Is Increasing Ewe Prolificacy the Key to Increasing Canterbury Dry Land Farm Profitability?

Research Using Linear Programming as a Modelling Tool

A dissertation submitted in partial fulfilment of the requirements for the Degree of Master of Applied Science

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By Cameron Ludemann

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Certification

I declare that the work presented in this dissertation, is to the best of my knowledge and belief, original and my own work, except as acknowledged in the text, and that the material has not been submitted either in part or whole for a degree at this or any other university.

Cameron Ian Ludemann

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The sheep industry contributed $3.47 billion in export earnings for New Zealand in 2007. Canterbury produced 22.6% of the lambs born in the 2007/08 season, making it a significant region for lamb production. Increasing ewe prolificacy (EP) has been a trend over the last 24 years to aid the industry's productivity to maintain economic sustainability. Previous research suggested that increasing ewe prolificacy could result in lower overall profitability to farms. However, none had related it specifically to Canterbury conditions.

This research involved the development of a Linear Program to relate ewe prolificacy to net profits and biological efficiency of a typical Canterbury dry land sheep and beef farm. Profits and biological efficiency were maximised at 190% and 208% EP respectively. Thereafter, profits and efficiencies reduced with increasing EP. Ewe prolificacy was the main driver of profitability when EP was between 129-190%. Survival rates of triplet and quadruplet lambs became more influential as EP increased, and allowed the biological efficiency to continue to increase (above 208% EP) when they were increased to that of twin lambs. The stated optimal ewe prolificacy levels related specifically to Canterbury dry land conditions and 'average' lamb performance in terms of survival and live weight gains. Further research and technology could help to improve these performance measures to increase the optimal ewe prolificacy.

Limitations and advantages of the Linear Program model as a farmer/consultant decision making tool were also discussed.

Acknowledgements

This research was first motivated by a desire to prove whether farmers with higher ewe fertility really did obtain higher profitability on average. Professor Keith Woodford set me in the right direction in order to answer my research questions. This I am grateful for.

I would like to thank Guy Trafford for his patience and the imparting of knowledge when he taught me the fundamentals of the Linear Program as well as other advice throughout the period of research. Also, I would like to thank my parents for their support (and the odd lamb for the freezer) during my time at Lincoln University.

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Chapter One

Introduction

1.1 Background

New Zealand lamb producers operate under a seasonal pasture system which contributes significantly to the New Zealand economy. In the 2006/07 season New Zealand sheep farmers sold 26, 921, 000 lambs passed as fit for local and export consumption, producing 452, 703 tonnes of lamb meat (Ministry of Agriculture and Forestry, 2007a). The sheep industry contributed approximately $3.47 billion (freight on board) in export earnings for New Zealand in 2007 (Ministry of Agriculture and Forestry, 2008). The Canterbury/Marlborough region in particular was the largest producer of lamb for the 2007/08 season, contributing 22.6% of the total lambs born in New Zealand (Meat and Wool New Zealand, 2008a).

There has been a trend in the New Zealand sheep industry to strive towards achieving higher productivity since the removal of subsidies in 1984. From 1978 to 1984 New Zealand sheep farmers were pledged ‘Supplementary Minimum Prices’ (SMP’s) for their products. Minimum prices for lamb meat and wool were underwritten by the Government of that period to instil ‘confidence in its (the industry’s) future prospects and profitability’ (RBNZ, 1982, p. 1). SMP’s distorted market signals so that farmers did not understand what the end consumer of their products wanted. As stated by the Ministry of Agriculture and Forestry (2006) higher subsidies for sheep farmers over beef and dairy farmers meant that farmers produced more lamb, some of which had to be rendered down to fertiliser due to a lack of demand. The SMP scheme thus encouraged ‘agricultural output gains’ (RBNZ, 1986, p. 448) with the implication being that farmers were incentivised to have high stocking rates producing 13kg (carcass weight) lambs.

As stated by (Dobson & Rae, 2006) Government subsidies to farmers by 1984 made up 3.2% of the country’s Gross Domestic Product (GDP) and a third of the total Government’s deficit. By then even farmers realised that the subsidies were unsustainable for a country lagging in GDP growth per capita (which was 15% that of the Organisation for Economic Co-operation and Development (OECD) average).

In 1984 there was a removal of the SMP’s and other agricultural subsidies such as for fertiliser and credit. The effective rate of assistance to pastoral agriculture declined from

‘115% in 1984 to approximately 0% in 1989’ (Dobson & Rae, 2006, p. 62) The change from a subsidy to non subsidy environment fostered farmers to increase their productivity and to better meet their end consumer demands.

The mean percentage of lambs tailed per ewe mated for instance increased since 1984 from 98% to 126% in New Zealand (Ministry of Agriculture and Forestry, 2007b). Over the same period average lamb carcass weights increased from 13kg to around 17kg (Meat and Wool New Zealand, 2008b). Lamb weights reached a plateau up until recently to the 16-17kg mark, owing to customer preferences. New lamb supply contracts that target consumers with preferences for larger lambs such as the ‘Backbone’ Silver Fern Farm contracts (Silver Fern Farms, 2008) will likely lift the average lamb carcass weights to aid in productivity gains. However, farmers also have the option to increase the quantity of lamb meat they produce on their farm through increasing their lambing percentages.

Increasing lambing percentages can come at a cost. Higher ewe fertility in general will increase ewe pregnancy and lactational energy requirements. This may require a reduction in the number of ewes carried on a farm. A higher proportion of the ewe’s litter as triplets and quadruplets with lower survival rates described by Amer et al. (1999) also contribute to the costs of higher ewe fertility. The question of whether increasing lambing percentages makes economic sense then becomes apparent.

To avoid ambiguity, this research will primarily focus on ewe prolificacy defined by Morrison & Young (1991) as the number of lambs born per ewe lambing. The research involves linear programming (LP) to quantify whether farms do receive additional economic benefits from increasing ewe prolificacy above the average (152%) levels. Linear programming is an appropriate technique for this research as it is less costly and time consuming than setting up a farm trial. It also takes away environmental variation which can make it hard to interpret full farm trial results.

This research will relate specifically to a ‘typical’ Canterbury dry land sheep farm, similar to that modelled by the Ministry of Agriculture and Forestry (2007) to provide trends in overall farm profits depending on the level of ewe prolificacy.

