Farm system modeling to enhance the efficiency of quality red-meat production from pasture.

D.G. McCall
AgResearch Ruakura, Private Bag 3123, Hamilton, New Zealand

Abstract

It is argued that in variable farming environments, system improvements from new technology or altered farm practice can rarely be predicted intuitive or partial system analyses. This is accentuated for quality production where more complex analyses are required to make decisions that op farm performance. Inadequate account is taken of the inherent conservative behaviour of biological systems, caused by negative feedback, and the of variability in production responses, particularly in pastoral agriculture. From the heady early days of exaggerated promise, whole-farm system technology is now being usefully applied. A case study shows the on-farm costs of out-of-season lamb supply from using different technical appr to the issue. The on-farm analysis provides a benchmark against which to assess the efficiency of a range of industry options for supplying out-of lamb. A criticism of the present is that there has been little emphasis in promoting farm system research models for use by other than the develo teams. A vision for the future is that whole farm model software will become sufficiently accepted and used by a range of scientists to test and de their technology dreams. A barrier may be the threat to those who fear the scrutiny of a system analysis before promoting potential technology bene

Keywords: Farm technology, lamb, out-of-season supply, value chain.

1. Introduction

The critical role of the producer in the meat value chain is to manage the supply of stock. The control of any meat production system re management of a large number of interacting biological processes. Within grazed pasture systems these extend to include interactions between c and the quantity and quality of feed produced within the system. This leads to additional uncertainties compared to feedlot or controlled enviro poultry and pork production and is the major challenge in managing and designing improved pasture-fed livestock systems.

Previously, the improvement of grazing system productivity has been more straight-forward because of lesser market expectations of meat pro Trading in frozen carcasses and a greater tolerance of variation in carcass size allowed producers to maximise carcass production by adjusting the supply of stock to suit feed availability on the farm. For example, lambing and calving occurred in spring and stock were slaughtered in the autumn feed supplies reached critical minimum levels required to feed capital stock over winter. This simplified producer's management but resulted in seasonal demand for meat processing and variability between years in the timing and size of carcasses produced. Smaller carcasses were produced in the season in drought years than in years with high summer rainfall. New Zealand's average lamb and beef carcass weight has ranged from 12.5 kg and 210 to 253 kg over the years 1970-1990 (Sandrey and Reynolds 1990)

The frozen carcass, commodity marketing, era focused production technologists on practices which improved meat production per hectare. These associated with the greatest returns to the producer. A high degree of success was achieved in developing these practices. Major improveme productivity were made by simple controls such as the control of animal health and plant pests and the use of fertiliser and increased stocking (McCall and Sheath 1993). The latter controls were successful because of their dominant influence on pasture production and utilisation, and productivity per hectare of land. From 1960 to 1985, New Zealand's meat production increased 67% under stocking intensification which saw a increase in stock numbers (Sandrey and Reynolds 1990).

Now, changes to grazing systems are now being required to meet the changing needs of markets for consistent supply and to reduce the seasonal meat processing. The move toward supply of fresh carcasses and to more closely defined specifications with greater spread of production througho year provides a stern challenge to pastoral producers. The technologies and farm practice that will enhance production efficiency are no longer sim is unlikely that individual components of the system will provide simple controllers of production efficiency. Rather, we will need to evaluate the e of a new technology for its effects throughout the system because of subtle interactions with other components in the system. In addition we will n determine the modifications required to farm practices in order to obtain maximum benefit from a new technology. There are also likely to be more one stock policy and technology option that will meet supply criteria and which need to be evaluated.

2. Evaluating new technology

The challenge in evaluating the benefit of a new technology on-farm is to forecast the physical and financial outcomes arising from the change (Bo et al, 1989). This is the problem faced by the producer in deciding whether or not to adopt a new practice (Parminter et al, 1993). The more interacti effects of a new technology within the system, the more complex it is for producers to comprehend and learn to manage (Paine 1993). Knowledge robustness of a technology in a range of climatic conditions is also important in assessing risk, as is knowledge about changes to farm practi implement the technology to best effect. For these reasons results from component research do not directly translate into improved farm perform This is because we miss the consequences of changes to one component of the system when it is part of a larger system. We also miss in accountin the variability of response. Cacho and Bywater (1994) have shown that it is possible to reach quite different conclusions when variability is consider part of the evaluation of a new farm practice.

