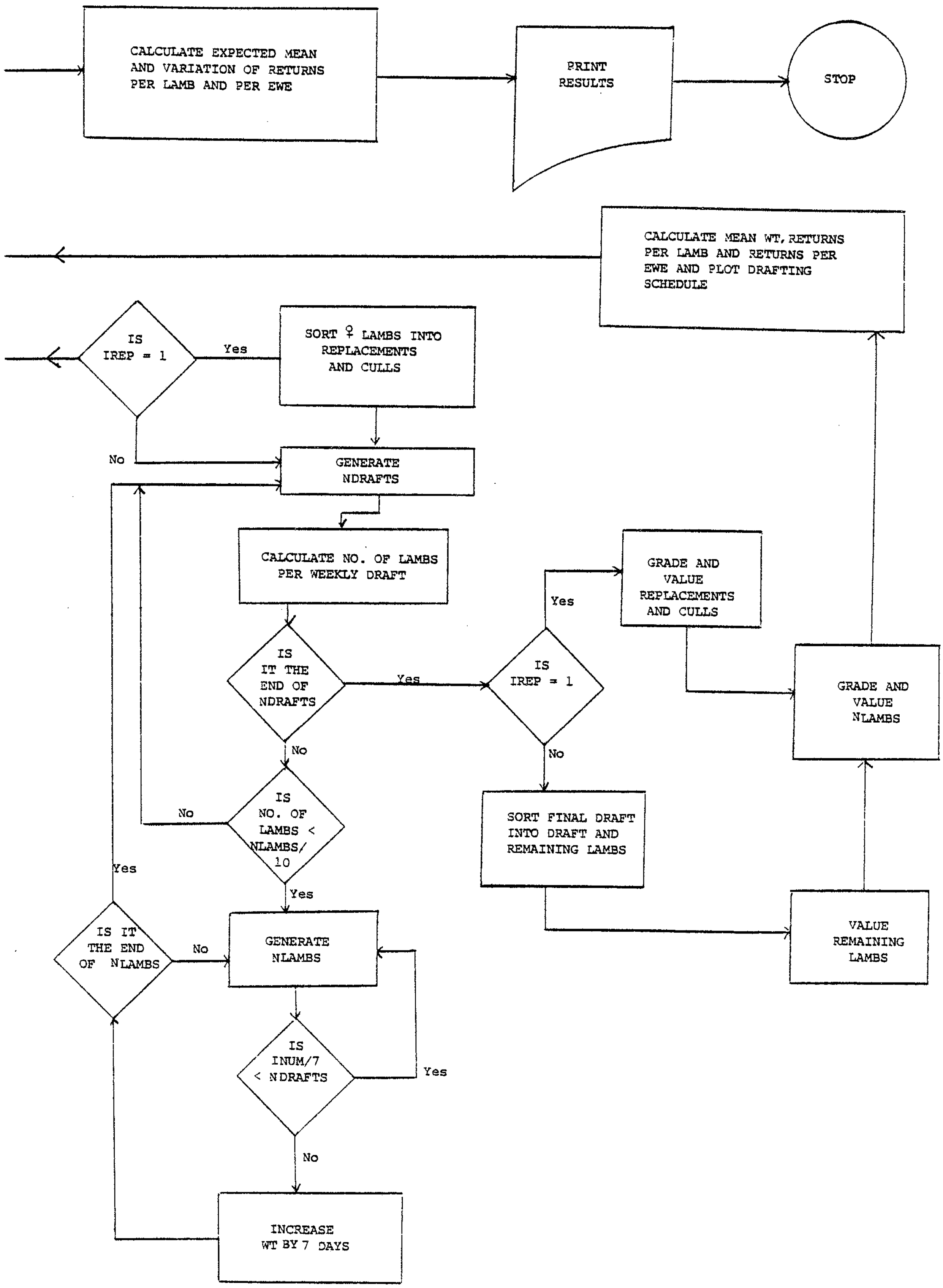


Fig. 11: Flow Diagram of Lamb Drafting Model

CHAPTER 4

VALIDATION

4.1 Introduction

This phase, as the model is assessed in relation to its prescribed use, is a continuing process during which confidence in the model steadily increases through a succession of formal and informal tests (Dent and Blackie, 1979). Up to this phase in model construction the validity of the model is only made probable, not certain, by its underlying assumptions (Reichenbach, 1951).

Dent and Blackie (1979) recommend that a first step to take in validation which provides both a feel for the situation and a basis for further analysis, involves drawing out data in a time series with both the real system and the model output (the average and variation from a number of runs) on the same graph. From this visual presentation it is possible to determine whether the real world data could have come from the simulated distribution of results produced by the model. For the validation of this model it was possible to compare the percentage of lambs drafted through the season in a real system with the mean and variance simulated by the model.

It must be made clear at this point that all variation in model output is the result of environmental and within flock variation alone while variation in the drafting strategies of a real system reflect a number of factors not included in the model. For example, industrial disputes and, possibly, holiday periods, would tend to alter the drafting patterns dictated by pasture supply. Both the quality of management and the managers attitude to risk will also influence 'real' drafting patterns.

'Real' systems data were available for validation from the Winchmore Irrigation Research Station and the Templeton Research Station, both on irrigated land in mid-Canterbury.

4.2 The Winchmore System

The Winchmore Irrigation Research Station provided data from its "S" block ewe flock. These included mean flock tupping weights, mean slaughter weights and dates of its lambs, and the drafting schedules through each season from 1973 to 1981. Since 1975 the system has gradually changed from early lambing, 12 week weaning, Down cross lamb production from Romney ewes to a system of later lambing, 8 week weaning and ewe lamb replacement rearing from Coopworth ewes. The stocking rate is 22 ewes per hectare.

Model and real system output were compared for the slaughter seasons of 1973/74 and 1975/76 to 1980/81. The season of 1974/75 was not used because in the 'real' system the lambs were not all weaned on the same day.

The model was set up to mimic the management strategies practised in each season, as outlined in Table 15, and was run for 50 seasons to produce a distribution of results. As the 'modal' lamb values were not known they were calculated as being those with which the model most accurately simulated a traditional management strategy. They were calculated therefore to suit the 1976/77 and 1977/78 seasons when management involved early lambing and 12 week weaning. By fitting the model output as closely as possible to the real system, under traditional management, the effect of the changes in management, that occurred in later seasons, could be assessed more accurately. The ability of the model to mimic the effect of changes in management from a traditional base, reflects the accuracy with which the conversion factors within the model alter the growth rates.

The values for the 'modal' lamb in the Winchmore system were calculated to be a birth weight of 4 kg and pre and post weaning growth rates of 180 g/day and 130 g/day respectively. Lambs were drafted as they achieved a carcass weight of over 12 kg and before their GR fat measurement exceeded 15 mm.

The mean slaughter weight and draft date (in weeks from weaning) per season are given in Table 16 and the distribution of the cumulative percentage of lambs drafted through the seasons produced by the model is plotted against the real world data in Figure 12. The 'fit' between model and 'real' system data improved as the number of drafts per season increased. However, in 1973/74 when there were only 5 drafts in the season, the mean drafting date of the 'real' system is near that produced by the model. In the seasons up to 1977/78 management strategies varied little although the weaning date in 1976/77 and 1977/78 was two weeks later than in 1973/74 and 1975/76.

In 1978/79 the lambing date in the Winchmore system was two weeks later than the previous seasons and weaning age was reduced by one week to 11 weeks. The calendar date at which 50 per cent of the lambs had been drafted was February 1st in the real system with the mean date of the previous three years being about one week earlier. Reducing the weaning age by one more week in 1979/80 meant that the mean drafting date was delayed by a further 3 days. When the same changes were made to the management strategies in the model the results it produced indicated similar alterations to mean drafting dates.

TABLE 15

Management Strategies in each Winchmore Slaughter Season

	Mean Tupping Weight(kg)	Sire Breed	Replacements Retained	Lambing Date	Mean Weaning (weeks)	Weaning date in 'real'system	Ram Lambs Castrated	No. of weeks from lambing to final draft
1973/74	52.9	Down	No	Early	10	26/11	Yes	28
1975/76	53.7	Down	No	Early	10	26/11	Yes	28
1976/77	56.3	Down	No	Early	12	6/12	Yes	30
1977/78	56.4	Down	No	Early	12	6/12	Yes	26
1978/79	59.2	Down	No	Late	11	11/12	Yes	27
1979/80	60.7	Down	No	Late	10	5/12	Yes	28
1980/81	59.0	Wool	Yes	Late	8	25/11	No	26

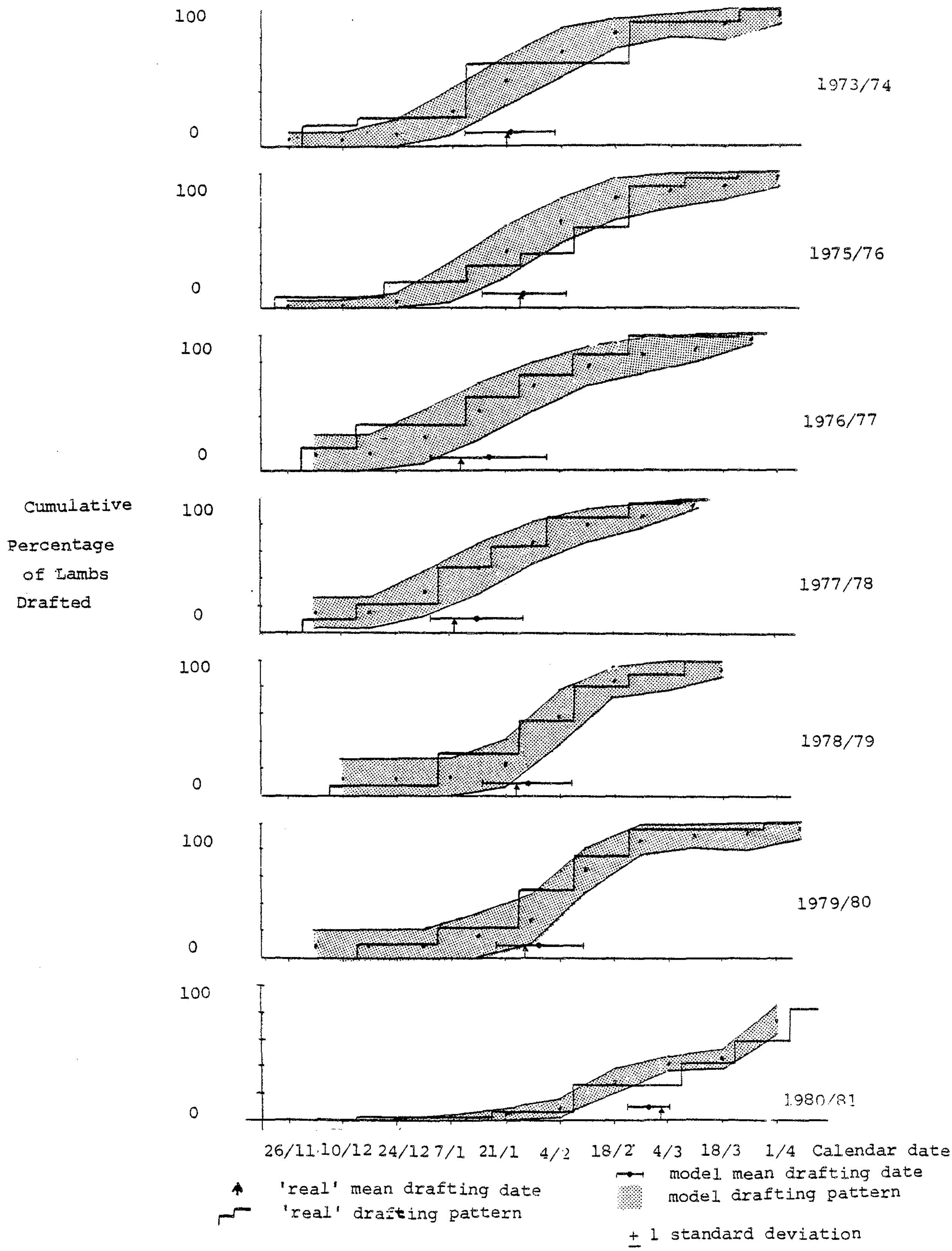


Fig. 12: Cumulative Percentage of Lambs Drafted Through the Seasons - Model and 'Real' System Output Compared.

TABLE 16

Model and Winchmore System Seasonal Output.