1.2 Research Aim

The economic benefits (in the form of farm net profit) as well as biological efficiency of increasing ewe prolificacy will be examined in this research. This will be to provide sheep farmers with a better idea of how high they should aim to increase the fertility of their ewes. The process of this investigation will involve the development of a Linear Program model suitable for a range of sheep farms however, the primary focus of this investigation will be on a Canterbury dry land sheep and beef farm situation.

1.3 Key Questions

This research will focus on answering the following questions:

- How does increasing ewe prolificacy affect Canterbury dry land farm profitability?
- How does ewe prolificacy affect the efficiency of energy conversion to lamb meat?
- What are the most important drivers of profits across the range of ewe prolificacy?
- What are the most profitable management strategies for farming at high ewe prolificacy?
- Is increasing ewe prolificacy the best way to increase Canterbury dry land sheep and beef farm profitability?
- How does the Linear Program stack up as a tool for farmer decision making?

Chapter Two
Review of Literature

2.1 Introduction

Increasing lambing percentages was found in the literature to be achievable if a focus on increasing the number of lambs carried from conception to sale/slaughter, while limiting lamb mortality was made. Appropriate management of ewe nutrition as well as practices such as the Androvax® vaccination (Intervet, 2006), and mid pregnancy shearing (Meat and Wool, 2000) were found to aid in increasing lambing percentages. The use of genetic selection was also found to have significant lambing percentage benefits, but had to be weighed up against some of its drawbacks.

Several research papers focussed toward the topic of lambing percentages and farm profitability. However, none related it specifically to Canterbury conditions. In addition, not all the literature was in agreement to the actual benefits of increasing ewe fertility or its importance relative to other factors such as lamb live weight gains.

2.2 Increasing Ewe Fertility

Ewe ovulation rates set the maximum number of lambs a ewe can give birth to and subsequently mother until weaning. The aim for increasing ewe lambing percentages is to increase the ovulation rates and/or increase lamb survival to maximise the number of lambs carried from conception to slaughter/sale. The survival of lambs is to a large degree based on lamb birth weight so it is important for a farmer to manipulate nutritional, genetic or management factors to aid in attaining optimal lamb birth weights. As Dalton, Knight, & Johnson (1980) concluded there was found to be a significant ($P<0.001$) quadratic relationship between lamb birth weights and survival. An optimal birth weight was then suggested as being 4.7kg ± 0.2kg. Variations (above or below) in average birth weights from this optimal range would thus lead to increased lamb mortality.

2.2.1 Nutrition

The ovulation rate also sets the maximum number of lambs a ewe can produce for sale. Therefore if ovulation rates could be increased, *ceteris paribus* more lambs would be available for sale from a farm. As shown in Figure 1, the pasture allowance for ewes in the month prior to mating can have a significant positive relationship with the ovulation rate. This positive relationship existed up until pasture allowances reached above 2kg dry matter/ewe/day.

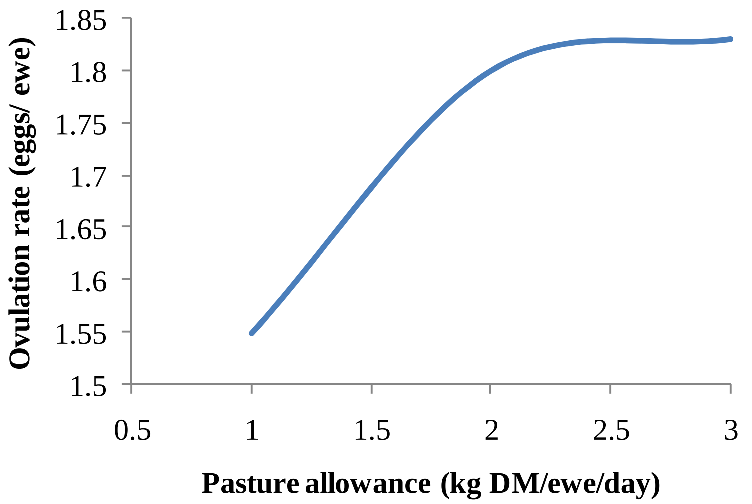

Figure 1: The effect of ryegrass pasture allowance on 58kg Coopworth ewe ovulation rates. Adapted from Rattray et al. (1983).

Significant joining live weight to ovulation rate relationships were calculated by Rutherford, Nicol, & Logan (2003). However, the relationship experienced diminishing marginal returns (in ovulation rate) much like that of pre-mating pasture allowance. It was found that only slight increases in ovulation rates tended to occur at ewe joining live weights above 67.5kg. This is depicted in Figure 2.

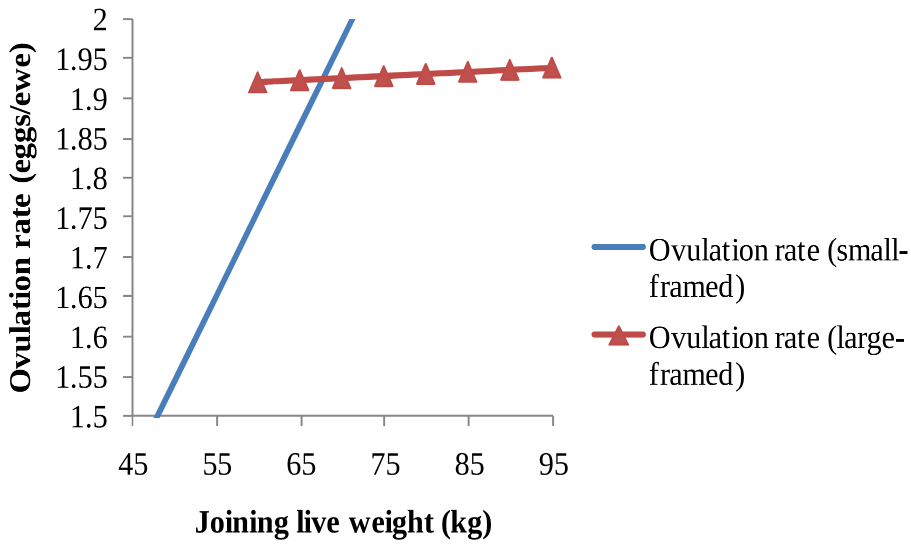

Figure 2: Relationship between ovulation rate and joining live weight of small and large framed ewes. From Rutherford et al. (2003).