A feature of complex biological systems is that they exhibit conservative behaviour because many aspects of the system are subject to neg feedback's. (Seligman 1993). Negative feedback occurs in grazing systems through factors such as future pasture quality and quantity. For exa attempts to feed animals for high levels of daily gain in spring can result in wasted pasture which can reduce pasture quality in the late summer and depress pasture growth rates in the autumn (Korte et al 1982) and ultimately animal growth rate. Seligman (1993) quotes the example of numerous where variations in the timing of supplementation and nutritional composition of the diet offered to dairy cows have produced short term differe milk yield but when long term effects are analysed there is a remarkably constant relationship between total energy fed to the cow and total production out. This demonstrates the buffering capacity of biological systems that evolve toward an equilibrium, in this case a cow body size production equilibrium.

Exaggerated notions of the gains from introducing a new technology arise when perceived benefits are extrapolated directly into whole recommendations (Sheath and Bryant 1984). Brougham (1973) and Hight (1979) noted that theoretical gains in farm system performance calculat aggregating component benefits of improved plant and animal performance, far out-strip realised gains in farm system performance.

A solution that ensures system feedback's are taken into account in technology evaluation is to test the input / output affects of a change to the sy within the system itself. This philosophy has led to the successful development of farmlet trial research and farm demonstration research (Lowe 1988, Parker 1989) . Farmlet research has been valuable in assessing the biological benefits of new pasture species (Webby et al, 1990), sheep performance (Rattray et al, 1978), intensification using fertiliser and stocking rate (Clark et al, 1986, Sibbald and Maxwell 1990) and increased lambing rates (Harris and Hickey, 1978) to name a few. Presently farmlet experiments are being conducted in New Zealand to evaluate the benefits of enhanced ewe milk production (P. D. Muir *pers comm*) and twinning technology in breeding cows (D. C. Smeaton *pers comm*).

The factors constraining more widespread use of farmlet systems trials are the level of physical and financial resources required to run them, the limited number of system configurations and years over which the system response can be evaluated and hence difficulty in learning about system sensitivities. These factors can limit the development of changes to other farm practices which would optimise the benefit of a technology in the system. It also limits assessments of risk associated with the variability in physical and financial responses from a technology. The major research use of biological models of farm systems has been to fulfill the above needs. These models are a tool for use by systems researchers.

3. The role of modeling

There is now the realisation that the most useful models for researching biological interactions at the farm system level are not grandiose models which link very detailed sub-system models of plant and animal physiology and soil chemistry (Seligman, 1993). These sub-system models are not sufficiently well developed and when combined create a model that is so 'dense' that it is difficult to determine model validity and explain results. This is not to discount detailed mechanistic models of sub-systems, as mathematics will be an increasingly valuable tool in understanding and explaining biological behaviour at this level (Wake, 1993).

Grassland and farm system science is typically conducted at an empirical level and the need for farm system models is tc generate physical input / output production functions for economic analysis and to understand system sensitivities and risk. In this sense the farm system models represent tools to aid reasoning rather than being ubiquitous problem solvers (Seligman, 1993). These are biological 'accounting' models, often using regression relationships to describe interactions between variables. Bywater and Cacho (1994) describe them as farm management research models because they are designed to look at the effect of system organisation (farm practice) or system intervention (eg new technology) on financial and physical outputs of the farm system. These models faithfully compute the daily consequences of climate effects on pasture growth and take care of system constraints such as the need to maintain pasture and animal states within certain bounds in order for the system to be biologically feasible.

The purpose of a good farm system model is to provide a conceptual framework to bring together information about the system and to create knowledge about how it will respond to manipulation. Different models often need to be constructed for different problems and the results of the studies may be specific to the problem and environment studied. A feature of managing these modeling studies is to ensure appropriate use is made of the basic biological information required to describe the farm system and then deciding whether it is most efficient to develop or use a new or existing model for the problem at hand.

4. Modeling applications

A number of examples of studies conducted using farm system models. Bowman et al (1989) demonstrated the use of such a model in their evaluation of ultrasonic scanning for differential management of twin and single bearing ewes in self-replacing Merino flocks in Australia. When the potential production benefits of scanning are listed they are numerous; targeted ewe feeding, culling of non-pregnant ewes leading to less ewe pregnancy toxemia, heavier twin lambs at birth and reduced lamb mortality. Also, higher lamb growth rates among twins post-lambing and the opportunity to reduce supplementary feed use through better targeting of its use.