Slaughter Seasons	Mean Lamb Slaughter Weight (kg)		Mean Lamb Draft Date - Weeks from weaning	
	Model (standard deviation)	Real	Model (standard deviation)	Real
1973/74	12.47 (0.05)	12.85	9.11 (1.65)	9.0
1975/76	12.46 (0.05)	12.2	9.65 (1.55)	9.5
1976/77	12.50 (0.17)	12.67	7.36 (2.13)	6.3
1977/78	12.46 (0.15)	12.3	6.94 (1.71)	6.1
1978/79	12.82 (0.11)	13.4	7.85 (1.64)	7.4
1979/80	12.77 (0.10)	12.8	9.24 (1.60)	8.7
1980/81	13.6 (0.29)	11.8	14.24 (0.76)	14.7

These results are best understood from an examination of Figure 12 which is so positioned as to allow any vertical line through it to be equal to the same calendar date. For example, by 21/1, it was only in 1973/74, 76/77, and 77/78 that over 50 per cent of lambs had been drafted in the 'real' system, although the model distribution indicates that it is only in the 1980/81 management strategy that there is no probability of drafting 50 per cent by that date.

In 1980/81 only wool breed rams were used over the ewe flock, and replacement ewe lambs were retained for the first time. Ram lambs were not castrated and all ewe lambs were shorn in February. As the model does not allow for the effect of shearing on lamb growth rates it produced heavier mean weights than those recorded in the real system. The replacement ewe lamb's mean live weight produced by the model was 37.35 kg ($\pm$1.84) compared with 33.2 kg in the real system.

At this stage confidence in the model has been increased as it appears that it will adequately mimic the production of light to medium weight lambs under the Winchmore system. The conversion factors relating to lambing date and weaning age changes appear to alter growth rates and thus slaughter weights sufficiently. However, the relatively good fit between the model and the Winchmore data may be indicative of the fact that strategies are possibly better adhered to when part of a research plan, in practice more variation might be expected in a large farm system.

4.3 The Templeton System

The second system is that of an experimental flock at Templeton Research Station, also on irrigated land in mid-Canterbury. The production given was that recorded in the 1980/81 slaughter season. In that year the results pertained to a number of groups within the flock as both down and wool breed sires were used and some of the ewes were mated at a later date than others. Lambs were not drafted throughout the season but a random number were slaughtered at weaning (12 weeks), at 18 weeks and also at 24 weeks of age. Both Romney and Corriedale ewes were put to the down breed sire and just the Corriedale put to the wool breed, a Border Leicester sire. The stocking rate was 18 ewes per hectare.

Slaughter data were available for only the 12 and 24 week slaughter groups for 1980/81. As the model does not differentiate between breeds but allows for heterosis when sire breed is not that of the ewe flock it was assumed that all lambs raised benefitted from cross-breeding so no definition was made between the wool and down sire breed groups.

The 1980/81 season was one of the driest for many years and, even on irrigated land, stock performance was poor. As only one season's data were available it was not possible to establish whether in fact, given 'modal' values from previous years, the model would cater for a year of this type. Instead the 'modal' values were calculated to suit the group of lambs reared under the traditional system in that one year. The 'modal' values were set at a birth weight of 4 kg and pre and post weaning growth rates of 265 g/day and 120g/day respectively. Lambs were weaned at 12 weeks of age and all ram lambs were castrated. Results were calculated for both early and late lambing dates. Between season variation was not necessary as the Templeton data were specific to the one year. Instead the within-flock variation created by the model was presented.

The Templeton data were from relatively small lamb groups, from about 65 in the early lambing group to 35, 23 and 23 in the three later groups respectively. However there were a number of factors measured for each group which was useful for validation. Table 17 presents the average liveweights, carcass weights, GR measurements and returns per group measured in the 'real' system as well as those calculated by the model.

It can be seen in Table 17 that while the model mean liveweights reflect a heavier lamb from delaying the lambing date, in practice, in the 1980/81 season, lamb weights from the later lambing groups failed to better those achieved by the group lambing before mid-September.

This Templeton data can also be used to validate the equations used by the model to calculate carcass weight and fatness. It can be calculated from data in Table 17 that the killing out percentage of lambs killed at weaning (i.e. 12 weeks) would seem to differ between the 'real' and model systems. The equation used by the model for milk lambs:

$$CWT = .461 * SWT + 0.807$$

where CWT = carcass weight (kg)

SWT = slaughter liveweight (kg)

is based on measurements taken at Winchmore by Kirton (pers comm) over a large range of lambs.

The killing out percentages measured at Templeton for lambs slaughtered at weaning were 43, 44, 48 and 44 percent for the early and late lambing groups respectively. Those measured for the 24 week old lambs were 43, 41,42 and 43 percent respectively and compared more favourably with the equation used by the model for lambs slaughtered after weaning :

$$CWT = .405 * SWT + 1.34$$

It is possible that some seasonal variation may occur with respect to those factors most affecting the killing out percentages. Their isolation is necessary before more accurate simulation of the carcass weights of milk-fed lambs can occur. This is particularly important when a specific carcass weight is required e.g. for the Alpha grade light lambs that have to weigh between 7 and 7.5 kg carcass weight to qualify for the premium price currently being offered by some exporting companies. In practice these lambs are drafted by estimations of their carcass weight, based on individual weighings.

Finally, the mean returns per lamb carcass can be compared between model and 'real' system output. Where the carcass weights and G.R. measurements were relatively similar it can be seen that the model calculations, based on the number one schedule structure and the minimum price of the 1980/81 season, were similar to the returns gained in the real system. With the heavier lambs, slaughtered at 24 weeks of age, the returns per lamb are less as carcass weight increases, because of more overfat carcasses.

4.4 Conclusion

While only the Winchmore system provided time series data that could be graphically compared with the model output, both systems allowed comparisons to be made between the mean slaughter weights and draft dates achieved by both the real system and the model under specified management strategies.

TABLE 17

Model and Templeton System Output

		System (Lambing Date)					
		Early Lambing Mobs		Late Lambing Mobs			
		Templeton (9/ 9/81)	Model (Early) (Standard Deviation)	Templeton (16/ 9/81)	Templeton (23/9/81)	Templeton (4/10/81)	Model (Late) (Standard Deviation)
12 week slaughtering	Liveweight (kg)	26.94	26.90 (6.18)	25.36	21.33	26.29	27.04 (6.61)
	Carcass wt. (kg)	11.75	13.21	11.25	10.37	11.75	13.22
	G.R. Measurement(mm)	8.09	8.98 (3.86)	6.70	5.46	6.77	9.06 (4.08)
	Returns/carcass ($)	12.35	13.94	11.61	9.80	12.71	13.89
24 weeks slaughtering	Liveweight (kg)	38.77	38.76 (5.97)	36.40	39.36	36.86	40.75 (6.35)
	Carcass Wt. (kg)	16.84	17.04	15.19	16.74	16.06	17.84
	G.R.Measurement (mm)	11.35	12.47 (3.73)	9.89	11.51	11.19	12.80 (3.94)
	Returns/Carcass ($)	17.05	16.15	16.48	17.80	16.63	16.25

Validation of the model with the Templeton system data was not totally satisfactory as the data are specific to one unusually dry year. However, the within-flock variation simulated by the model seemed to adequately allow for 'real' system eventualities.

While not all 'real' system factors that affect drafting weights and dates can be included in the model it would appear at this stage that enough factors are included to allow the model to adequately mimic the production of lambs under irrigated systems.

CHAPTER 5

SENSITIVITY ANALYSIS

Anderson (1974) describes sensitivity analysis as the testing of the robustness of a model through recognition of its imperfections. It is addressed to learning about the structural soundness of a verified and validated model. It may also direct the modeller back to systems synthesis if, for example, it reveals shortcomings in a particular part of the model (Dent and Blackie, 1979).

One of the areas of concern or uncertainty in the construction of this model was the values for the conversion factors used within the model. While an average value was calculated from all available research data for each conversion factor, it is possible that some subjective weighting of the data may provide more accurate forecasts of lamb growth and development. It was decided therefore to assess the sensitivity of the model projections to alternative values of the conversion factors.

On examination of all the conversion factors used in the model (see Chapter 3) it was decided that not all conversion factors required further analysis. In some circumstances (e.g. sire breed, where it was decided only to allow for the effect of hybrid vigour, or birth ranking and the effect of a lamb's sex on its birthweight) where research results do not differ significantly, further analysis was not deemed necessary.

There are three major groups of conversion factors which relate to lambing date, weaning age and docking policy respectively. All these have an effect on lamb growth rates. There is one other group, relating to docking policy, that affects the relationship between carcass weight and carcass fatness.

Initial sensitivity analysis involved comparisons between outputs from various sets of alternative values of these conversion factors with the model standard for each group. Further analysis examined the sensitivity of the model to specific conversion factors within each group.

Analysis was carried out at two weight ranges (i.e. minimum drafting weights of 12 kg and 14 kg respectively), ewe tupping weight equalled 55 kg and the 'modal' lamb was assumed to be born at 4 kg liveweight and grow at 200 and 150 g/day pre and post weaning respectively. Hybrid vigour was allowed by selecting a down breed sire. Each analysis was for one year only, identical conditions were simulated by using the same random number seed for each. It was decided that the inclusion of environmental variation would increase computing costs unnecessarily. Adequate sensitivity analysis could be carried out from the one year's data. The model was not exposed to conversion factor values outside those reported in the current literature and presented in the tables in Chapter 3.

5.1 Groups of Conversion Factors

The conversion factors within each group were changed subjectively (and therefore, not necessarily proportionately) according to research results. Because of this it was decided to measure the sensitivity of the model projections by calculating the percentage change in output produced by each alternative set of conversion factors. Two key parameters were chosen to represent model response to changes in growth rate factors, the values given to each set being given in Table 18. The two parameters are:-

1. Mean carcass weight (kg)

2. Mean drafting date (weeks from weaning).

5.1.1 Lambing date

Because of the paucity of data available on the effect of lambing date on growth rates these conversion factors were the most uncertain. Sensitivity analysis involved using both the Rattray (1978) and the Geenty (pers com) conversion factors given in Table 4. The results are given in Table 18. The Rattray (1978) set of values has a greater effect on the production of lighter lambs while the Geenty (pers comm) values benefit heavier lamb production by reducing drafting date by over 13 percent.

5.1.2 Weaning age

By subjectively isolating just two research results as being more representative of reality (Jagusch et al (1971) and Geenty (pers com)) and taking the mean of their conversion factors an alternative set of values was devised with which to compare the model standard. The values of the alternative set were greater than the mean values used in the original conversion factors. They caused a 10-13 per cent reduction in drafting date as shown in Table 18. These results relate to an earlier weaning age of 8 weeks.

5.1.3 Docking policy

a) Growth rates

The effect of the sex of a lamb on its growth rates are well documented. An alternative set of values for converting ewe lamb growth rates to ram lambs was devised by excluding the 'Sheeplan' assumptions which differed from other data from the calculation of the mean in Table 7 (Chapter 3). This reduces the value of both conversion factors. The effect of this on lamb weights and draft date would appear to be small.

This is probably because the proportion of lambs affected would also be small (Table 18) since only the single, early ram lambs are kept as entires.

TABLE 18

Sensitivity Analysis of Conversion Factors Affecting Lamb Growth Rates

	Conversion Factors	Percentage Change from Model Standard			
		Mean Carcass Weight %		Mean Drafting Date %	
		Min^m draft wt. 12 kg	14kg	Min^m draft wt. 12kg	14kg
Lambing Date	Geenty (pers com)	+2.15	+1.68	+3.75	-3.75
	Rattray (1978)	-0.30	-1.55	-8.27	-1.50
Weaning Age	Jagusch *et al* (1971) & Geenty (pers com)	+0.87	+0.41	-13.38	-10.5
Docking Policy	Everitt & Jury (1966) & Argue (1980) & Kirton (pers com)	-0.15	-0.21	0	+0.27

b) Carcass fatness calculations

The key parameters chosen to represent model response to changes in carcass fatness factors are:

1. Mean GR measurement (mm)

2. Mean Returns/Lamb ($)

From Table 8 (Chapter 3) it can be seen that there are a number of possible linear regression equation coefficients and intercepts to calculate carcass fatness from carcass weight. One equation from both above and below the mean values was selected for both the ram lambs and the ewe and castrates. The sensitivity of the model to such changes is illustrated in Table 19.

When single, early ram lambs are kept as entires within a flock the mean return of all the lambs is insensitive to the equation used to determine the fatness of the ram lamb carcasses, at both weight ranges. The GR measurement of the ewe and castrate lambs, however, can vary greatly depending on which equation is used for its calculation. This is reflected in the sensitivity of the returns per lamb to the GR measurement.

5.2 Specific Conversion Factor Analysis

It was decided to examine the effect of specific conversion factors within just the two groups that the model appeared to be most sensitive to i.e. lambing date and weaning age. Sensitivity of the model to single parameter changes can be measured from calculations of the elasticity of response (Beck, 1978).