Increasing the ovulation rate of ewes does not necessarily mean that other factors remain constant (ceteris paribus). As will be discussed in sections 2.3 and 3.3.2, when increasing ewe fertility, a larger proportion of a ewe's litter become triplets and quadruplets. Lambs with these 'birth ranks' have lower survival rates. However, the nutrition of ewes during and after pregnancy was found by Kenyon, Revell, & Morris (2006) to be a significant factor in increasing lamb survival. This was because it allowed for adequate placental growth increasing the birth weight of lambs and improving the milking ability of the ewe. However, it was suggested by Morris & Kenyon (2004) that 'triplet bearing' ewes could be physiologically limited in how much they could eat in the critical final trimester of pregnancy, even with adequate pasture allowances. This was presumed to be caused by rumen restrictions brought on by pressure from the three foetuses. Further, even when ewes were given an excess pasture allowance above their requirements by Penning (1986) the daily dry matter intake for the ewes reached an asymptote at approximately 2.5kg DM/ewe/day. If the pasture is not of high enough quality then the animal would have its intake of energy limited by its ability to consume dry matter. The plateau in dry matter intake was suggested by Cosgrove & Edwards (2007) to be due to the rate of dry matter intake (in grams DM/minute) reaching an asymptote at high pasture allowances. At the same time a reduction in time the animal spent grazing each day at high pasture allowances was observed. This limited the quantity of dry matter the ewe consumed. Therefore there could be limits to how well pregnancy nutrition in ewes could enhance triplet and quadruplet lamb survival.

2.2.2 Lamb Birth Ranking

As depicted in Table 1, twins were reported by Amer et al. (1999) as having lower rates of survival under a range of environments compared to single lambs. Triplets had even lower survival rates than twins. Tarbottom & Webby (1999) found the major cause of lamb death varied depending on how many lambs were in the litter. Fifty three percent of single lambs were found to have died from dystocia and only 6% through exposure and starvation.

Table 1: Lamb survival from birth to weaning according to birth rank and topography. From Amer et al. (1999).

Farm type	Singles	Twins	Triplets	Quadruplets
Intensive	0.9	0.85	0.65	0.55
Easy hill country	0.85	0.85	0.6	0.5
Hard hill country	0.8	0.7	0.4	0.3
Harsh hill country	0.75	0.65	0.35	0.25

A major influence of dystocia in lambs is birth weight. Higher lamb birth weights were found by Tarbottom & Webby (1999) to increase the incidences of dystocia. Dystocia can be managed by putting the ewes bearing single lambs on a ration lower than that of ‘multiple bearing’ ewes during pregnancy. This is justified due to the lower energy requirements of the single lamb bearing ewe than a ewe with multiple lambs (Nicol & Brooks, (2007). In contrast twin and triplet lambs were found by Tarbottom & Webby (1999) to have died from exposure and starvation 41% and 30% of the time respectively. To explain this Meat and Wool (2005) stated that triplet lambs were found to have a 1^{o} C lower body temperature at birth due to their smaller size (and greater surface area to volume ratio) than twins. Increasing the birth weight of the multiple lambs could thus allow for higher body temperatures at birth to reduce the 41% of multiple lambs that die of exposure. This justifies why farmers should aim to increase the birth weights of multiple lambs closer to (but not above) the optimal birth weight of 4.7kg suggested by Dalton et al. (1980). Above this weight could induce higher incidences of multiple lamb dystocia.

2.2.3 Genetic

When utilising genetics in order to accomplish increased reproductive performance it generally involves trade-offs. The Inverdale gene is a good example of a genetic method of increasing reproductive performance in ewes. The introduction of this gene is controlled by a carefully monitored breeding programme. A single copy of the Inverdale gene on the X chromosome of the ewe was reported by Davis et al. (1991) as being correlated with an increase in a ewes ovulation rate by 1 extra egg shed per ovulation. The trade-off arose in the form of embryonic losses. The addition of the gene was measured by Davis et al. (1993) to equate to only 0.58 more lambs born per ewe lambing for every one extra egg shed. Further, the presence of two Inverdale genes in the female would render it infertile.

Crossbreeding was suggested by Dalton et al. (1980) to introduce reproductive hybrid vigour with up to 20% increases in the number of lambs born per ewe lambing. This could be achieved through the crossbreeding of fecund breeds like Finn with Romney. However, the trade-off as described by Dalton et al. (1980) to crossbreeding was the possible introduction of detrimental traits from the fecund breed such as lower growth rates and health problems.

There is an alternative strategy to fixing the problem of a high proportion of triplets with high ewe prolificacy. This was researched by Amer & Bodin (2006) by trying to select for sheep genetics which had a higher incidence of twinning but lower rates of triplets. This involved indexing the progeny of rams to see how many triplets and twins they subsequently produced. Rams with the trait for producing more offspring as twins, relative to those born as triplets could then be selected for.

Amer & Bodin (2006) explored how successful selecting for ewes with more twins but fewer triplets would be by undertaking a quantitative analysis of historical sheep flocks from the 1970's to 2004. The research quantified the genetic correlation between the 'number of lambs born and a triplet trait, coded as 1 for ewes lambing triplets or higher multiples, and 0 for ewes lambing singles or twins'(Amer & Bodin, 2006, p. 429). The genetic correlations of the two 'triplet trait codes' were estimated separately over 13 data sets. It was found that genetic selection for more twins and fewer triplets would have slow progress because of its low heritability. However, there were differences in the 'triplet trait' across flocks of ewes. So although heritability of the trait was found to be low it would still be a beneficial addition to a breeding index. It was also suggested by Amer & Bodin (2006) that selecting for fewer triplets could be done without reducing the number of lambs born.

2.2.4 Management

Some management practices have the potential to increase lambing percentages. Androvax® is a vaccine which elevates antibody levels. This induces hormonal changes which block the release of eggs for a short period of time. More eggs mature and are released when the antibody levels fall. As a consequence lambing percentages were found on average to increase by 20% (Intervet, 2006). However, Intervet (2006) concluded that the increased incidence of triplets if the vaccine was administered to moderately or highly fertile ewes was a drawback to the vaccine.