The simulations showed that the channeling of resources to favour one stock class (twin bearing ewes) could only be achieved at the expense of the other stock. In Australian flocks where wool contributes more than 55% of total revenue, no economic gain occurred from the use of scanning in flocks with low lambing percentages because there were insufficient twin lambs from which to recoup the costs of scanning. In this case the benefits of extra progeny from lowered twin mortality rates were largely offset by wool production losses from single-bearing or non-pregnant ewes unless additional supplementary feed was purchased. Scanning did produce benefits where there were at least 10% of twin bearing ewes in autumn lambing flocks. In these flocks there were frequently feed shortages in late pregnancy and lactation due to effects of drought.

Korte and Rhodes (1993) have provided another example in the use of modeling when analysing the benefits of including a part of the farm in drought tolerant specialist pasture species in dryland farming environments in New Zealand. This study provides a classic example of how the modeling analysis led to consideration of other parts of the system that needed to be altered to gain a benefit from sowing and maintaining drought tolerant pasture species. In this example the new pastures needed to be used to support increased production from a high return enterprise (bull beef) to be economic.

McCall and Marshall (1991) considered genetic effects on the efficiency of beef finishing. Despite greater intake per head, finishing systems with higher mature size cattle yielded greater beef production per hectare. This related to decreased animal conversion efficiencies as animals mature, and that high mature size cattle are less mature at commercial slaughter weights. The greatest efficiency advantages to high mature size cattle occurred where they were slaughtered at carcass weights which could be achieved in one year of finishing compared to lower mature size which took an extra year. This was because of the large decrease in carcass gain per hectare in cattle taken through a second winter (55 to 60% of year one; McCall and Marshall 1991).

A fourth aspect of evaluating a new farm practice is a knowledge of the risk associated with variable responses due to interactions with climatic conditions. Cacho and Bywater's (1994) analysis is an example of this where the economically optimum stocking rate was considered for sheep farms in the Canterbury region of New Zealand. Physical and financial outputs were simulated for a range of stocking rates of capital stock over 10 years of climatic data using a common set of decision rules for stock sales and supplementary feeding. This was compared with a simulation using an 'average' year's climate. Results from the study showed the importance of considering this variability in system evaluations and explained the conservative behaviour of farmers in choosing a stocking rate. The optimum stocking rate was 20% lower than predicted by an average year analysis. The average financial performance over the 10 years was 12% lower than predicted by an average year analysis.

Consistent and efficient supply of lambs is of importance to the competitiveness of the lamb meat sector. The following case study is a modeling analysis aimed at determining the most cost efficient method of producing out-of-season lamb on a New Zealand pastoral farm. This includes the option of using technology which allows ewes to breed out-of-season.

5.0 Case Study: modeling options for lamb supply

There is a growing demand for producing lambs for slaughter on a year-round basis to meet the requirements for a continuous supply of lamb. The natural production season for lamb is from mid December until July. The year-round chilled lamb trade is partially aided by controlled atmosphere packaging technology which extends the shelf life of chilled meat (Bell and Penney 1993). This allows effective supply to be extended into July and August. However, a gap remains over September through December period. Most farms commence lambing in late August or September, because this coincides with the onset of peak pasture growth rates and is achieved by mating ewes during the natural breeding season.

A simulation model (McCall, 1984) was used to evaluate a number of options for supplying 30% of lambs for slaughter between Septemb December. It consists of four components; pasture, sheep and cattle production and management decision rules. These are described merely to gi appreciation of the scope of the model.

5.1 Model description

The model is driven by climate variables (radiation, temperature, and soil moisture) and the amount of green leaf area available to intercept light. T are used to predict photosynthesis. Senescence of green plant tissue (vegetative and reproductive) occurs in proportion to the amount present thoug modified seasonally by soil moisture deficit (it increases during drought) and following plant reproductive development. Dead matter accumulat then disappears via decay. Decay rates reflect soil decomposition activity (fastest during warm wet conditions) and removal into the soil lin earthworms. Intake from the green and dead drymatter pools by sheep and cattle are determined by pasture accessibility (McCall et al 1986), d intake preferences and the relative amounts of green and dead matter. Green drymatter is strongly preferred by sheep. Energy available from gree dead drymatter (MJME/kg Drymatter) is seasonally dependent.