The elasticity E of model response Y to variations in parameter M is given by

$$E = (\Delta Y/Y) \ / \ (\Delta M/M)$$

where Y and M are the standard values and Y and M are the changes induced by sensitivity analysis.

All the results are presented in Table 20.

5.2.1 Lambing date

The three least certain factors relating to a later lambing date are the extent to which:

1. Lamb birthweights are increased

2. Feed quality reduces growth rates for 6 weeks, and

3. Compensatory growth increases growth rates again.

TABLE 19

Sensitivity Analysis of Carcass Fatness Calculation

	Linear regression equation		Percentage Change from Model Standard			
	Coefficient	Intercept	GR measurement %		Mean Returns per lamb %	
			Min^m draft wt. 12kg	14kg	Min^m draft wt. 12kg	14kg
Ewe & Castrate Lambs	1.4	-7.7	+21.16	+20.53	-1.6	-9.8
	0.79	-3.53	-22.02	-23.73	-0.38	+1.03
Standard Values	1.163	-6.455				
Ram Lambs	0.6	-1.3	+ 1.5	+ 1.26	0	0
	0.46	-1.8	- 2.2	- 1.86	0	0
Standard Values	0.54	-1.45				

Each factor (DATEWT, DATEPQ and DATEWG respectively) was individually reduced and increased in value within the bounds of the available data e.g. DATEWG was increased or reduced by only 28 per cent.

5.2.2 Weaning age

Two main areas of uncertainty occurring in data on earlier weaning ages are the extent to which:

1. Pre-weaning growth rates are increased, and

2. Compensatory growth increases growth rates after a post weaning growth check.

Both factors (EARLGR and EARLWR, respectively), were varied within the bounds indicated by the available data.

5.2.3 Summary

The results shown in Table 20 suggest that the model is not highly sensitive to changes in the parameters tested. None of the calculated elasticities was greater than one. At the lighter weight range the model is more sensitive to the six weeks of reduced growth rates caused by later lambing (DATEPQ) and the extent to which compensatory growth affects post-weaning growth rates when lambs are weaned at 8 weeks (EARLWR). The model also appears to be sensitive to a reduction in both the compensatory growth factor relating to later lambing (DATEWG) and the pre-weaning growth rates when weaning at 8 weeks (EARLGR).

For the heavier weight lambs a similar trend is noticeable but with more sensitivity to an increase in both the compensatory growth factor and the increase in lamb birth weights relating to late lambing. The most sensitive model response of 0.903 (for the mean drafting date), indicated that a 4 per cent reduction in the conversion factor that increases pre-weaning growth rates under 8 week weaning, led to a 9.03 per cent increase in the mean time taken to draft the lambs off. Similarly a decrease of 11 per cent in compensatory growth after 8 week weaning will lead to a 7.68 per cent increase in mean drafting date.

5.3 Conclusion

From the single parameter sensitivity tests it is possible to isolate those factors having most effect on model output. Dent and Blackie (1979) suggest that the isolation of such control points, by sensitivity analysis on the model, provides direct guidelines for management. An example from this analysis would be the importance of achieving higher pre-weaning growth rates with early weaning to avoid unnecessary delays in drafting dates.

They also point out that by ranking control points by the degree of sensitivity of model output is a first step in providing priorities for a conventional research programme associated with the system being

TABLE 20

Sensitivity Analysis of Single Value Parameters

	Parameters Tested	Standard Value	Change	Elasticities			
				Mean Carcass Wt.		Mean Drafting Date	
				Min[m] draft wt.		Min[m] draft wt.	
				12 kg	14kg	12kg	14kg
Lambing Date	DATEWT	1.11	+ 21%	-0.006	+0.006	+0.084	-0.595
	DATEPQ	0.635	+20%	+0.031	+0.072	+0.420	-0.273
			-20%	-0.051	-0.134	+0.598	+0.375
	DATEWG	1.69	+28%	+0.014	-0.017	-0.098	-0.405
			-28%	+0.016	-0.026	+0.499	+0.480
Weaning Age	EARLGR	0.041	+ 4%	+0.021	-0.125	+0.0571	+0.084
			- 4%	+0.145	-0.036	+0.485	+0.903
	EARLWR	1.12	+11%	+0.089	+0.032	-0.573	-0.271
			-11%	-0.007	-0.141	+0.635	+0.768

modelled. An example from this analysis would be to rank all compensatory growth factors first, primarily because model output is relatively sensitive to the values given and also because very little data were available upon which to base the conversion factors.

This drafting model, however, goes beyond the assessment of lamb growth rates in that it also attempts to predict the slaughter fatness of each lamb and its return. Analysis showed that the model output (returns per lamb) is relatively sensitive to the equation used to calculate carcass fatness for ewe and castrate lambs. However, it also showed that a greater than 20 per cent increase in GR measurement only affected returns by 1.6 - 9.8 per cent with the greater effect being realized at heavier carcass weights. A reduction in GR of about 20 per cent benefitted the heavier carcass returns by 1.03 per cent but reduced the returns of the lighter carcasses by 0.38 per cent. Here again, because of the sensitivity of model output to the equations used, their accurate estimation could become a priority for a conventional research programme.

Although the model did not appear sensitive to specific conversion factors it was sensitive to the alternative sets of values for lambing date and weaning age subjectively selected from current literature.

CHAPTER 6

EXPERIMENTATION

6.1 Introduction

The development stages of model synthesis have made it possible now to explore alternative management and drafting strategies more confidently. The model is designed to evaluate the returns and the variation about each return from selected strategies. Varying lamb growth rates by imposing different management stratēgies provides a choice of expected returns, with the variation about each return reflecting uncertainty present within each strategy. Where a management strategy results in none of the lambs being drafted until the end of the season and, possibly, none achieving the carcass specifications, then either a different management strategy or reduced target parameters must be input to produce a more realistic drafting schedule. Through this learning process a number of alternative drafting strategies can be outlined and the degree of risk associated with each can be estimated.

There are, in effect, two areas of uncertainty in the lamb production system. These include the expected returns, judged from current prices and trend forecasts and the expected feed supply, controlled by both seasonal variation and management. Drafting priorities must become a balance between these two areas of uncertainty. The model is designed to provide some information to each area. It can be utilised in a variety of approaches to the problem; for example, it could be used to analyse production possibilities under irrigation and vary management strategies to produce drafting schedules most suited to expected feed supply. The relative worth of the alternative practices can then be assessed within the restrictions of the schedule system.

Alternatively, given a certain target return from lamb sales, the model could be used to assess the carcass weight required to achieve such a return. The mean drafting date required to produce that return, and the variation about that date, could then be compared for alternative management strategies, and for varying lamb growth rates.

Experimentation with the model is divided into three sections. The first involves an exploration of alternative management strategies, the second an exploration of alternative drafting strategies. The third involves an example application of model output i.e. an analysis of the effect of changing ewe tupping weights and lamb growth rates on both the returns per lamb and per ewe, and the drafting pattern required, to suit a predetermined feed supply.

Sections 6.2.1 and 6.2.2 below evaluate the effect of change on a light to medium weight and a medium to heavy weight lamb production system, respectively. The former was based on production on the Winchmore Irrigation Research Station's 'S' Block. The latter was based on trials run at the Templeton Research Station (Geenty pers comm). Therefore, initial experimentation was aimed at assessing the relative worth of alternative management and drafting strategies to each of the systems that had been used to validate the model.

For the Winchmore system the mean ewe tupping weight was set at 55 kg and the modal lamb was born at 4 kg and grew at 180 and 130 g/day pre and post weaning respectively. The Templeton system used a tupping weight of 60 kg and modal lamb data of 4.5 kg, 250 and 170 g/day for birth weight, pre and post weaning growth rates respectively.

It was decided to adopt just two management strategies for the analysis. The first, named the 'traditional' system, reflects an early lambing, 12 week weaning strategy and the second, the 'alternative' system a late lambing, 8 week weaning strategy. When replacement ewe lambs are not retained in both strategies it is assumed that a down breed sire has been used. All ram lambs are castrated.

6.2 Exploration of Alternative Management Strategies

6.2.1 Light to medium weight lambs

It was found, in validation using Winchmore data, that the model provides adequate forecasts of lamb growth when ewe tupping weight, sire breed, lambing date and weaning age are all altered within the Winchmore management strategy. However, a change in docking policy in a non-replacement strategy has not been evaluated nor has the effect of alternative combinations of strategies been assessed.

a) Ram lambs

The effect of keeping single, early ram lambs as entires was compared for the two management strategies. Because ram lambs fatten at a heavier weight than ewe and wether lambs it was decided to draft the lambs solely on a fatness basis to permit the production of prime ram lamb carcasses. This also more accurately mimics the method of drafting currently practised. At 12 kg carcass weight it can be calculated from the equations used in the model that ram lambs GR measurement is about 2.5 mm less than ewe and wether lambs while at 8 kg the two groups have a relatively similar GR measurement. Therefore lambs were drafted after they had reached 7 mm GR measurement to equate to an average weight over rams, wethers and ewes of 12 kg, and at 3 mm to equate to a carcass minimum of 8 kg.

From the results presented in Table 21 it can be seen that under the traditional strategy both the mean carcass weight and returns increased when the ram lambs were kept as entires. However, the mean drafting date also increased by about half a week so in practice, the availability of feed will dictate whether a farmer is able to benefit fully from the 50 cents extra per lamb achieved from keeping ram lambs.

TABLE 21

The Effect of Keeping Single, Early Ram Lambs as Entires in the Winchmore System

Winchmore System

	Traditional			Alternative		
	Carcass wt.(kg)	Carcass Return ($)	Drafting Date (wks from weaning)	Carcass wt.(kg)	Carcass Return ($)	Drafting Date(wks from weaning)
Ram Lambs Castrated	11.9 (±0.22)	16.45 (±0.34)	5.65 (±1.42)	12.03 (±0.14)	16.69 (±0.23)	10.56 (±1.70)
Single, early ram lambs left entire	12.26 (±0.24)	16.94 (±0.34)	6.16 (±1.83)	12.39 (±0.15)	17.14 (±0.22)	11.23 (±1.53)

( ) = standard deviation about each mean

Similarly under the alternative strategy returns improved by nearly 50 c per lamb from a 0.36 kg increase in mean carcass weight and the mean drafting date was delayed by just over half a week.

Although ram lambs grow at a faster rate than castrate or ewe lambs they also 'finish' at heavier weights so a slight delay in drafting as evidenced in the model output might be expected.

b) <u>Retaining replacements</u>

During validation of the 1980/81 Winchmore data it was apparent that the minimum draft weight of castrate lambs had to be reduced when ewe lambs were retained for replacement stock, to ensure that 50 per cent of all lambs had been drafted by the same date (19th week from the later lambing date) as in previous seasons.

It must be realised at this point that a farmer aiming to rear replacements has two objectives in mind, firstly to optimise the weight of his ewe lamb replacements and secondly to optimise his returns from the castrate and cull ewe lambs.

When the traditional strategy was compared with the alternative strategy at Winchmore (Table 22) it was the latter that produced the heavier replacement weight and cull lamb returns. Therefore, even though the final draft was two weeks earlier because of the later lambing the compensatory growth produced as a result of both later lambing and early weaning permitted a better overall liveweight increase.

Retaining replacements under the traditional system resulted in lighter weight ewe lambs but heavier castrates since the latter have the benefit of more weeks growth because of earlier lambing and they suffer none of the growth checks associated with early weaning ages or later lambing dates.

The returns per ewe do not differ greatly between the two systems. The long term returns possible from heavier replacement ewe lambs does however make the alternative system, on average, a more attractive strategy.

c) <u>Combinations of Strategies</u>

The 'alternative' stategy involves both a later lambing and an earlier weaning age than practised in the 'traditional' strategy. It was decided to explore the effect of early weaning on an early lambing strategy as well as later weaning on a later lambing strategy, then to permit the alternative docking policy for both combinations. All lambs were drafted at a minimum GR measurement of 7 mm.

Under an early management regime the greatest returns are provided in the strategy of early weaning and keeping early, single ram lambs as entires (Table 23). Later weaning and keeping no ram lambs resulted in the earliest drafting date (allowing for the 4 weeks difference in

TABLE 22

The Effect of Alternative Strategies on Replacement and Slaughter Weights and Returns per Ewe

Strategy	Carcass Weight		Replacement Liveweight (kg)	Returns per Ewe ($)
	Castrates (kg)	Cull Ewe Lambs		
Traditional	10.42	13.14	32.74	18.00
	(±0.47)	(±0.62)	(±1.89)	(±1.21)
Alternative	9.01	13.54	34.04	17.98
	(±0.39)	(±0.64)	(±1.78)	(±1.19)

( ) = standard deviation about each mean

weaning dates) but reduced returns per lamb by over 40c. The combination of early weaning and keeping ram lambs in fact delays the mean drafting date by one and three quarter weeks, by castrating ram lambs this is reduced to one and a quarter. However, the latter combination produced the lightest mean carcass weight possibly because of the four week period of reduced growth rates post weaning. By drafting lambs at this relatively light weight they are unable to utilize compensatory growth so cannot achieve the heavier weights of the later weaning lambs. It must be recalled however that the benefits of early weaning are not only for lamb growth but also to allow better ewe and pasture management.