The timing of shearing was found by Mackenzie, Thwaites & Edey (1975) to have a non significant effect on ewe ovulation rates. Research by McMillan et al. (1984) measured a 'slight' effect on the number of lambs born depending on the timing of shearing. Shearing ewes two weeks prior to mating produced slightly more lambs born than unshorn ewes, but this was fewer lambs than for ewes shorn 4 weeks pre-mating. The limitation to the research by McMillan et al. (1984) was that it did not state whether the differences in the number of lambs born were actually significant, and it only measured the effect on two tooths. Therefore, it could be assumed from the non significant Mackenzie et al. (1975) results and 'slight' effects measured by McMillan et al. (1984) that the timing of shearing has no, or a very minor influence on lambing percentages.
However, the timing of shearing was shown to offer benefits in terms of lamb survival if done at the right time. Meat and Wool (2000) stated that shearing between day 50 and 100 of pregnancy had the potential to increase the birth weights of lambs by 0.7 kg. This would contribute to a higher lamb survival rate with fewer lambs being lost due to exposure. Practices to increase (multiple) lamb birth weights such as mid pregnancy shearing may be the more economic option compared to intensifying husbandry over lambing time. This is likely owing to increasing labour costs and the fact that lamb survival is highly correlated to lamb birth weights, as was mentioned by Dalton et al. (1980).

2.3 Effect of Lambing Percentages on Farm Profitability

Morrison & Young (1991) calculated the then $1.80 (AUD) per ewe benefit in increasing lambing percentages by 10% was unlikely to be high enough to offset the costs of delivering the increase in lambing percentages. It must be noted that this research was conducted in the Western Australian Wheat Belt under low ewe prolificacy (EP) (number of lambs born per ewe lambing of 60-80%) and would require more expensive supplementary feed to obtain the desired levels of lamb output (ie. grain) than perhaps in New Zealand. On the other hand it was stated by Geenty (1998) that improvements in lambing percentages in New Zealand made the biggest contribution to higher profits on sheep farms. Reasons to justify the stated importance of lambing percentages were not fully explored by Geenty (1998). Limitations such as lamb losses, and changes in management to accommodate higher ewe fertility were discussed. However, it did not compare nor quantify the impacts other factors such as lamb growth rates could have on farm profitability. The difference in relative importance of lambing percentages between Morrison & Young (1991) and Geenty (1998) highlights some discrepancies that exist in the literature on the impacts lambing percentages have on farm profitability.

When the effect of lambing percentages on farm profits were quantified in a New Zealand context by Morel & Kenyon (2006) it was found that lambing percentages were less than or equal to the most important factor affecting farm profitability. This was dependent on the intensity of the farm operation. Farm intensity was in part based on how high the ewe prolificacy was. Results were derived from a computer simulation model. In a "high productivity" farm with 200% ewe prolificacy, a 1% increase in lamb growth rate was equivalent to a 3% increase in ewe prolificacy. The lambing percentages were more significant relative to lamb growth rates on low productivity farms (120% EP). Low productivity farms were shown to have a similar rise in profit from a 1% increase in lamb growth rates compared to when the EP% increased by 1% (Morel & Kenyon, 2006). The relationship between EP and farm gross margin (FGM) was not linear across the EP ranges. A 1% increase in EP between 140-160% increased FGM by $3.95/ha, between 160-180% it increased by $2.51/ha. A $1.33/ha increase was calculated between 200-220% and finally a $2.83/ha increase was recorded for every 1% increase in EP between 220-240%. When the results were plotted with the increases in gross margin added to the 'base' gross margin (at 140% EP) of zero it showed that there was a lower increase in the gross margin between 180 and 200%. This was explained by (Morel & Kenyon, 2006, p. 379) to be due to ' at those EP levels single-born lambs being replaced by triplet-born lambs and this resulted in proportionately greater lamb mortality and lower lamb growth rates'.

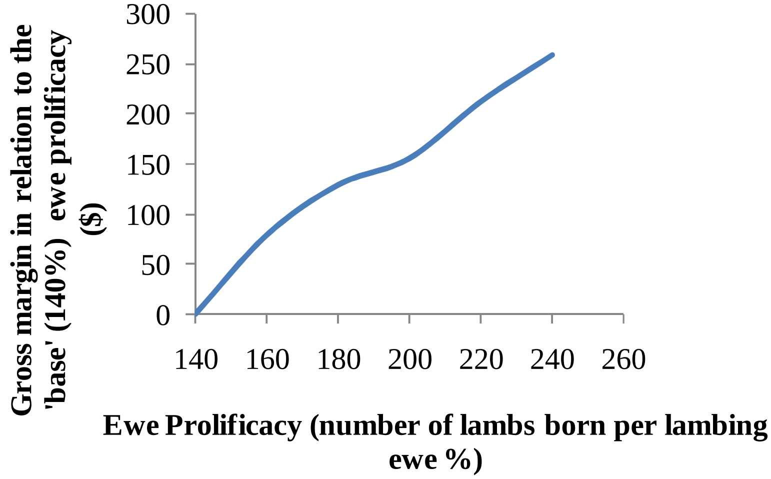

Figure 3: Farm gross margin in relation to the 'base' 140% EP scenario as ewe prolificacy increased with ewes at 75kg live weight at mating. Adapted from Morel & Kenyon (2006).

While the research by Morel & Kenyon (2006) is relevant for assessing the general effect of lambing percentages on farm profitability, it did not base its assumptions on Canterbury conditions. Morel & Kenyon (2006) based their pasture growth curve on Manawatu conditions for a 500 ha farm. The researchers tried to extrapolate findings by giving a range of farming intensities (low, medium and high) related to ewe prolificacy. However, they did not relate it specifically to the Canterbury environment, making an obvious discrepancy between pasture growth curves. They also used a simple selling policy with lambs being valued at $2/kg of live weight at weaning time- effectively only relevant for a farmer producing all store lambs and selling them at weaning. There are a range of lamb selling policies followed by Canterbury sheep farmers which Morel & Kenyon (2006) did not include in their analysis. Relating lambing percentages and farm profitability to the Canterbury farm environment as well as exploring the impacts of different selling policies is therefore an area which is lacking in the literature at present.

Reasons why there is reduced marginal farm profitability with increasing lambing percentages has had much research. One way in which increasing lambing percentages can reduce profitability is a function of stocking rate adjustments. Selection pressure for more fecund ewes has at the same time increased the live weights of those ewes. Bigger ewes were found by Geenty & Rattray (1987) to eat more for maintenance and production. With a finite supply of feed each year a farmer has to possibly reduce the number of ewes to accommodate the increased demand. In this case the cost to the reduction in the total number of ewes on a farm could outweigh the increased per head production from those ewes, making for lower total farm profitability.