The animal models are energy driven. Energy intake is first used to satisfy maintenance, pregnancy and lactation requirements. The energy deman lactation and pregnancy is determined from potential energy demand based on stage of lactation or pregnancy but is mediated by the level of e intake and animal body reserves. Any surplus or deficit in energy balance is absorbed by body reserves.

The ewe breeding season is described by relationships describing the probability of a ewe showing oestrous on any given day of the year. Mean lar date and lambing pattern are then predicted for given mating dates. Lambing rate is determined from ewe weight and weight gain effects on ovulation followed by constant loss rates of single and twin embryos and neo-natal lamb mortality. The cattle component of the model is much simpler and models the growth of finishing cattle.

The user supplies details of the farm to be simulated. These include the number of paddocks present on the farm. All paddocks are assumed to b same area. Initial conditions are required for all pasture and animal state variables and a simulation run-length is chosen. The number of grazing de periods to be applied per year is an input along with the length of time each period is to last. For example, the year may be segmented into 5 period first covering sheep mating, the second from post-mating until lambing, the third from lambing until lamb weaning, fourthly from lamb weaning mid-summer and finally from mid-summer until mating. Up to two mobs of each of ewes, ewe hoggets, ram hoggets, ewe lambs, ram lambs and fini cattle are permitted. Numbers for each mob at the start of the simulation are specified. Lamb mobs are generated automatically out of the ewe mob lamb weaning. The transfer of lambs into hogget, and hoggets into the ewe mobs is done on a user supplied date.

The execution of the model is driven by decision rules that simulate the way farmer's decisions are made. For example, grazing decision rules for mob include the number of paddocks available for grazing by a mob over a decision period, whether the block will be continuously or rotationally gr the number of days spent grazing each paddock (for rotational grazing), the names of any other mobs grazing in the same block of paddocks and wh these mobs are grazing in with, a paddock ahead or a paddock behind the mob concerned.

The grazing decision rules are applied within the period on the same daily time-step that the model obeys. The amount of pasture accumulation removal from each paddock is computed daily and the pasture state variables for each paddock updated.

Stock purchase and sale decision rules, mating dates, weaning and shearing dates comprise the remaining management input variables. Purchases specified by stock class (mob), number, weight and date of purchase. Sale decisions are specified by date for each mob. A minimum sale weight number of animals to be sold are specified.

The decision to simulate the grazing management flexibility available to a farmer has led to a demanding array of inputs which need to be supplied to model. Complexity is evident in the large number of possible grazing management decisions that could be explored in an attempt to 'optimise' management of a given option. Justification for the input structure is that it's mimicry of farmer decision processes may facilitate translation into far practice.

5.2 Case study design

The farm production and economic implications of two systems of producing lambs for slaughter between September and December were considered compared with a standard spring lambing system. The aim was to produce approximately 30% of the lamb crop for slaughter out-of-season. Opt considered were to autumn lamb (April - May) 30% of the flock, or retain 33% of the latest born spring lambs through winter for spring supply pri tooth eruption.

The standard system was based on a breeding ewe flock (70% of total farm stock units) and bull beef production (30% of stock units, 1 bull equivalen 4 ewes). For simplicity, replacement ewe lambs were assumed to be grazed off the farm for one year commencing mid January. Cull ewes were dispensed from the system in mid January. Potential pasture production figures were fed into the model to simplify the simulation rather than run model from climate data inputs. These data applied to hill pastures in the Waikato region of New Zealand (McCall and Bywater 1987).

Six grazing decision periods were used. Rather than attempt to optimise grazing decision rules, which would require an optimisation routine to incorporated into the model, grazing decision rules were chosen to represent current 'best practice' for Waikato sheep and beef farms (Sheath and Bo 1984). These included a 60 day rotation for ewes from post-mating (1 May) until the start of lambing (25 August). The grazing duration on each padd was 3 days. Cattle grazed the paddock ahead of the ewes on an overlapping leader/follower grazing system. That is, cattle grazed a paddock alone for days with the ewes being moved in with the cattle for their third day of grazing. From lambing until early October ewes were set-stocked over 70% of farm and from early October until weaning (30 November) they were set-stocked over the entire farm. Cattle remained on a 30 day rotation over 30% the farm until early October and then rotated through the ewes and lambs on a 20 day rotation. From 1 December (shearing) lambs grazed ahead o combined mob of ewes and cattle in a leader/follower rotation. A 20 day rotation until mid January was extended into a 40 day rotation until 30 Ma By April all previous season's lambs and cattle were sold and during mating the ewes and replacement calves were grazed together on a 20 day rotat until 1 May.