The combination of later lambing and early weaning reduced mean drafting dates by 3-4 days. If a two weeks delay in lambing date is assumed, there is an actual delay in drafting of about one and a half weeks. The carcass weights, returns and draft dates under a late lambing regime reflect similar trends to alternative management combinations to when lambing at an earlier date.

It would appear from the standard deviations measured in each strategy that, in fact, seasonal variation would at times negate or aggravate the effects of alternative combinations of strategies on lamb drafting dates. This variaton would need to be taken into account by the decision maker when assessing the other criteria affected by the alternative combinations, such as ewe liveweight and pasture management.

6.2.2 Medium to heavy weight lambs

The Templeton system allows more rapid lamb growth and heavier lambs at slaughter. It was validated in one year only and provided adequate forecasts of the effect of varying lambing dates on lamb

TABLE 23

The Effect of Alternative Combinations of Management Strategies on the Expected Mean and Standard Deviation (±) of Lamb Carcass Weight, Carcass Returns and Drafting Date in the Winchmore System

	Early Lambing				Late Lambing			
	8 wk weaning	+ ram lambs	12 wk weaning	+ ram lambs	8 wk weaning	+ ram lambs	12 wk weaning	+ ram lambs
Mean Carcass Wt (kg)	11.82 (±0.08)	12.22 (±0.11)	11.90 (±0.28)	12.20 (±0.24)	12.03 (±0.14)	12.39 (±0.15)	12.11 (±0.20)	12.37 (±0.17)
Mean Carcass Ret.s ($)	16.32 (±0.14)	16.88 (±0.17)	16.46 (±0.43)	16.86 (±0.36)	16.69 (±0.23)	17.14 (±0.22)	16.80 (±0.30)	17.11 (±0.24)
Mean Drafting Date (weeks from weaning)	11.11 (±1.08)	11.66 (±1.09)	5.88 (±2.04)	6.17 (±1.93)	10.56 (±1.70)	11.23 (±1.53)	6.01 ±1.62)	7.01 (±1.77)

performance. As lambs were slaughtered on only two dates, 12 and 24 weeks from lambing a drafting strategy was not available for validation. Analysis was aimed therefore at examining the drafting dates and returns from alternative management strategies.

a) Retaining replacements

When replacements are being retained it is assumed that all ewe lambs remain on the farm until the final draft date. For best comparison with a 'real' system all ram and castrate lambs should be drafted by the mean slaughter date of the non-replacement system. To achieve this the minimum GR measurement for drafting ram and castrate lambs was 8 and 7 mm for the traditional and alternative systems respectively. Although the mean slaughter date of the 'real' system is not known it is presumed that the constraints of pasture quality and quantity would dictate a similar date to that at Winchmore. That is, the 19th week from the late lambing date and the 21st week from the earlier date if a 2 week difference in date is presumed.

Because of pasture constraints the alternative system has only a 24 week slaughter season as compared with 26 weeks for the traditional system. For the same reason the wether lambs had to be drafted at a lighter weight in the alternative system. Because of compensatory growth the ewe lambs in the alternative system are heavier by the end of the season (Table 24).

Although the returns per ewe are greater under the traditional system these returns do not reflect the long term benefit of having heavier replacement ewe lambs to enter the winter. It would seem, also, that there is less variation apparent in the weights achieved under the alternative system although there is more variation in returns per ewe. The latter case is caused by some of the heavier cull ewe lambs being drafted as overfats. In practice this would not occur if such lambs had been sold as breeding stock instead of being slaughtered.

b) Combinations of strategies

Various combinations of lambing date, weaning age and docking policy were explored in the same way as the light to medium weight lamb strategies had been (Table 25). The minimum GR measurement was increased to 12 mm.

Under the early lambing regime the later weaning age produced heavier lambs in less time. Weaning at 8 weeks delayed the mean drafting date by nearly 2 weeks and keeping ram lambs entire delayed drafting almost a further week at both weaning ages. With later lambing the delay in drafting date from earlier weaning was less extreme, only 3-4 days delay. When early single ram lambs are kept as entires the returns per carcass increased by about 70c in each strategy.

As growth rates are higher than those used in the Winchmore system the effect of the conversion factors would be greater. It is possible however that the heavier lambs in this system may have a greater capacity to withstand the checks in growth caused by early weaning so in fact require less severe conversion factors.

TABLE 24

The Effect of Alternative Strategies on Replacement and Slaughter Weights and Returns per Ewe for Medium to Heavy Weight Lambs.

Strategy	Carcass Weight			
	Castrates (kg)	Cull Ewe Lambs (kg)	Replacement Liveweight (kg)	Returns per Ewe ($)
Traditional	13.65 (±0.70)	16.88 (±.04)	43.53 (±2.93)	22.57 (±1.14)
Alternative	12.23 (±0.29)	17.12 (±0.81)	44.13 (±2.23)	21.87 (±1.32)

TABLE 25

The Effect of Combinations of Management Strategies on the Expected Mean and Standard Deviation (±) of Lamb Carcass Weight, Carcass Returns and Drafting Date in the Templeton System.

	Early Lambing				Late Lambing			
	8 wk weaning	+ ram lambs	12 wk weaning	+ ram lambs	8 wk weaning	+ ram lambs	12 wk weaning	+ ram lambs
Mean Carcass Wt. (kg)	15.85 (±0.16)	16.47 (±0.30)	15.90 (±0.28)	16.56 (±0.37)	16.17 (±0.20)	16.95 (±0.31)	16.20 (±0.23)	16.92 (±0.30)
Mean Carcass Ret.s ($)	20.07 (±0.38)	20.75 (±0.32)	20.07 (±0.33)	20.74 (±0.40)	20.28 (±0.29)	20.99 (±0.32)	20.26 (±0.36)	21.0 (±0.30)
Mean Drafting Date (weeks from weaning)	12.31 (±1.35)	13.55 (±1.28)	6.88 (±1.75)	7.60 (±1.75)	11.41 (±1.65)	12.39 (±1.20)	7.07 (±1.48)	7.87 (±1.41)

6.3 Exploration of Alternative Drafting Strategies

6.3.1 Increasing carcass weights

For this analysis it was decided to compare two management strategies for both the Winchmore and Templeton systems to illustrate another potential use of the lamb drafting model. Both systems were used to assess the effect that increasing mean slaughter weight has on the mean drafting date and the expected mean returns per lamb under the three possible schedule price structures outlined in Chapter 3.

Slaughter weight was increased by raising the minimum GR measurement from 3 to 15 mm in five steps. The results are illustrated graphically for both strategies in the Winchmore (Figure 13) and the Templeton (Figure 14) systems. The expected weights, drafting dates and returns under schedule structure number 1 are given in Tables 26 and 27.

In both systems the effect of compensatory growth, under the alternative management strategy, seen as the difference between its mean drafting dates and those of the traditional strategy, becomes less as mean carcass weights incease. Under the Winchmore system the mean drafting date (after allowing for the 4 week difference in weaning age) is equated when the mean carcass weight reaches 13 kg, in the Templeton system this equality of date is reached at a mean carcass weight of 16 kg.

The variation about the mean drafting date is shown to increase as mean carcass weight is raised, then to decrease as the constraint of slaughter season length comes into effect.

For example, in the Winchmore system when the minimum GR measurement was set at 15 mm there were few lambs above that level before the end of the season, therefore, the mean drafting date was dictated more by the end of the season than by when the required carcass type was drafted. With the Templeton system this was not as obvious as higher growth rates permitted more lambs to reach the required carcass fatness.

The increase in variation about the mean drafting date is the result of the compounding effect of low or high growth rates throughout a slaughter season. A decision maker must, therefore, not only assess the variation in expected return at a certain mean carcass weight but also acknowledge the degree to which seasonality will vary the mean drafting date.

The three schedule structures used by the model to assess the possible variation in returns are merely representative schedules based on historical data. They do serve, however, to highlight the effect of increasing carcass weights on expected returns, especially in the Templeton system. The financial disincentive provided by the schedule structures of producing heavy weight lambs is aggravated by the risk of producing overfat lambs at such weights. This could be reduced, however, by retaining some of the ram lambs as entires.

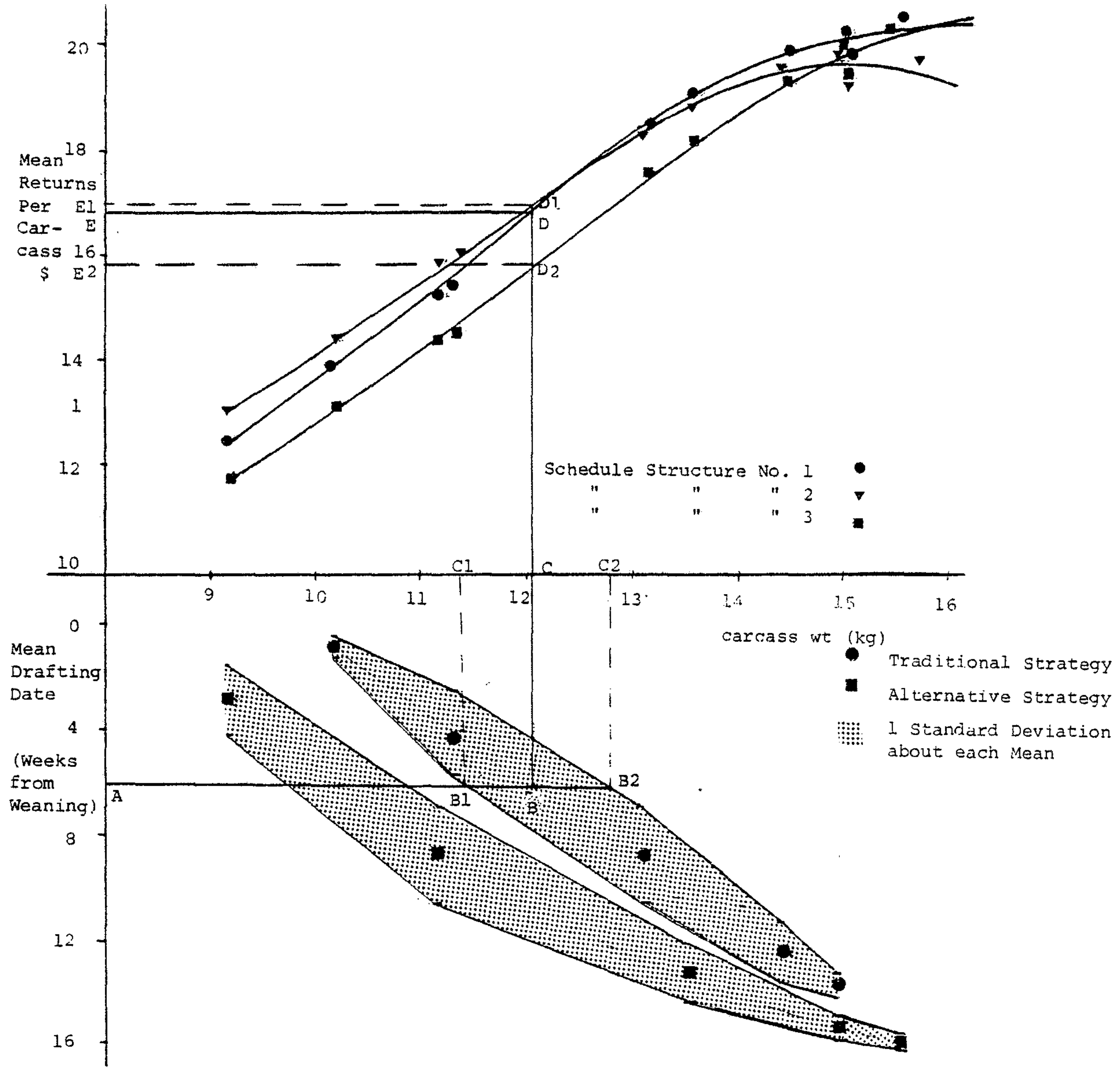


Fig. 13: Exploration of Drafting and Management Strategies in the Winchmore System