Farm profitability can also be reduced at higher lambing percentages due to the number of triplets and quadruplets being produced. A higher incidence of triplets and quadruplets was suggested by Amer et al. (1999) to occur at higher lambing percentages. Triplets can become problematic and costly due to lower survival rates. Table 1 (section 2.2.2) shows significant reductions in lamb survival, especially from twin lambs to triplets and quadruplets. Survival rates of all birth rank lambs reduced with increasing topography. In addition, Amer & Bodin (2006) suggested multiple birth rank lambs can take longer to finish, or attain lighter carcass weights at the same slaughter date.

Chapter Three
Methodology

3.1 Introduction

The methodology of Linear Program research required a number of steps, beginning with: sourcing the input data, building the linear program, analysing the output, validating the output with Farmax, reanalysing, and changing the linear program. Finally, the dissertation was written up (Figure 4).

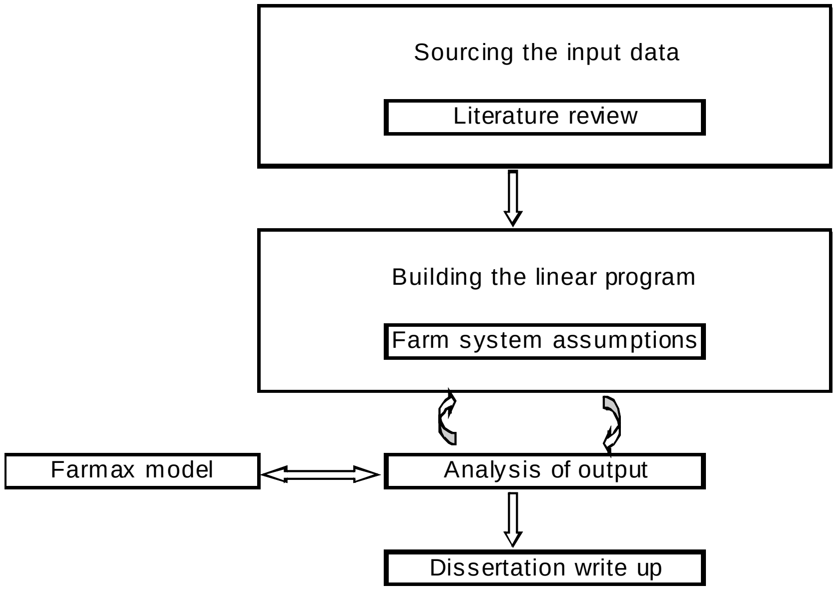

Figure 4: Methodology diagram for the Linear Program

3.2 Linear Program Model

Linear programming is a research method developed in 1947 by George Dantzig to solve military based planning problems (Pannell, 1997). Since then it has been implemented in a range of fields including agriculture. Dent, Harrison, & Woodford (1986) viewed this method as an extension to simple planning techniques such as gross margin analysis. Frontline systems Incorporated developed the 'Solver' tool function and can be used in combination with Microsoft Excel (2003-07) for Linear Programming.

Certain assumptions have to be made for Linear Programming. For example it assumes for a defined activity that linear relationships are present between resource use, resource cost, activity levels and activity returns.

This technique can be applied to any problem which has the following characteristics defined by Dent et al. (1986):

- a range of activities possible, which the farmer can choose to select to put into the farms operations;
- various constraints which prevent free selection from the range of activities; and
- rational choice of the combination of activity levels, related to some measure of the farmer's utility (eg. profit).

Examining the effects of lambing percentages on the profitability of Canterbury sheep farms complies with these characteristics. A range of activities in regards to increasing the lambing percentage exists. These include activities like varying ‘stocking rates’, ‘supplementary feed making’ or ‘lamb sales times’ to put into the farms operations. Sheep farms also have certain constraints such as a finite area of land and monetary resources. These constraints prevent the farmer from selecting just any activity. A change in lambing percentages must in general correspond with maximising farm profit; therefore the most rational combination of activities will aim toward achieving this result.

The use of Linear Programming on sheep farms by farmers has historically been low. Doubt was suggested by Dent et al. (1986) to exist amongst farmers about the accuracy of Linear Programming. The unavailability of suitable input data was also concluded to contribute to the low rate of adoption. Dent et al. (1986) noted that this perception of Linear Programming was generally false. They concluded that when enough time and ingenuity was put into Linear Programming, it could achieve a high degree of realism, even for a complicated sheep farm operation.

The relevance of Linear Programming to farm management decision making is dependent on reliable values for inputs and forecasted yields etc. Sensitivity analysis can overcome some of the problems associated with trying to accurately forecast yields and prices. In addition, absolute values are not always of most importance in Linear Programming. It is the ‘relative sense’ made between activities which enable a farmer to decide on the best management option (Dent et al., 1986).

3.3 Input Data

Dake (1994) is an example of research which utilised Linear Programming to investigate a real farm problem- farm diversification. Dake (1994) sourced data from the NZ Meat and Wool Board’s Economic Service (1992), the Ministry of Agriculture and Forestry and Fisheries (1993) as well as the Lincoln University Farm Technical Manual (Fleming, 1992). Updated versions of most of these sources are available. The approach taken by Dake (1994) can thus be implemented to current research that utilises Linear Programming.

3.3.1 Feed Supply

To compare the relative profitability of two different lambing percentages in Linear Programming requires accurate input data. Feed availability and feed demand are of major consideration in a pastorally based sheep system. To standardise and reduce the variability of the units of feed, the units are best done in terms of mega joules of metabolisable energy (MJME). MJME accounts for the variation in feed quality that exists across a farm and over time, unlike kilograms of dry matter (kg/DM). The energy value of each kilogram of dry matter can differ according to the proportions of leaf, stem and dead material. It can also vary between seasons and pasture species (White & Hodgson, 2005).