Sale decision rules for ram lambs were to sell all those greater than 13 kg carcass weight every two weeks commencing 30 December. The heaviest lambs (30% of ewe mob) were retained for replacements with the rest sold as per ram lamb decision rules. All unsold lambs were sold in mid-Ma regardless of weight. Cattle above 220 kg carcass weight were sold every two weeks commencing mid-January. All remaining cattle were sold on 30 March regardless of weight. Replacement bull calves weighing 200 kg liveweight were purchased on 1 April.

Withholding the lightest third of ram lambs for supply in September was accompanied by three changes to the grazing decision rules. The ram lambs were allocated 10% of the farm over winter (15/ha) which allowed them to grow at between 30 and 60 g/day. The number of days overlap on the cattle leader/follower grazing rotation was adjusted up to ensure that ewes maintained their conceptus-free liveweight over winter. The ram lambs and cattle were grazed together over 35% of the farm in early spring. This reduced the area available for ewes and lambs back 5% to 65% of the farm.

Autumn lambing was timed to occur between 20 and 30 April from a synchronised hormone treatment that induced breeding in late November. Spring lambing ewes were weaned on 10 November to provide additional ewes for out-of-season breeding since only 50% of ewes treated were assumed to become pregnant (Andrewes and Taylor 1986). Sufficient ewes were treated to ensure that 30% of the flock lambed in autumn. Autumn lambing ewes comprised 21% of the capital stock units wintered. They were grazed on 40% of the farm on a 40 day rotation from 1 April until weaning on 19 July. From mid July until spring lambing the weaned lambs and cattle were grazed ahead of the autumn lambed ewes (48% of capital stock units) on a 60 day rotation on half of the farm. This arrangement continued until spring weaning (10 November) with a 25 day rotation on 40% of the farm. Autumn born lambs greater than 13 kg carcass weight were sold from 1 October.

5.3 Case study results

Starting with the standard system, Table 1 shows summaries of model outputs with stocking rate set at either 10 or 12 stock units per hectare (su/ha). All per head performance indicators declined with increased stocking rate. Average lamb carcass weight fell below the minimum target of 13 kg at 12 su/ha and bull average carcass weight declined to just above the minimum target level of 220 kg. However, all per hectare indicators of performance increased from 10 to 12 su/ha except bull carcass-weight gain per hectare. The reduced per head performance at 12 su/ha was reflected in a greater percentage of lambs and bulls still present on the farm in March which were sold regardless of weight (Figure 1).

A financial analysis of the results in Table 2 showed that the gross income was greater at 10 su/ha ($444 / ha) than 12 su/ha ($420 / ha). This assumed prices of $2.65 / kg for lamb carcasses in the 13.5 to 16 kg range and $2.50 / kg for other carcasses. Bull beef prices were assumed to be $2 / kg for carcasses over 220 kg and $1.90 /kg for carcasses under 220 kg. Bull replacement costs of $300 / bull were deducted. Wool was assumed to attract $2.50 /kg. In addition to a lower gross income the high stocked scenario will incur added variable costs in the order of $8 / ha to carry the additional stock. The financial analysis favours the lower stocked scenario and this was taken as the base for comparison with out-of-season production scenarios.

Table 2 shows physical production summaries for the retained lamb and autumn lambing scenarios alongside the standard system. The similarity in lambing rates reflected the management strategy to buffer ewe performance from the effects of additional feed demands on the system caused by retaining ram lambs and autumn lambing. Autumn lambed ewes had a slightly lower lambing rate (110%) than spring lambers (116 - 117%) despite being in better condition at mating. This reflected innately lower ovulation rates in out-of-season bred ewes (Andrewes and Taylor 1986). Enhanced wool production from the retained lamb system was due to the additional 2.4 kg of fleece obtained from each retained lamb. Ewe fleece weights were slightly lower than the standard system. Retained lambs obtained a carcass weight of 19 kg at slaughter in September. These lambs were responsible for inflating the average carcass weight in this system. Lambs slaughtered in late summer-autumn averaged 12.9 kg which was very similar to those in the standard system. New seasons lambs slaughtered in spring averaged 14.7 kg carcass weight and contributed to the improvement in average carcass weight from 13 kg in the standard system to 13.4 kg in the autumn lambing system