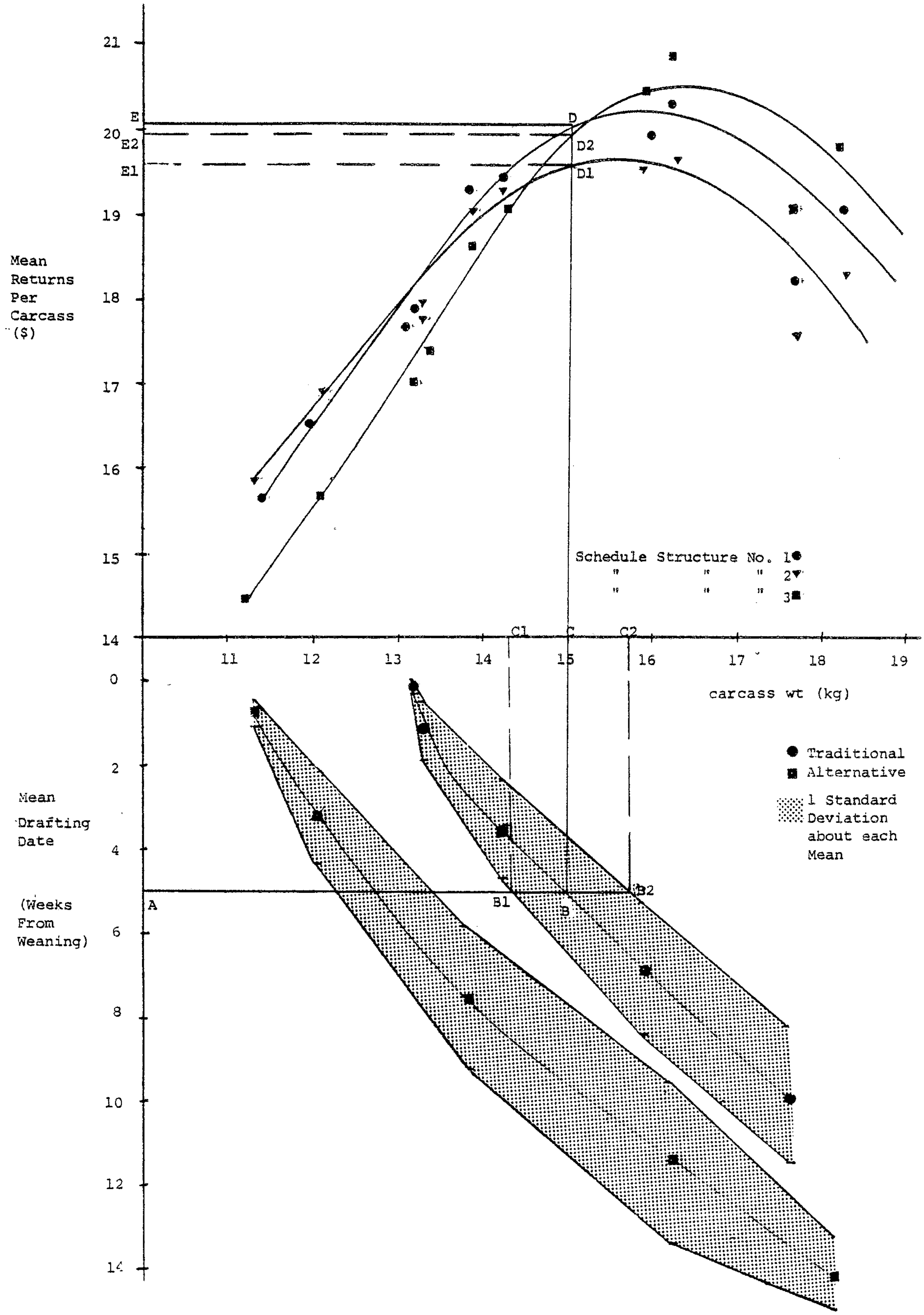


Fig. 14: Exploration of Drafting and Management Strategies in the Templeton System

TABLE 26

Winchmore System - Exploration of Drafting Strategies

Minimum GR Measurement mm	Traditional			Alternative and Ram Lambs		
	Carcass Weight (kg)	Carcass Returns ($)	Drafting Date (wks from weaning)	Carcass Weight (kg)	Carcass Returns ($)	Drafting Date (wks from weaning)
3	10.15 (±0.75)	13.92 (±1.09)	0.83 (±0.50)	9.18 (±0.46)	12.52 (±0.65)	2.96 (±1.34)
6	11.26 (±0.31)	15.45 (±0.47)	4.48 (±1.55)	11.14 (±0.15)	15.28 (±0.23)	8.48 (±1.97)
9	13.13 (±0.23)	18.56 (±0.35)	8.80 (±1.81)	13.55 (±0.15)	19.09 (±0.22)	13.25 (±0.99)
12	14.49 (±0.52)	19.92 (±0.47)	12.30 (±1.12)	15.00 (±0.39)	20.37 (±0.29)	15.25 (±0.42)
15	15.05 (±0.75)	19.88 (±0.44)	13.63 (±0.32)	15.57 (±0.60)	20.58 (±0.33)	15.86 (±0.11)

TABLE 27

Templeton System - Exploration of Drafting Strategies

Minimum GR Measurement mm	Traditional			Alternative		
	Carcass Weight (kg)	Carcass Returns ($)	Drafting Date (wks from weaning)	Carcass Weight (kg)	Carcass Returns ($)	Drafting Date (wks from weaning)
3	13.04 (±1.07)	17.63 (±1.12)	0.17 (±0.13)	11.39 (±0.86)	15.65 (±1.15)	0.77 (±0.33)
6	13.17 (±1.02)	17.88 (±0.99)	1.18 (±0.70)	11.97 (±0.52)	16.50 (±0.75)	3.26 (±1.13)
9	14.2 (±0.62)	19.43 (±0.31)	3.72 (±1.61)	13.80 (±0.22)	19.28 (±0.24)	7.59 (±1.97)
12	15.97 (±0.38)	19.93 (±0.37)	6.54 (±1.64)	16.18 (±0.17)	20.30 (±0.40)	11.44 (±1.90)
15	17.71 (±0.29)	17.8 (±0.92)	9.71 (±1.52)	18.20 (±0.28)	19.03 (±0.93)	14.03 (±0.88)

In practice, it is the current schedule structure or a forecast structure that will dictate whether mean carcass weights can be further increased. As can be seen in Figures 13 and 14 there is less overall variation in expected returns under the three probable schedule structures when carcasses are in the weight range of 13.5 - 14.5 kg. This is because at these weights more of the lambs would be qualifying for the benchmark grade (PM) price which does not change between structures. At weights above or below this range, the variation in expected returns increases because of the uncertainty of the non-benchmark grade prices. However, it is not always feasible to achieve 13.5 - 14.5 kg mean carcass weights because the drafting pattern required may not always match the pattern of feed supply. For example, in the Winchmore system an increase of mean carcass weight from 12.5 kg to 13.5 kg would result in a benefit of approximately $1.50 per lamb but a delay in mean drafting date of nearly 3 weeks.

A further example of this is illustrated in Figures 13 and 14. Following the example for Figure 14, if a producer decides that he wants 50 per cent of his lambs drafted by a certain date, e.g. 5 weeks after weaning under the traditional management strategy, then it is possible to draw line A-B, then line B-C, to get an estimate of his mean carcass weight (15 kg). If he has a below average season of pasture growth his mean carcass weight could be reduced to 14.3 kg (C1); an above average season could result in a 15.6 kg carcass (C2). Obviously, in practice, the season should dictate the mean drafting date but there are examples cited in which both tradition and other unrelated factors tend to regiment drafting date e.g. the wish to get one draft away before Christmas: the model does not allow for Christmas.

The expected mean return ($20.10) per lamb is found from line C-D which is drawn to the line of the returns calculated from schedule structure No. 1. The possible variation, D->D1 and D->D2, taking into consideration other possible structures is $0.50.

6.4 An Example Application of the Lamb Drafting Model

The drafting model can be used to produce a number of drafting strategies from which feed demand profiles can be calculated. These can then be assessed by determining which strategy best suits the feed supply profile.

It was decided to use the model to evaluate, for a number of management systems under the same feed supply profile, both drafting strategies and the expected returns per hectare and per stock unit (Hayman and Shadbolt, 1982).

The management systems investigated involved "average" and "high" fertility ewes being run at three stocking rates. These treatments allowed the effect of an increase in lambing percentage, with associated higher lamb deaths and lower average birth weights and growth rates, to be compared for different stocking rates.

Hayman and Shadbolt (1982) made the initial assumption that both ewe liveweights at tupping and lamb performance decrease as stocking rates increased. The stocking rates and assumptions used are given in Table 28; lamb performance was reflected in the 'modal' values used at each stocking rate,

i.e. a) birth weights were 4.0, 4.3 and 4.5 kg.

b) pre-weaning growth rates were 200, 225 and 250 g/day,

for the 24, 21 and 18 s.u./ha flocks respectively. Two post weaning growth rates were used at each stocking rate; 170 g/day and 130 g/day, the latter used to reflect an 'ill thrift' condition in weaned lambs.

Replacement ewe lambs were retained so the feed demand calculations also included hoggets. Lambing began in early September and the weaning age was 10 weeks. All ram lambs were castrated and lambs were drafted as they reached a specified carcass fatness.

Feed demand profiles were calculated for the ewes, hoggets and lambs for each management system (Appendix V) with the number of lambs present through the slaughter season being dictated by the drafting patterns produced by the model. The feed supply profile consisted solely of pasture production and was based on the adaptation of Winchmore Irrigation Research Station data, presented in Appendices II and III. It is apparent from these profiles of feed demand and supply for both 24 s.u./ha and 18 s.u./ha that, while winter feed supply constrains sheep numbers, an improvement in lambing percentage makes better use of feed available in the summer. Because of the surplus feed in December and January the first lamb draft was delayed until late January in each management system. The final draft was in mid-March, to ensure adequate feed for flushing the ewes.

The effect of changing stocking rate, ewe fertility and lamb performance on the weight of both meat and wool produced per hectare (Table 29) is illustrated in Figure 15. Relativity between prices of wool and meat will dictate the extent to which benefit can be gained from increasing stocking rates.

Finally, the returns per hectare and per s.u. are calculated for each management system. The gross margin analyses are given in Appendices VI to VIII. A summary of the results is presented in Table 29 and these are also illustrated in Figure 15.

At the 1980/81 season product prices it would appear to be profitable to decrease stock numbers if the decrease is concurrent with an increase in performance. Increases in ewe fertility alone achieved net benefits of \$19-\$52 above the \$556-\$642 per hectare achieved by average fertility ewe flocks.

Decreases in stocking rate produced net benefits of \$34-\$52 per hectare under average ewe fertility and \$58-\$61 per hectare at higher ewe fertility.

When the 'modal' lamb's post weaning growth rate is reduced to 130 g/day, in 'ill thrift' situations with average ewe fertility, the gross

TABLE 28

Assumptions of Production for Three Stocking Rates

	Stocking Rate/ha								
	24			21			18		
Ewes/100 ha	2000			1750			1500		
Hoggets/ 100 ha	500			438			375		
Rams/100 ha	23			20			17		
Ewe tupping wt (kg)	50			60			70		
Death Rate (%)	4			4			4		
Cull Ewes Sold/100ha	420			368			315		
Wool Weights (kg)									
per ram	5.0			5.5			6.0		
" ewe	4.5			5.0			5.5		
" hogget	3.5			3.6			3.7		
" ewe lamb	1.1			1.2			1.3		
*Lambing Percentage	Av. Fertility		High Fertility	Av. Fertility		High Fertility	Av. Fertility		High Fertility
at lambing	117		133	140		165	163		203
at sale	105		120	127		150	147		180
*Ewe Lambs Retained									
% of ewe no.	25		25	25		25	25		25
% of lamb nos.	23.8		20.8	19.7		16.7	17.0		13.9
*Slaughter Weight (kg)		'Ill thrift'			'Ill thrift'			'Ill thrift'	
Wether lambs	14.08	12.89	13.14	14.18	13.04	12.86	15.10	13.95	13.35
Cull lambs	13.93	12.50	13.89	14.4	12.87	14.22	14.73	13.46	14.62
*Carcass Value ($)									
Wether Lambs	19.74	18.18	18.55	19.85	18.43	18.03	20.40	19.54	18.80
Cull Ewe Lambs	19.32	17.37	19.29	19.85	17.93	19.68	20.19	18.66	20.01
Wool Pull/Carcass (kg)									
Wether Lambs	1.1	0.9	1.0	1.1	1.0	0.9	1.3	1.1	1.0
Cull Ewe Lambs	1.1	0.8	1.05	1.2	0.9	1.15	1.3	1.0	1.25

* = calculated by the lamb drafting model

TABLE 29

Summary of Production and Gross Margin Analyses for Three Stocking Rates.