Feed supply expressed in terms of energy (MJME) was calculated by using average monthly pasture growth data from the Winchmore research station (Table 2). Data were based on the unirrigated trial site situated in mid- Canterbury at 160 metres above sea level. Soils were Lismore stony silt loam - typical of many Canterbury dry land sheep and beef farms. The pasture dry matter production was converted to energy by multiplying it by the average energy concentration for the South Island, stated by Litherland & Lambert (2007). It was assumed that the feed supply was utilised at a rate of 80% of feed available each month.

Table 2: Winchmore (unirrigated) pasture production and quality used for Linear Program. From Fleming (2003)* and Litherland & Lambert (2007).

Month	Pasture growth rates* (kg DM/day)	Pasture quality (MJME/kg DM)	Utilisation (%)
June	5	10.75	80
July	5	10.7	80
August	9	10.6	80
September	30	11	80
October	37	11.25	80
November	27	10.5	80
December	19	10.75	80
January	13	10.75	80
February	14	10.65	80
March	16	10.5	80
April	14	11.25	80
May	8	11.2	80

3.3.2 Feed Demand

A number of useful sources of information were available for calculating the appropriate energy demand of a sheep system. Geenty & Rattray (1987) reported energy requirement data for sheep and cattle. Energy requirements were recorded for the weight, age and physiological state of sheep, lambs and cattle. The limitation to this data was that it did not quantify ewe energy requirements for ewes with more than two lambs. (Nicol & Brooks (2007) provided the most up to date feed demand information and accounted for higher ewe fertility, therefore was used for this Linear Program.

The background 'Livestock Energy and Demand' (Appendix C) spreadsheet was designed to take into account the effect of ewe fertility on monthly energy requirements. Pregnancy energy requirements for example were based on approximated formulae to reflect the pregnancy energy requirements shown in Table 3. Increasing the number of lambs born would thus increase the total lamb birth weight a ewe would bear. Therefore the average lamb birth weight was multiplied by the number of lambs born before the equations shown in Table 3 were used.

Table 3: The metabolisable energy requirement of ewes for pregnancy (in addition to maintenance) and the formulae used to calculate those requirements for the Linear Program. From Nicol & Brooks (2007).

Lamb birth weight (kg)(a)	Weeks before lambing			
	-6	-4	-2	0
	MJME/ewe/day			
3	1.5	2.0	3.0	4.5
4	2.0	3.0	4.0	6.0
5	2.5	3.5	5.0	7.0
6	3.0	4.5	6.0	8.5
Formula used	0.5× a	0.75× a	1× a	1.5× a

The weaning weights, post parturition live weight gains, and number of lambs weaned per ewe would have an influence on the daily lactational energy requirements for ewes. Formulae to approximate the additional lactational energy requirement used in the Linear Program are shown in Table 4. What also had to be taken into account when calculating the lamb weaning weights were the proportion of the litter that were of different birth ranking (ie single, twin, triplet). This was because lambs of different birth ranking were given different birth weights and live weight gains, thus varying weaning weights. Therefore the average weaning weights had to take into account the proportion of the litter as each birth rank.

Table 4: The metabolisable energy requirement of ewes for lactation (in addition to maintenance) and the formulae used to calculate those requirements for the Linear Program. From Nicol & Brooks (2007)

Lamb weaning weight (kg) (b)	Weeks after lambing			
	2.0	6.0	10.0	12.0
	MJME/ewe plus lamb(s)/ day			
20.00	8.5	10.5	12.5	13.0
25.00	10.5	13.0	16.0	17.0
30.00	12.0	16.0	20.0	21.0
35.00	14.5	19.5	24.5	26.0
Formula used	0.43× b	0.53× b	0.64× b	0.7× b

Amer et al. (1999) stated that the proportion of a ewe litter as singles, twins, triplets and quadruplets varied according to ewe prolificacy. Figure 5 highlights how the proportion of different birth ranking lambs in a litter changed with increasing ewe prolificacy. There became a higher proportion of the litter as twins from a ewe prolificacy of 1 to 1.5. Above 1.5 ewe prolificacy there became an increase in the proportion of triplets. The proportion of quadruplets increased above a ewe prolificacy of 2.3. Equations that related ewe prolificacy to the proportion of birth rank lambs in a litter using data from Amer et al. (1999) were calculated using 'Minitab 15' statistical software. The equations used are listed in Equations 1-4.

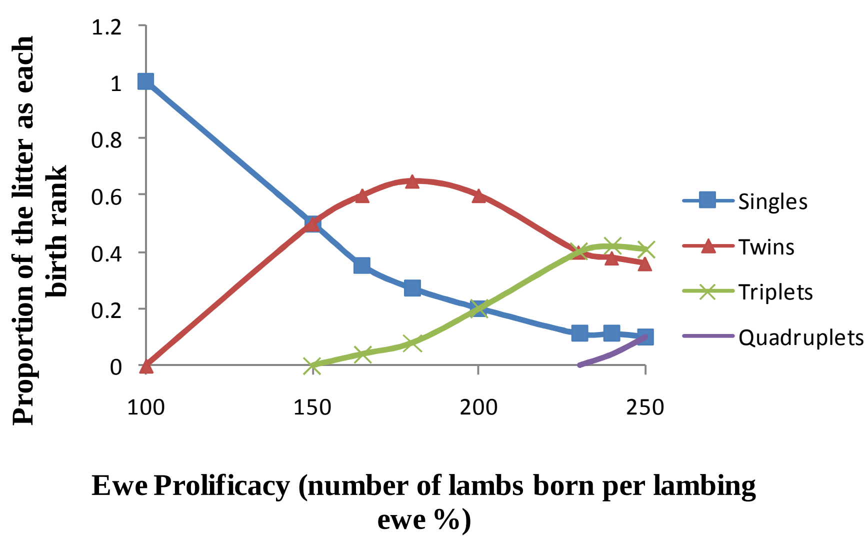

Figure 5: The proportion of a ewe litter as each birth ranking according to ewe prolificacy. Adapted from Amer et al. (1999).

Equations 1-4: Formulae to estimate the proportion of singles, twins, triplets and quadruplets in a ewe litter according to ewe prolificacy.