The major production difference between systems occurred in bull carcass weights. Reductions in bull carcass weight reflected reduced winter and early spring feeding priorities given to bulls in the retained-lamb and autumn-lambing systems (Figure 2). Intake levels of the bulls were managed down to balance the increased demands of autumn lambing ewes and retained-lambs. Autumn-lambing ewe demands were more than double those of spring lambers over winter. The lower efficiency of lamb growth (kg liveweight gain / kg feed eaten) during lactation than post-weaning was due to the need to support the overhead of this increased ewe feed requirement. It was reflected in a greater penalty to beef carcass weights with autumn-lambing.

Additional winter grazing pressure in the non-standard systems also reduced average farm pasture levels in early spring (Figure 3). This had a flow on effect of reducing early spring pasture growth rates and the intake rate of bulls since cattle intake is more severely reduced by low levels of pasture cover than is that of sheep (Bircham and Sheath 1986). However, there was system compensation for these effects. Improved pasture quality in summer and voluntary intake compensation by the bulls reduced liveweight differences by mid-summer (Figure 2).

The retained-lamb and autumn-lambing systems both achieved the desired aim of spreading lamb supply (Figure 4). However, there was a marked difference in the type of lamb produced. The retained-lamb option will invariably produce both older and heavier carcasses than the autumn-lambing option. It will be difficult, ethically, to restrict the carcass weights of retained lambs to 15 kg. The moderate 7% drop in total meat production from 193 kg / ha (standard system) to 180 kg / ha (autumn-lambing system) is able to be managed within a flexible farming system by substituting beef production for lamb and using compensatory growth. In less flexible systems (eg high stocking rate or sheep only systems) larger drops in efficiency could be expected (McCall and Bywater 1987).

Production information was synthesised into a financial figure for comparative purposes. The 'gross returns' presented were adjusted for the additional shearing and animal health costs ($3.75 / ha) to retain 1.5 ram lambs per hectare through winter.

Provided that lamb prices remain favourable relative to beef, the option of retaining lambs through winter will improve financial performance ($454/ha) compared to the standard system ($444/ha). This occurred in the absence of a financial incentive for early season lamb. However, returns from autumn-lambing are likely to be down ($418/ha) owing to the larger penalty in beef carcass weights. This amounts to an additional $11 required per lamb supplied in October to break-even with income from the standard system. The $11 differential per lamb is a minimum figure based on the decline in system efficiency. In addition there may be costs associated with the technology and labour used to achieve out-of-season breeding in ewes.

5.4 Case study interpretation

The simulation provides a quantified forecast of the physical and financial implications of two options for producing lambs out-of-season. If satisfactory from a meat quality perspective, the retention of lambs through winter for early spring supply is the most efficient option. The use of a conservative stocking rate and the strategy to penalise finishing cattle rather than ewe performance through winter were the critical elements of farm practice. The latter practice allowed production efficiency to be maintained because of the ability of the finishing cattle to exhibit compensatory growth in late spring and summer and reduce the effect of winter growth depression on final carcass weight. This was aided by a positive feedback from reduced farm pasture cover in early spring which enhanced pasture quality in late spring. Any partial system analysis which extrapolated from results on the direct effect of options on cattle growth rates in winter would have overstated the negative production consequences. Even if the positive feedback interactio foreseen by the analyst, providing an accurate quantitative estimate of the effect would be near impossible.

If new season lamb is required to supply the out-of-season market, then out-of-season breeding will be required. The results of the simulation pr benchmark against which to evaluate technical options for out-of-season lamb production. There are at least two technical approaches that may b on-farm to achieve out-of-season breeding in ewes. These are genetic or breed selection (McQueen and Reid 1988) and reproductive intervention et al 1988). Genetic selection is a long term approach that requires the identification and multiplication of animals that naturally breed out-of-sea still possess other desired traits. It has the advantages of reducing annual operating costs and ease of management once suitable animals hav identified and multiplied. The major cost is in the initial investment and the time required. In contrast, reproductive intervention can assist by stim ewes to exhibit oestrous, ovulate and conceive outside of the normal breeding season (eg Smith et al 1988). The technology is currently avail achieve conception in around 50% of ewes treated at a cost of around $12 per lamb produced out-of-season (McCall and Bywater 1987). A net p value analysis would allow comparison of the economics of each option given assumptions about the cost of the genetic selection approach and t length required for out-of-season lamb production.