Stocking Rate	Ewe Weight (kg)		Meat kg/ha	Wool kg/ha	Gross $/s.u.	Margin $/ha
24	50	high fertility	254.91	133.50	23.77	575
	50	av. "	224.46	131.75	23.01	556
	50	'ill thrift'	204.10	130.64	21.51	520
21	60	high fertility	279.18	131.49	30.06	636
	60	av. "	242.48	129.93	28.74	608
	60	'ill thrift'	220.59	128.78	26.98	571
18	70	high fertility	322.77	127.96	38.27	694
	70	av. "	273.64	126.06	35.39	642
	70	'ill thrift'	251.73	125.83	33.24	604

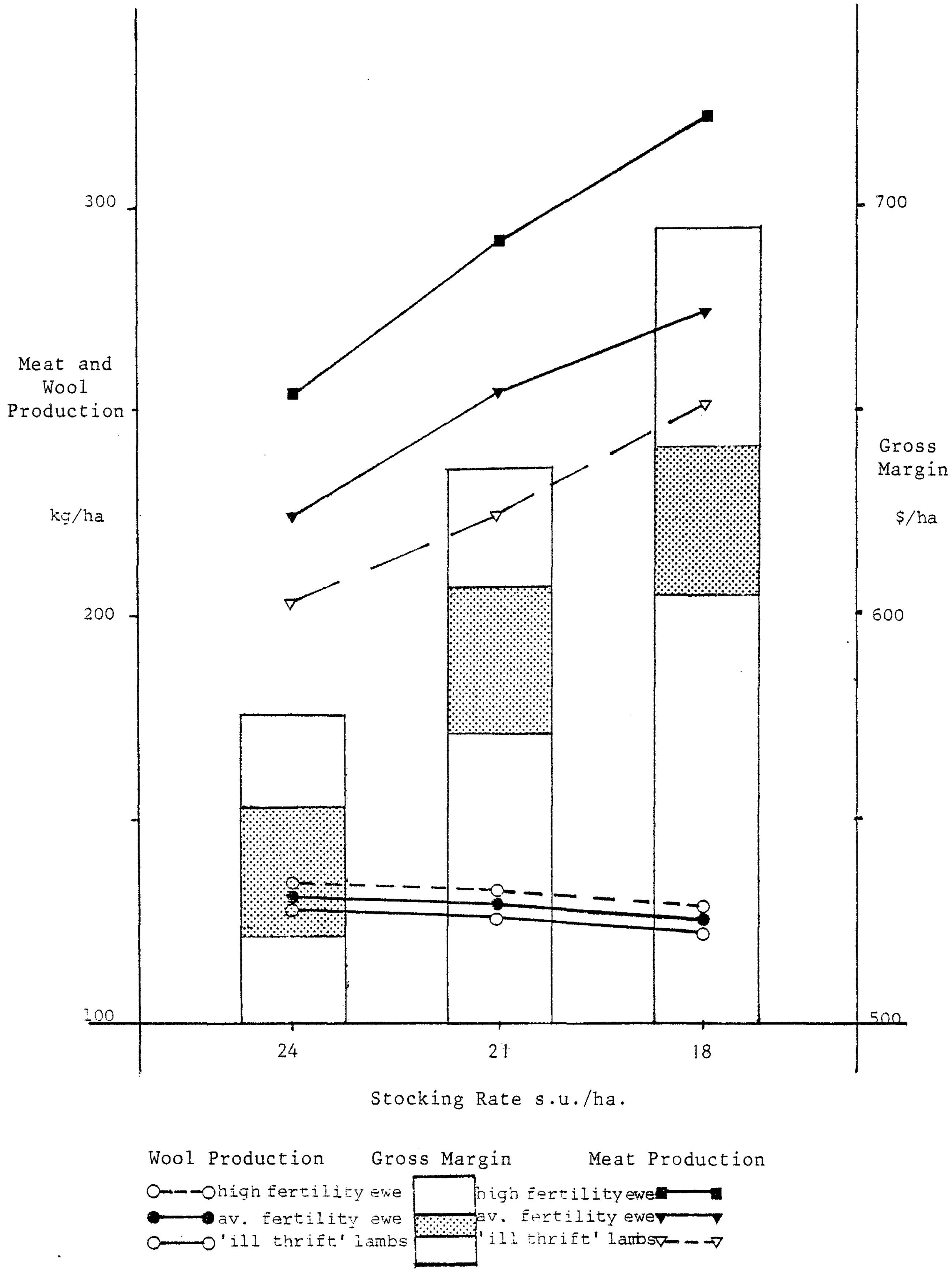


Fig. 15: Meat and Wool Production and Gross Margins Per Hectare at Three Stocking Rates and Three Levels of Productivity

margins per hectare are reduced by 36, 37 and 38 dollars for stocking rates of 24, 21 and 18 s.u./ha respectively.

6.4.1 Decreasing stock numbers

While it has been shown to be profitable to decrease stock numbers, if stock performance improves, such improvements may not always be the case. The extent to which decreases in both meat and wool production and, therefore, gross margins, per hectare occur when stock numbers are reduced and performance remains constant can be seen from further analysis (Appendix X and Figure 16). For example, the difference in returns between a 50 kg average fertility flock at 18 s.u./ha and 24 s.u. is $124 per hectare. Similarly a 60 kg average fertility flock returns $74 per hectare less at 18 s.u./ha than at 21 s.u./ha. At the lower stocking rate the total feed requirement per hectare is less for the 50 and 60 kg ewe flock than at the higher stocking rate so the additional feed costs present with the higher stocking rate were excluded from these gross margin analyses. Even so, gross margins per hectare reflect no profit from decreasing stocking rates if performance is not improved at the same time.

6.4.2 Costs and returns of delaying the final draft

For the situation in which lambs are showing 'ill thrift' in their post-weaning growth rates the slaughter season ends before they are able to achieve reasonable carcass weights. To achieve greater weights the season was extended by 4 weeks to give a last draft date of 15th April. The model output of slaughter weights and carcass values plus the calculated gross margins are presented for each stocking rate in Table 30.

TABLE 30

Productivity and Gross Margin Analyses for Delaying the Final Draft at Three Stocking Rates with Ewes of Average Fertility and 'Ill Thrift' Lambs.

Stocking Rate		Slaughter Weight (kg)		Carcass Value ($)		Gross Margin ($)	
		wethers	cull ewe lambs	wethers	cull ewe lambs	/s.u.	/ha
24		13.24	14.13	18.75	19.52	22.98	556
21	*	13.33	14.46	18.87	19.77	28.29	594
18	*	14.38	15.17	19.95	20.37	34.63	629

* assumes an increase in performance with a reduction in stocking rate.

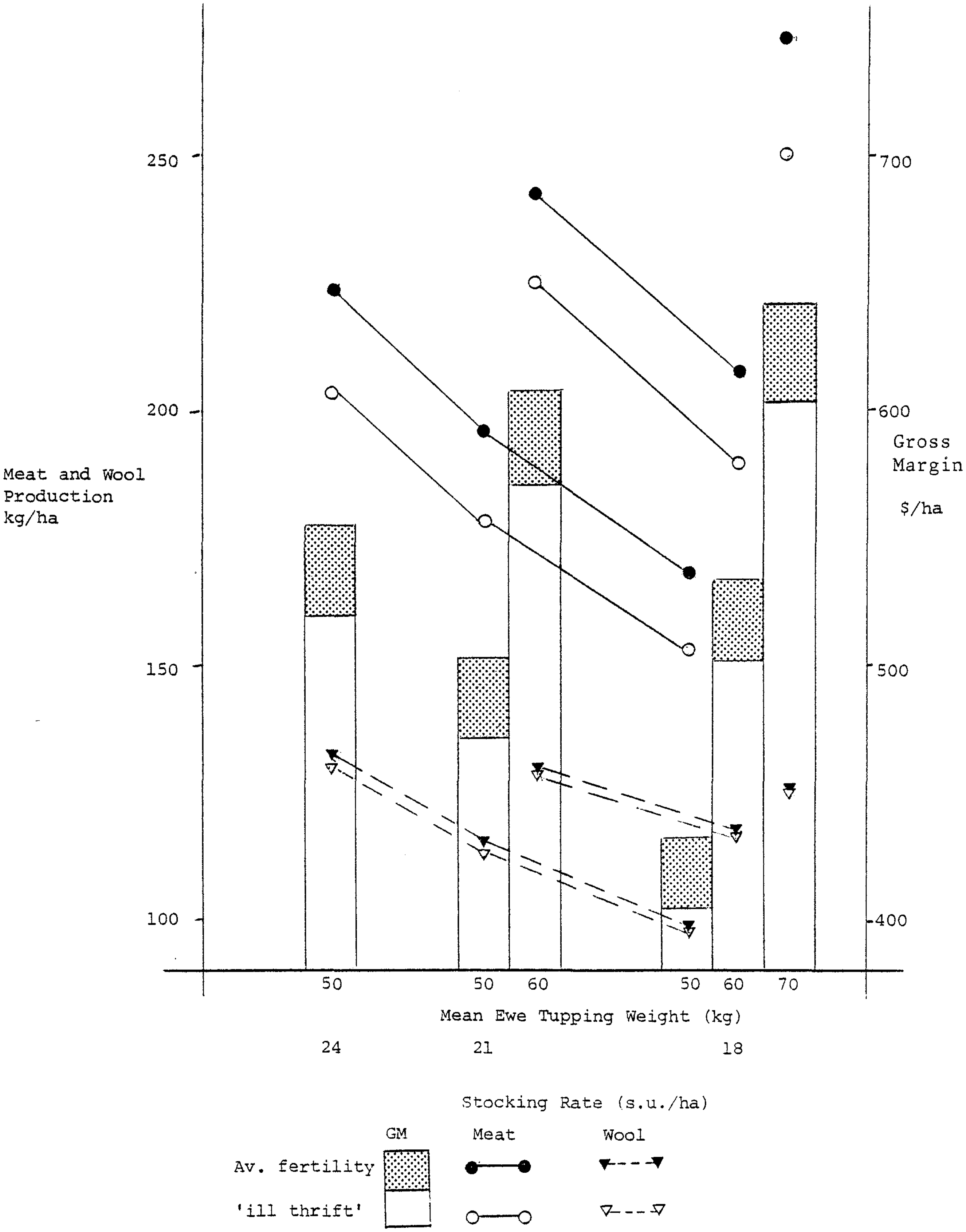


Fig. 16: Meat and Wool Production and Gross Margins Per Hectare At Three Stocking Rates At Constant Performance Levels.

The gross benefits per hectare of delaying the final draft are $36 $23 and $25 for the 24, 21 and 18 s.u./ha stocking rates respectively. However, by delaying the final draft into the tupping period a feed deficit situation is created as demand exceeds supply. Therefore, an alternative feed source must be provided and its cost taken from the calculated net benefits.

Two alternative feeds were examined; fodder rape and barley. The latter feed can be fed to the ewes and is an alternative that might suit a border-dyke irrigation farmer who is unwilling to plough up permanent pastures. The former is assumed to be grown as part of the rotation in a mixed cropping and sheep farm, typical of the spray irrigation farms of Canterbury.

The additional feed requirements are calculated based on the assumption that 21 percent of saleable lambs are present in the 4 weeks from mid-March to mid-April for the three stocking rates. This figure was produced by the drafting model. Under the lowest stocking rate, lambing percentage is highest, as is the proportion of twins and triplets. Thus drafting is not necessarily any more rapid than that at higher stocking rates and lower lambing percentages. The total number of lambs finished under the three stocking rates (24,21 and 18 s.u./ha) was 1600,1785 and 1830 respectively per 100ha. It was assumed that each lamb required 15 MJ ME/ha/day so the requirements for 28 days were 5040, 5300 and 5985 MJ ME/ha for the 24, 21 and 18 s.u./ha stocking rates respectively.

Fodder rape if yielding 5 t DM/ha (Douglas, 1980) with an energy value of 12 MJ ME/kg DM, provides a total MJ ME/ha of 60,000. If a 95 per cent utilization is assumed this equates to a feed supply of 57,000 MJ ME/ha. To fulfill the lamb demand per hectare 0.088, 0.093 and 0.105 hectares of rape would be required at the three respective stocking rates. The approximate costs of growing fodder rape are:-

2 kg seed @ $3/kg	=	6.00
0.125 t super @ $120/t	=	15.00
4 hrs cultivation @ $9/hr	=	36.00
Total Cost	=	$57.00 /ha

The costs of re-establishing pasture are:-

Seed	=$	60.00
.375 t super @ $120/t	=	45.00
4 hrs cultivation @ $9/hr	=	36.00
		$141.00/ ha

The costs of providing the additional feed requirements with fodder rape will be $5.02, 5.3 and 5.99 per hectare for the 24, 21 and 18 s.u./ha respectively. Re-establishing pasture increases the costs per hectare to $17, $18 and $21 which reduces the gross margins per hectare to $539, $576 and $608 for the 24, 21 and 18 s.u./ha stocking rates respectively. The benefits per hectare of delaying the final draft, after taking into account these costs, is reduced to $19, 5 and 4 for the 24, 21 and 18 s.u./ha stocking rates respectively.