Equation	Birth rank	Equation
1	Singles	$P=2.621-2.027EP+0.4044EP^2$
2	Twins	$P=-3.508+5.573EP-2.380EP^2+0.3086^3$
3	Triplets	$P=9.943-16.11EP+8.433EP^2-1.402EP^3$
4	Quadruplets	$P=-1.765+0.75EP$

P is proportion of litter as that birth ranking
EP is ewe prolificacy

3.3.3 Financial- Sheep Product Prices

The sheep industry in New Zealand operates in a free market, making it prone to input and product price volatility. To ensure reliability of price assumptions, historical product prices were used. Agridata (2008) provided a comprehensive compilation of weekly store and prime lamb prices. The weekly prices for the PM2 grade of lamb from November 2006 to July 2007 were used to calculate average monthly lamb sales prices. Prices of lamb grades above and below PM2 were compared to see the difference in price relative to PM2. It was found that on a price per kilogram of meat basis there were no significant differences in meat prices between the PM1, PM2, PM3 and PX2 grades of lamb. This was indicated by the fact that the aforementioned grades were within 8% of the PM2 meat price (Table 5). Therefore lamb meat prices were only differentiated into three price categories. One for lambs below 13.3kg (carcass weight), one for lambs sent between 13.3-19.5kg (carcass weight), and one for lambs above 19.6kg. This was to simplify the process of building the model.

Differentiating the lamb sales into all the possible grades set by PPCS (Primary Producers Co-operative Society Ltd) (now Silver Fern Farms) would have increased the time required to build the model with few additional benefits in accuracy. The two grades (below 13.3 and above 19.6kg) that did have significant differences in price per kilogram of meat were calculated as a proportion of the PM2 grade price indicated in Table 5. Therefore if the price for PM2 lamb was increased, for example for sensitivity analysis, the higher and lower lamb grade prices would change accordingly, in proportion to the PM2 grade price.

Table 5: Lamb prices as a proportion of the PM2 grade of lamb. Adapted from Agridata (2008).

	Lamb carcass grade	PL	PM1	PM2 base	PM3	PX2	PX3	PH2
Month	Carcass weight range (kg)	9.1-13.2	13.3-15.5	15.6-17	17.1-18.5	18.6-19.5	19.6-21.2	21.3-23
		Proportion of price paid in relation to the PM2 grade of lamb						
November		0.83	0.97	1.00	1.00	0.92	0.75	0.70
December		0.79	0.98	1.00	1.00	0.94	0.72	0.64
January		0.69	0.98	1.00	0.98	0.94	0.62	0.52
February		0.65	0.95	1.00	0.98	0.93	0.65	0.55
March		0.79	0.98	1.00	1.00	0.94	0.72	0.64
April		0.67	0.95	1.00	0.98	0.93	0.75	0.76
May		0.67	0.95	1.00	0.98	0.93	0.75	0.76
June		0.68	0.95	1.00	0.98	0.93	0.75	0.77
July		0.68	1.00	1.00	0.98	0.93	0.75	0.77

The store lamb sales prices were also based on data from Agridata (2008) and are shown in Table 6. The monthly store lamb prices showed a significant reduction over the period from December to April, followed by a price recovery in May. This was to reflect the general monthly store price trend illustrated in Appendix A. Table 6 also indicates the actual monthly prices per kilogram of PM2 lamb based on the 2006/07 data from Agridata (2008). The PM2 lamb prices also followed a decline over the peak kill season between December and May. This recovered in June when a lower supply of lambs to the works incentivised price premiums in order for processing plants to stay closer to their lamb slaughter capacities. Prices for dry cull and culled for age ewes were kept at a constant $40 per ewe, and cull hoggets at $50 per head throughout the year.

Table 6: Monthly price schedules for lambs, hoggets and ewes. Adapted from Agridata (2008)

Month	Monthly Avg store price for lambs ($/kg Live wt)	Monthly average price for Prime (PM2) lambs ($/kg carcass wt)	Average price for dry cull ewes ($/head)	Average price for culled for age ewes ($/head)	Average price for cull hoggets ($/head)
November	1.80	4.48	40	40	50
December	1.62	4.02	40	40	50
January	0.90	3.19	40	40	50
February	0.90	3.00	40	40	50
March	0.90	2.93	40	40	50
April	0.90	2.90	40	40	50
May	1.26	2.93	40	40	50
June	1.44	3.53	40	40	50

The Linear Program model was designed to allow changes to the timing of lamb sales. As indicated in Table 7 the number of lambs sold each month aimed to replicate the sales times of a typical Canterbury sheep farm selling all prime lambs. All classes of lambs were sold in the same proportions (as a proportion of the total lambs born) each month. Ten percent (0.1) of the lambs born for instance were assumed to be available for sale in November. But to take into account the various survival rates of the lamb classes, the proportion sold was then multiplied by the survival rates of each class of lamb (shown in Table 1 section 2.2.2). This allowed for the variation in lamb survival between birth ranking to be reflected in the monthly lamb sales figures. For example although single and triplet lambs would have the same proportion of lambs available for sale in November (0.1) this figure would be multiplied by the 90% and 65% lamb survival rates of the single and triplet lambs respectively. This meant a lower proportion of lambs would actually be sold in that month for triplets ($0.1 \times 0.65 = 0.065$) compared to singles ($0.1 \times 0.9 = 0.09$).

A row in the Linear Program also allowed the various classes of lamb to be either sold prime or as store if a 1 or 0 respectively was added to the column that represented the various classes of lamb. The model automatically altered the lamb sales price according to the respective prices in the 'Lamb Price Schedule' spreadsheet and the monthly average carcass weights calculated in the 'Livestock Fertility and Demand' spreadsheets.

Table 7: The proportion of lambs sold over the November-June selling period for the Linear Program 'base model'.

	Class of lamb	Ewe lambs from ewes (singles)	Ewe lambs from ewes (twins)	Ewe lambs from ewes (triplets)	Ewe lambs from ewes (quadruplets)	Wether lambs from ewes (singles)	Wether lambs from ewes (twins)	Wether lambs from ewes (triplets)	Wether lambs from ewes (quadruplets)
	Month								
Proportion of total lambs born that are sold	November	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
	December	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
	January	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300
	February	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
	March	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
	April	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
	May	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
	June	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025

3.3.4 Financial- Sheep Costs

All farm costs were based on average 2006/07 New Zealand data for sheep and beef farms recorded by Meat and Wool New Zealand (2008c). Financial costs were divided into fixed and variable costs (Appendix B). Fixed costs were entered into the Linear Program as per hectare figures, as typically fixed costs (ie. Rates, and ACC levies) change in proportion to the area of a farm. Fixed costs per hectare were assumed to be $267/ha or $100930 over the whole farm. Interest (excluding interest on stock) and fertiliser were the highest fixed costs at $80/ha and $50/ha respectively. Variable costs such as shearing and animal health costs were based on per stock unit figures. This aimed to most accurately estimate the change in costs according to changes in stocking rate and farm area.