The cost to the farmer of using an out-of-season breeding technology will be in addition to the opportunity cost on production. The latter was show around $11 per lamb. This means the use of reproductive intervention, at current costs, adds around $23 to the cost of supplying a new season l spring, compared to the cost of supplying a lamb in late summer. The $23/lamb figure provides a benchmark against which to assess the efficien range of industry options for supplying out-of-season lamb. For example, the challenge may be met more cost effectively by technology which e the shelf life of chilled lamb carcasses supplied in early to mid winter. Balanced against the cost of shelf-life technology will be additional storag for the product. However, the point is that a farm system analysis using a whole-farm model can provide a reference point for comparing options, no behind the farm gate but throughout the value chain.

There are seldom simple single factor options which maximise efficiency in complex biological production systems. Experience in farm system an has led to the belief that reliance should not be placed on 'silver bullet' technologies as these not yield the results expected. Rather, optimum s configurations will depend on the desired production outcome and will comprise contributions from a number of variables working in combinati McMillan and McCall 1992). At it simplest, this will mean adjusting other farm practices to incorporate the technology to best effect, such as, the m restrict finishing cattle growth rather than ewe performance. The present case study merely provided an entree into the possibilities for determinin practices and technologies that would maximise production efficiency in response to a new challenge. For example, the economics of using a winte supplement for cattle, in combination with lamb retention, could have been investigated.

The important consequence on physical and financial performance of variability in feed supply between years was not considered in the case st would be straight-forward to extend the analysis to this dimension using the model. An example of the effect of feed supply variability on variabl returns from forward contracts for beef production is given by the analysis of McCall et al (1993). It is expected that the incorporation of vari would have led to a larger average opportunity cost for out-of-season production than was derived for the average year scenario (Cacho and By 1994, McCall et al 1993).

Sensitivity of financial results to a change in the relative price of lamb and beef is another analysis which can be performed when produ consequences have been determined by simulation. In this case study it is expected that, economic support for retaining lambs would remain unless prices become significantly higher than lamb.

6. Conclusions

Examples have been provided of the application of whole-farm system models in confronting an industry challenge, and in forecasting produ responses to the introduction of a new technology. Pastoral meat production systems are complex biological systems. It is difficult, if not impossib provide a quantitative prediction of production from competing options for say, out-of-season lamb supply, using intuitive logic or partial system anal Yet such predictions are critical to decision makers. Methods of prediction other than from some form of whole-system analysis often fail to accou account for the effects of feedback on system performance. Models provide systems researchers with a tool to undertake system analyses.

Clearly the development of whole-system models can be a resource demanding activity owing to the breadth required in these models to represent a system. Evidence of this breadth is apparent in the model presented in the case study. The model extended from pasture to animal production included a management component. However, progress in the development of farm system models means that there is now a literature to support rapid and efficient development. Also, there is a realisation that the scale of the model is important. Farm system models which incorporate a seri very detailed biological sub-models are not only very resource demanding to develop but may be equally as difficult to interpret or validate. It m more efficient to use the literature to develop a new model for a new class of problem rather than attempt to build one ubiquitous model capable of us all farm system problems.

The evaluation of options for out-of-season lamb supply demonstrated two important points. These were that not only can on-farm options be evalu but benchmark costs can be provided for solving the problem in another part of the value chain. The cost of supplying new season lamb in spring calculated at around $23 per lamb. This can be compared to the cost of say, developing controlled atmosphere packaging technology to extend pro shelf life.

The use models to evaluate benefits from new technologies applied on-farm remains, as yet, a largely unfulfilled promise. There is scant evidence literature where farm systems models have been used in multidisciplinary teams of systems researchers and disciplinary scientists to evaluate techno and farm practice options. Rather, models appear to have largely been used by the development team of systems researchers. A challenge for the futu to gain the acceptance and confidence in outputs of whole-farm system software by disciplinary agricultural biologists. A desirable prospect for the fu is that systems scientists and biologists will form more effective interdisciplinary links around models to test and develop their technology dreams.