However, if the MJ ME/ha requirements for the 28 days were met by feeding barley to the ewes, the costs negate the benefits at all stocking rates. The required MJ ME/ha over the 28 days equates to 403.2, 424 and 478.8 kg DM/ha of barley for the respective stocking rates if an energy value of 12.5 MJ ME/kg DM is assumed. The requirement (kg/ha) of barley, assuming an 85 percent DM, is 474, 499 and 563 kg barley per hectare at the 24, 21 and 18 s.u./ha stocking rates respectively. With feed barley costing approximately $200/t the cost per hectare of providing barley to the ewes to allow for a delayed final draft date is $95, 100, 113 per hectare for the respective stocking rates.

6.4.3 Risk analysis of alternative management strategies

Because the analyses were replicated over 50 continuous seasons, the results included not only the expected mean value per carcass, but also the variation about that mean. The final stage in this example application of the model therefore involves calculating the variation caused by carcass returns about each gross margin per hectare, for the eighteen management strategies that have been analysed.

The results are plotted as an E,V graph (Figure 17) from which an assessment of the dominant strategies can be made. The strategies can be divided into performance groups with respect to the mean ewe weight at tupping and each strategy is numbered:-

No. 1 = high fertility flock (50, 60 and 70 kg ewes)

2 = average " " " " " "

3 = 'ill thrift' flock " " " "

4 = " " " with a delayed final draft date and fed fodder rape (50, 60 and 70 kg ewes)

5 = average fertility flock with 3 s.u. less per hectare (50 and 60 kg ewes)

6 = 'ill thrift' flock with 3 s.u. less per hectare (50 and 60 kg ewes)

7 = average fertility flock with 6 s.u. less per hectare (50 kg ewes)

8 = 'ill thrift' flock with 6 s.u. less per hectare (50 kg ewes)

It must be emphasized at this point that the seasonal variation

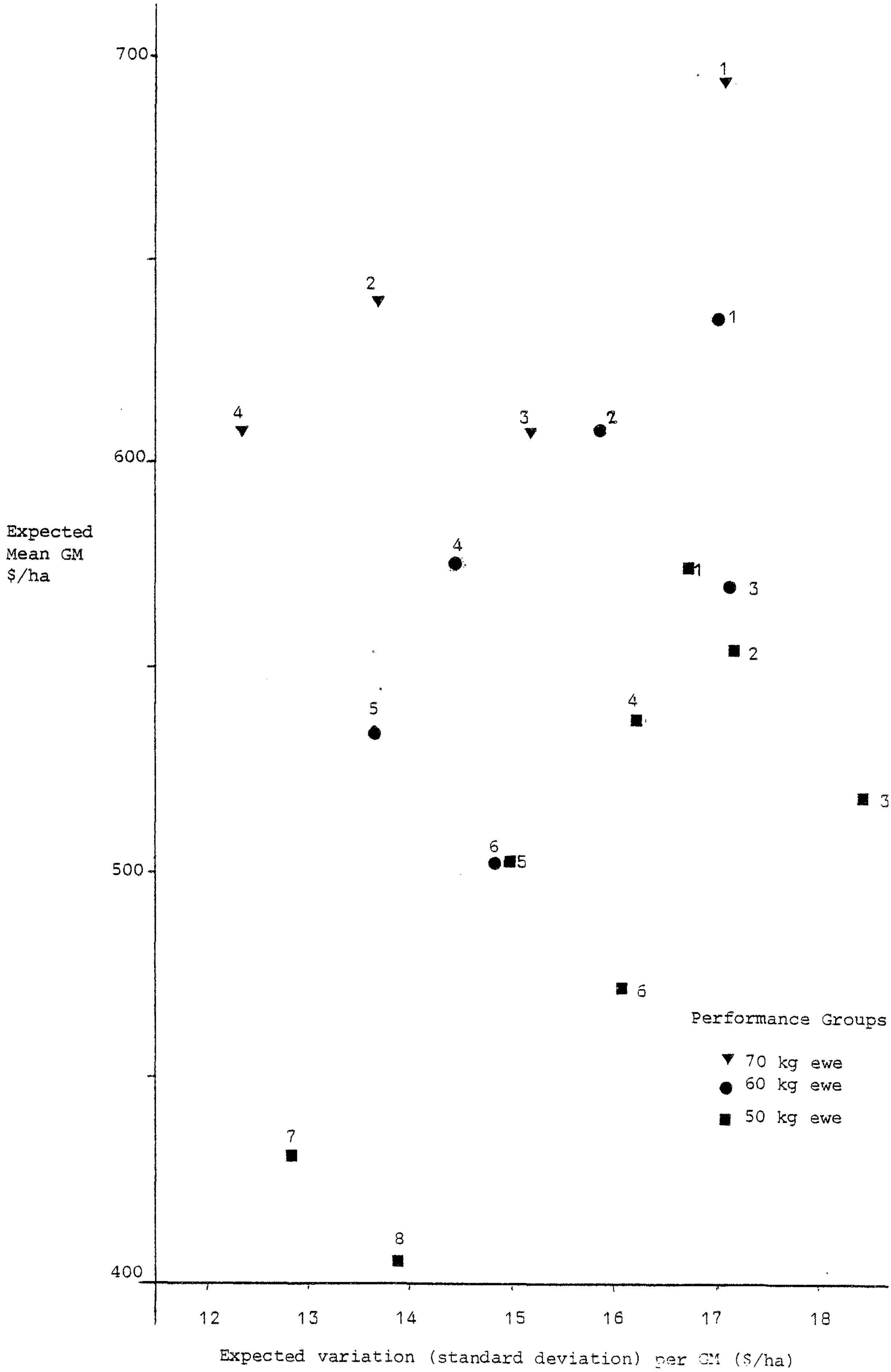


Fig. 17: E, V Performance Under 18 Management Strategies

described relates only to carcass returns and, as such, is likely to be an underestimate since lamb growth rates are likely to be positively correlated with wool weights with an even greater variation in total gross margins.

Because the variations described are only partial it is not possible to isolate strategies which are definitely risk efficient. It is possible however, to examine specific strategies with respect to their profitability or riskiness.

The effect of 'ill thrift' on the variability in returns is an interesting example. In all situations if a comparison is made between the average fertility flocks (nos. 2, 5 and 7) and their 'ill thrift' counterparts (nos. 3, 6 and 8), a noticeable drop in expected returns is coincident with an increase in the variation about such returns. The increase in variation is due to the fact that fewer lambs reach the required carcass weight by the final draft date; more are sold as unfinished lambs. By delaying the final draft date by 4 weeks, this variation is reduced considerably (from no. 3 to no. 4) as the lambs are able to 'finish' within the slaughter season. The slight increase in returns is dependent on the price of the feed required to permit such a delay; if barley replaced fodder rape and pasture in the gross margin there would be a significant decrease in the expected means between strategies no. 3 and no. 4.

The effect of decreasing stocking rate without improving performance is also illustrated in Figure 17. For example, if a comparison is made between strategies 2, 5 and 7 for the 50 and 60 kg ewe performance groups, both would show a similar trend i.e. a sharp decrease in expected mean with a corresponding decrease in variation. The least risky strategy, excluding the delayed drafting strategies, is that of a 50 kg ewe performance group of average flock fertility stocked at 18 s.u./ha. However, it also has one of the lowest expected returns. If it were possible to improve the performance of that flock without altering stocking rates, to that of a high fertility 70kg ewe flock it would be possible to increase expected returns to the highest value illustrated. However, because of the number of lambs produced, the variation in returns would also become the highest.

The actual management strategy chosen by a decision maker will depend on his attitude to risk so optimum strategies cannot be isolated from the E,V analysis. Instead it illustrates why, for example, an extremely risk averse farmer might decide to opt for a low stocking rate for his low producing ewe flock, and also why a farmer, with high producing ewes, may opt for a lower stocking rate and maintain ewe performance.

6.5 Conclusion

Experimentation with the lamb drafting model has allowed some assessment to be made of the expected risks and returns from a number of management and drafting strategies. It was found that alternative management strategies have a significant impact on the time required to 'finish' lambs. Whether that effect is detrimental or of benefit depends on the weight at which lambs are drafted. For example, under a management strategy that causes a check in growth after weaning followed by compensatory growth, benefits did not accrue from drafting lambs too light as such lambs were unable to fully benefit from compensatory growth. However, such a strategy appears particularly well suited to a system of rearing replacements where future breeding stock are able to benefit fully from the compensatory growth.

The uncertain effect of the environment on feed supply and thus lamb growth rates became more apparent as the drafting season progressed. Therefore, delaying the drafting date increased the variation in mean carcass weight. Conversely, by increasing the minimum carcass weight or fatness at drafting, the mean drafting date becomes less certain. However, as carcass weights increase and more lambs achieve the benchmark grade weight (13-16 kg) the expected variation in returns per lamb decreased. Drafting priorities, therefore, are a balance or "trade-off" between economic and seasonal uncertainties within the drafting system.

In the example application of the model the importance of both ewe fertility and lamb performance were assessed at various stocking rates. While the variation in returns per hectare could be calculated from the returns for meat only, they were able to provide some indication as to the degree of economic risk associated with alternative stocking rates and performance levels.

Personal preference and individual attitudes to risk will often determine both the management and drafting strategies selected by a decision maker. However, it is useful to explore the alternatives open to him, as well as the inter-relationships between them, and to provide him also with an assessment of the expected uncertainty associated with each option to enable him to make the best possible decision to suit his circumstances.

CHAPTER 7

CONCLUSIONS

The objective of this study was to determine the potential for farmers on irrigated Canterbury farms to vary the turn-off times for lambs. The working hypothesis associated with this objective was that the adoption of management strategies appropriate to an irrigated system would facilitate some extension of the drafting period, relative to dryland drafting policies.

Due to the complexities of the sheep production system as a whole, and data limitations associated with it, the study concentrated on modelling the lamb growth component of that system. The flexibility of lamb drafting strategies was thus explored based on the implicit constraint that adequate feed would be available for ewes at tupping and for winter reserves.

While further model developments are possible (see below) the approach taken in this study has allowed an assessment of, and a comparison between, traditional (dryland) management and drafting practices and alternative production practices under irrigation. It was found that the choice of management and drafting strategies was a complex problem involving risk and uncertainty arising from a range of controllable and uncontrollable exogeneous factors. Also the extent to which the schedule price structure restricts the choice of drafting weight, and the effect both management and the season have on the speed at which lambs achieve such a weight, all affect the final decisions for both management and drafting strategies. Never-the-less, the study was able to highlight the relationship between expected returns, risk and mean drafting date.

It was found that farmers who draft early in the season tend to minimize the risk associated with environmental variation affecting lamb growth rates but are less certain of their returns per carcass. Conversely, those farmers aiming for the PM grade lamb with its guaranteed price, face a greater degree of uncertainty with respect to feed supply.

However, when feed supply and demand profiles were taken into account, the surplus of feed in December and January indicated that delaying drafting until later in the season would be a worthwhile strategy for some farmers. Feed supply and demand were best equated when lambing percentages were highest and stocking rates lowest. A 'best fit' situation, that would not only equate pasture supply and demand but also reduce the uncertainty of expected returns, occurred if a maximum number of lambs were born and they grew at a rate that allowed as many as possible to be drafted as PM's by early March. High growth rates are not necessarily compatible with high lambing percentages, because of the increased number of twins and triplets, but the situation can be improved by delaying the mean drafting date to allow more of the multiple birth lambs to benefit from compensatory growth and achieve the required weight.

If lambs have not achieved a PM carcass by early March it was profitable to take them on another month with a crop of fodder rape. This may not always be a desirable alternative for all farming systems although it did decrease the expected variation in returns by allowing more lambs to be 'finished'.

Although slightly delayed drafting, relative to dryland practice, would appear to be appropriate if the full production potential of the irrigated system is to be realized, there would appear to be little scope for more significant changes in drafting policy to spread the kill. This is because the increase in breeding ewe numbers, which is justified with irrigation, increases feed demand in winter and early spring when there are no benefits from irrigation. This in turn means that the feed in late summer and autumn becomes critical as a source of conserved fodder and for flushing ewes, and will not usually be available for growing lambs.

The evaluation of strategies which involves delayed drafting to the point where tupping feed and winter reserves are reduced, with a subsequent effect on production, would require the development of both pasture and ewe models. These could interface with the lamb model to simulate the operation of the whole sheep production system throughout the year. Only with such a model could the true costs to the farmer of significantly spreading the killing season be estimated.

Such a model would then also have potential as an aid to farm management. Each farmer must assess the stocking rate and performance level at which he is most confident. The actual performance in terms of lamb growth rates is then dependent on each person's ability to manage both stock and feed successfully. There is obvious variation between the output from similar strategies caused by the limitations of managerial ability. A further development to the model could be to incorporate a central 'manager' module which would accept information from the pasture, ewe and lamb and economic modules, analyse it and return 'decisions' that would manipulate both management and drafting strategies to achieve the farmer's objectives.

Further developments of the model, as suggested above, could only be justified if better data on some of the important biological relationships became available. This study has been useful in highlighting the limitations that exist in the current literature on all aspects of the lamb production system. The sensitivity of the model to alternative sets of conversion factors calculated from the literature emphasises the need for more data on both the effect of lambing date on growth rates and the extent to which compensatory growth occurs after growth checks. Also those factors affecting carcass fatness need to be more accurately outlined before more extensive simulation can occur.

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Year	Prices Paid* by Sheepfarmers 1970 = 100	Returns/PM Grade Lamb # Schedule Price (Actual) 1970 = 100 (442c/kg)
1970	100	100
1	105	95
2	112	87
3	118	157
4	134	159
5	152	108
6	171	168
7	202	224
8	235	210
9	256	172
1980	314	209

* Source: NZMWBES Ann. Reviews of the Sheep & Beef Industry

Source: NZMPB Ann. Reports

Appendix I: On-farm Costs and Returns/kg

	DM kg/ha #		Adjusted * DM kg/ha		MJ ME/kg DM		Maintenance Requirement
	Grass	Clover	Grass	Clover	Grass	Clover	MJ ME/sheep/day
Jun	7.0	1.7	8.14	2.21	12.0	12.0	10.0
July	6.5	2.1	7.74	2.73	12.0	12.0	10.0
Aug	7.1	2.3	8.4	2.99	12.0	12.0	10.0
Sept	22.1	8.4	24.96	10.92	12.5	12.5	9.8
Oct	37.1	14.9	37.56	19.37	12.5	12.5	9.8
Nov	32.3	14.8	31.94	19.24	11.0	12.0	10.2
Dec	31.1	16.4	32.16	21.32	9.5	11.3	10.6
Jan	28.4	16.6	28.4	21.58	8.75	11.3	10.7
Feb	23.4	13.9	26.78	18.07	8.75	10.75	10.7
Mar	21.7	10.5	25.11	13.65	10.25	10.5	10.5
Apr	16.3	5.4	19.5	7.02	11.0	11.0	10.2
May	9.5	1.9	10.87	2.47	11.5	11.5	10.1

Yield measured from 4 weekly cuttings at Winchmore Irrigation Research Station by Rickard (pers comm)

* Adjustments - the trim technique used to measure yield favours upright species which suppress the clover, to equate these results to the more realistic difference technique the overall yield is increased by 15% with clover yielding 30% greater (Hayman. pers. comm).

Appendix II: Supply (DM kg/ha) & Maintenance Requirement (ME/Sheep/Day) of a 55 kg ewe

	Supply MJ ME Avail / ha/day	Utilization Coefficient Lambing Date		ME/ha/day Lambing Date	
		1st Sep	1st Oct	1st Sep	1st Oct
Jun	124.20	.90	.90	111.78	111.78
Jul	125.64	.90	.90	113.08	113.08
Aug	136.68	.75	.90	102.51	123.01
Sep	448.50	.75	.75	336.38	336.38
Oct	711.63	.75	.75	533.72	533.72
Nov	582.22	.75	.75	436.67	436.67
Dec	546.44	.80	.75	437.15	409.83
Jan	492.79	.80	.80	394.23	394.23
Feb	428.58	.75	.80	321.44	342.86
Mar	400.71	.50	.75	200.36	300.53
Apr	275.77	.50	.50	137.89	137.89
May	153.42	.90	.50	138.08	76.71

Appendix III: Supply (ME/ha/day) for Flocks with Lambing Dates of Sept 1st and Oct 1st Respectively

Physiological stage of ewe and proportion of maintenance (m) feed required		MJ ME/sheep/day Lambing Date		MJ ME/ha/day* Lambing Date	
		Sept 1	Oct 1	Sept 1	Oct 1
Pregnancy	0.8 m	8.08	8.0	161.6 May	160.0 Jun
Pregnancy	0.8 m	8.0	8.0	160.0 Jun	160.0 July
Prelambing	1.0 m	10.0	10.0	200.0 July	200.0 Aug
Prelambing	1.5 m	15.0	14.7	300.0 Aug	294.0 Sept
Lambing	2.5 m	24.5	24.5	490.0 Sept	490.0 Oct
Ewe + Lamb	2.0 m	19.6	20.4	392.0 Oct	408.0 Nov
Ewe + Lamb	2.0 m	20.4	21.2	408.0 Nov	424.0 Dec
Post Weaning	1.0 m	10.6	10.7	212.0 Dec	214.0 Jan
Post weaning	1.0 m	10.7	10.7	214.0 Jan	214.0 Feb
Post weaning	1.0 m	10.7	10.5	214.0 Feb	210 Mar
Flushing	1.5 m	15.75	15.3	315 Mar	306 Apr
Flushing	1.5 m	15.3	15.15	306 Apr	303 May

* Stocking rate = 20 ewes/ha

Appendix IV: Demand for a 55 kg Ewe (plus lambs until weaning) for the Two Lambing Dates.

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Total MJ ME/ha/year
Supply MJ ME/ha/day	124	126	137	449	712	582	546	493	429	401	276	153	134.550
Demand MJ ME/day													Maxm Carrying capacity su/ha (incl lambs and hoggets)
per Lamb	-	-	-	-	-	-	9	11	13	-	-	-	
per Hogget	11	11	11	14.6	18	19	-	-	-	14.6	16	11	
per 50kg ewe av.fertility	7.4	9.3	11.7	18.5	23.0	24.0	9.8	9.9	9.9	12.3	14.6	9.6	23.3
high fertility	7.4	9.3	12.2	20	25.0	26.0	9.9	9.9	9.9	12.3	14.6	9.6	22.6
per 60kg ewe av. fertility	8.5	10.7	13.4	21.3	26.5	28.5	11.3	11.4	11.4	14.1	16.8	11.1	20.5
high fertility	8.5	10.7	13.9	22.5	28.0	30.0	11.3	11.4	11.4	14.1	16.8	11.1	20.0
per 70kg ewe av.fertility	9.6	12.0	15.0	24.0	30.0	33.0	12.7	12.8	12.8	15.9	18.9	12.5	18.2
high fertility	9.6	12.0	16.0	26.0	32.0	35.0	12.7	12.8	12.8	15.9	18.9	12.5	17.6

Appendix V: Supply and Demand for Ewe Flocks on Irrigated Pasture

Capital Stock		S.U.	Capital Cost
Mixed Age Ewes	2000 @ $25/head	2000	50,000
Hoggets	500 @ $20/head	400	10,000
Rams	23 @ $200/head	18	4,600
		2418	64,600
			= $26.72/ S.U.

Gross Revenue	Av. Lambing % $	High Lambing % $
Wool 11415 kg @ $2.90/kg net	33104	33104
Lambs -wethers 1050 @ $21.74/head	22827	
1200 @ $20.30/head		24360
ewe 550 @ $21.32/head	11726	
700 @ $21.16/head		14812
slinkskins		
240 @ $0.80/head	192	
260 @ &0.80/head		208
Ewes 240 @ $10/head net	4200	4200
Total	72049	76684

Variable Costs		
Rams 5 @ $200	1000	1000
Shearing, crutching etc @ $1.60/s.u.	3869	3869
Animal Health- @ $1.07/s.u.	2598	
- @ $1.11/s.u.		2692
Transport - 1600 lambs @ 50c/head	800	
- 1900 lambs @ 50c/head		950
Interest 9% on Capital Stock	5814	5814
Feed Costs - 0.96 bales/s.u. @ $1/bale *	2321	
- 2.02 bales/s.u. @ $1/bale		4884
Total	16402	19209
Gross Margin/s.u.	23.01	23.77
Gross Margin/ha	556.47	574.75

Appendix VI: Gross Margin Analysis for 50 kg Ewe Flock per 100 ha

* calculated in Appendix IX

Capital Stock		S.U.	Capital Cost
Mixed Age Ewes	1750 @ $26/head	1750	45,500
Hoggets	438 @ $21/head	350	9,198
Rams	20 @ $200/head	16	4,000
		2116	58,698
			= $29.12 / s.u.

Gross Revenue	Av. Lambing % $	High Lambing % $
Wool 10962 @ $2.90/kg net	31790	31790
Lambs- wethers 1111 @ $21.85/head	24275	
1313 @ $19.54/head		25656
ewe 674 @ $22.10/head	14895	
874 @ $21.80/head		19053
slinkskins 228 @ $0.80/head	182	
263 @ $0.80/head		210
Ewes 368 @ $11/head net	4048	4048
TOTAL	75190	80757

Variable Costs		
Rams 4 @ $200	800	800
Shearing, crutching etc @ $1.60/s.u.	3226	3226
Animal Health - $1.41/s.u.	2300	
- $1.19/s.u.		2400
Transport - 1785 lambs @ 50c/head	893	
2187 " " "		1094
Interest 9% on Capital Stock	5283	5283
Feed Costs-0.93 bales/s.u. @ $1/bale	1875	
* 2.16 " " " " "		4355
TOTAL	14377	17158
Gross Margin/s.u	28.74	30.06
/ha	608.13	635.99

Appendix VII: Gross Margin Analysis for 60 kg Ewe Flock per 100 ha

* calculated in Appendix IX

Capital Stock		S.U.	Capital Cost
Mixed Age Ewes	1500 @ $27/head	1500	40,500
Hoggets	375 @ $22/head	300	8,250
Rams	17 @ $200/head	14	3,400
		1814	52,150
			= $28.75/ s.u.

Gross Revenue	Av. Lambing % $	High Lambing % $
Wool 10227 @ $2.90/kg net	29658	29658
Lambs -wethers 1103 @ $22.90/head	25259	
1350 @ $20.55/head		27743
ewe 727 @ $22.69/head	16496	
975 @ $22.38/head		21821
slinkskins 240 @ $0.80/head	192	
345 @ " "		276
Ewes 315 @ $12/head net	3780	3780
TOTAL	75385	83278

Variable Costs		
Rams 3 @ $200	600	600
Shearing,crutching etc @ $1.60/s.u.	2902	2902
Animal Health @ $1.14/s.u.	2068	
@ $1.22/s.u.		2213
Transport-1830 lambs @ 50c/head	915	
2325 " " " "		1163
Interest 9% on Capital Stock	4694	4694
Feed Costs* 1.26 bales/s.u. @ $1/bale		2286
TOTAL	11179	13858
Gross Margin/s.u.	35.39	38.27
/ha	642.06	694.20

Appendix VIII: Gross Margin Analysis for 70 kg Ewe Flock per 100 ha.

* calculated in Appendix IX

	t hay/100ha #	kg/ s.u.	Bales/ s.u. *
50 kg ewe			
av.fertility	58.2	24.07	0.96
high fertility	122.3	50.6	2.02
60 kg ewe			
av. fertility	46.9	23.3	0.93
high fertility	109.1	54.1	2.16
70 kg ewe			
av. fertility	18.5	10.2	0.41
high fertility	57.3	31.6	1.26

Calculated from deficit from Appendix V; assumes that hay has an M/D of 8 MJ ME/kg DM and a dry matter of 85 per cent

* Assumes 1 bale = 25 kg

Appendix IX: Requirements for Hay by Ewe Flocks

Stocking Rate	Ewe Weight (kg)	Meat kg/ha	Wool kg/ha	Gross Margin /s.u. $	/ha $
21	50 av. fertility	196.40	115.28	23.97	503
	50 'ill thrift'	178.50	112.88	22.47	472
18	50 av. fertility	168.35	98.81	23.97	432
	50 'ill thrift'	153.08	96.75	22.47	405
	60 av. fertility	207.84	106.07	29.67	534
	60 'ill thrift'	189.08	105.31	27.91	502

Appendix X: Summary of Production and Gross Margin Analyses for Two Stocking Rates at Reduced Performance Levels.

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