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Table 1: Performance indices under standard management

Stocking rate (su/ha)	Lambing percent	Lambs/ha	Ewe fleece (kg)	Wool wt/ha (kg)	Lamb carcass (kg)	Lamb meat/ha (kg)	Bull carcass (kg)	Bull meat/ha (kg)	Income ($/ha)
10	117	8.18	4.97	34.8	13.0	78.9	252	114	444
12	111	9.33	4.55	38.2	12.2	83.3	223	110	420

Table 2: Performance indices for three production systems

System	Lambing percent	Lambs/ha	Ewe fleece (kg)	Wool wt/ha (kg)	Lamb carcass (kg)	Lamb meat/ha (kg)	Bull carcass (kg)	Bull meat/ha (kg)	Income ($/ha)
Standard	117	8.18	4.97	34.8	13.0	78.9	252	114	444
Retained Lamb	116	8.12	4.86 (2.42)	37.6	14.5	87.1	244	107	454
Autumn Lamb	115	8.04	4.71	33.0	13.4	80.0	235	101	418

Fig 1: Distribution of lamb supply (standard systems)

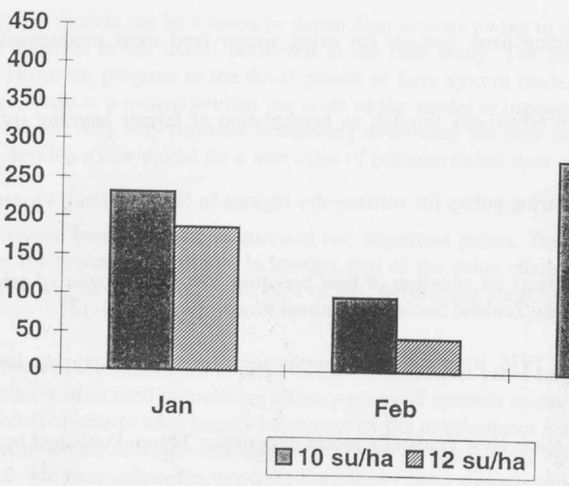

Fig 2: Bull growth

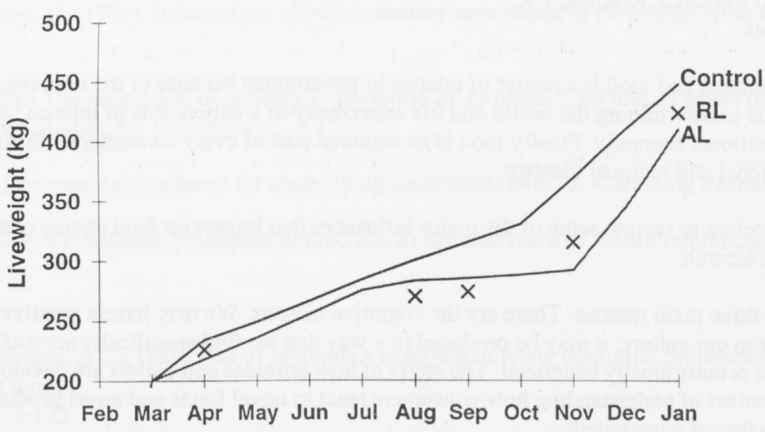

Fig. 3: Average farm pasture cover (kg DM/ha)

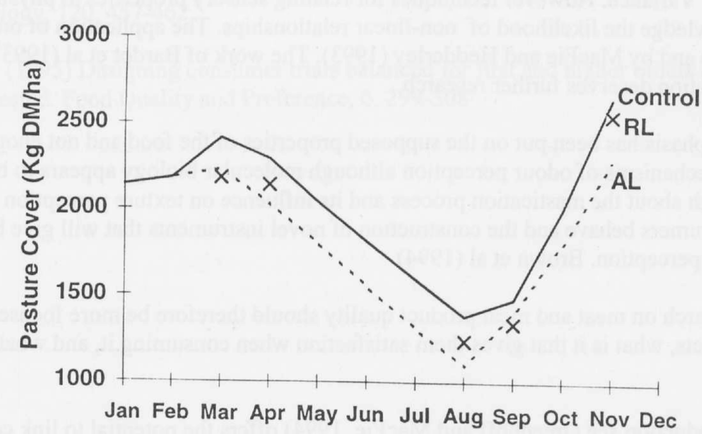

Fig 4: Distribution of lamb supply (out-of-season supply)