3.3.5 Financial- Cattle

The number of finishing cattle on the 'model' property was set at a fixed proportion (~7%) of the number of mixed aged ewes. The net revenue from the cattle was based on the gross margin shown in Table 8 multiplied by the number of those cattle. The finishing system was based around purchasing steers at live weights of 240kg and selling them at 19-24 months of age in the autumn. Gross margins per steer were assumed to be $378 after interest. Because the contribution of cattle to the overall farm net profit was proportional to the sheep stock units it meant that the cattle had no impact on the relative profitability of varying lambing percentages. Rather, it just increased the absolute net profit to provide a more realistic figure.

Table 8: Gross margin for beef steers purchased at 240kg (live weight) and sold at 19-24 months of age.

Death rate (%)	1.00%		Carcass yield % of liveweight as carcass			55.00%
Interest rate	9.00%					
Income						Total ($)
Steers sold at	298	kg Carcass weight	@	3.50	$/kg	1042
less meat not sold due to deaths						10
Total income when deaths taken into account						1052
Expenditure						
Steer purchases	240	kg liveweight at purchase	@	2.20	$/kg	528
Animal health						
Anthelmintics	3	each	@	2.00	$/dose	6
Pour on	2	each	@	3.00	$/dose	6
Cobalt injection	2	each	@	1.00	$/dose	2
Five in one	2	each	@	1.00	$/dose	2
Transport (based on 50km)						
Steers to farm			@	7.00	$/for trip	7
Steers to slaughter			@	14.00	$/for trip	14
Levies (AHB etc)			@	15.00	$/head	15
Other				0	$/head	0
Total direct costs						580
Total gross margin (before interest)						472
Less interest						94
Total gross margin after interest						378

3.4 Farm System Assumptions

For this Linear Program to be relevant, the model needed to be representative of typical dry land sheep farms in Canterbury. The Canterbury/ Marlborough sheep and beef model described by the Ministry of Agriculture and Forestry (2007) acted as a starting point for the kind of farm the Linear Program would model. The Ministry of Agriculture and Forestry (2007) model farm for example had 378ha effective area. This was used as the area constraint in the Linear Program (Table 9).

Table 9: Key farm parameters for the Linear Program 'base' model and the MAF Canterbury/Marlborough sheep and beef average data. From the Ministry of Agriculture and Forestry, (2007).

Farm Parameter	Linear Program 'Standard Model'	MAF Canty/Marl sheep and beef average data (06/07)
Area (effective ha)	378	378
No. Ewes	1789	2400
No. Hoggets	335	650
No. lambs born from ewes lambing	2720	N/A
No. lambs sold from ewes mated*	2213	2976
Lambs born per ewe lambing (EP %)	152%	N/A
Lambs sold per ewe mated (sts %)**	124%	124%
No. Cattle	122	148
Stocking rate (SU/ha)	9.10	10.00

* Also includes ewe lambs that became replacements
** Survival to sale

The Linear Program model showed some variation from the MAF average figures when it was forced to adjust stock numbers given the farm parameters explained throughout Chapter 3. This is evident in Table 9 where the Linear Program's 'standard model' farm had a 0.8 SU/ha lower stocking rate. Nine hundred and twenty six fewer mixed age ewes or hoggets and 26 fewer trading cattle in the Linear Program contributed to the lower stocking rate. The most likely causes for this discrepancy were the pasture growth rate figures; pasture quality figures; and the value of stock units used in the Linear Program.

The 2006/07 MAF Canterbury/ Marlborough data encompassed a vast area of New Zealand with significant variability in climate and pasture growth within that area. The Winchmore unirrigated pasture growth data may in fact have been lower than the average seen in the Canterbury/Marlborough farms surveyed by MAF. This would thus limit the carrying capacity of the same area of land. The South Island average pasture quality figures used for this Linear Program may have also been unrepresentative of the MAF farms surveyed.

The Linear Program assumed that 6000MJME was the measure for each stock unit. The Ministry of Agriculture and Forestry (2007) may have adopted the more traditional measure of stock units based on 1 stock unit being equivalent to one 55kg ewe with one lamb (Fleming, 2003). Quantified, this would be approximately 550kg DM/pa or 5775MJME/SU at an average pasture quality of 10.5MJME/kg DM. When the Linear Program had the stock unit measure changed to 5775 MJME/SU instead of 6000MJME/SU it was found that the Linear Program stocking rate came closer (9.5 SU/ha) to the MAF average datum.

The focus of this research was on ewe prolificacy; therefore hogget mating was not practiced on the model farm to reduce unnecessary complexity in the system. Further, the Linear Program assumed that 20ha of winter forage crop was sown. This comprised 10ha of swedes yielding 6000kg DM/ha and 10ha of kale also yielding 6000kg DM/ha. No summer forage crops were assumed to be grown.

3.4.1 Stock Performance and Production

Table 10 indicates the level of performance and production for the various classes of sheep. Birth to weaning live weight gains (LWG's) were set at a constant 0.2kg/day across the different birth ranking lambs. The average post weaning live weight gains were set in relation to the 0.130 kg LWG per day average figure reported by Amer et al. (1999) for flatland South Island/North Island sheep systems. Single lamb LWG's were set at 1.2 times the 'average' reported by Amer et al. (1999), twin lamb LWG's were set at the 'average', triplets at 80% of the twin LWG's, and quadruplets at 80% of the triplet LWG's.

Table 10: Performance and production for the various classes of sheep assumed for the Linear Program.

	Class of stock					
Stock performance and production	Hoggets	Ewes	Single lambs	Twin lambs	Triplet lambs	Quadruplet lambs
Average birth to wean live weight gain (kg/day)	N/A	N/A	0.2	0.2	0.2	0.2
Average post weaning live weight gain (kg/day)	N/A	N/A	0.156	0.13	0.104	0.083
Wool Production (kg greasy pa)	3.5	4	1*	1*	1*	1*
Wool Price ($/kg greasy)	3.00	3.00	3.50	3.50	3.50	3.50
Live weight at mating time (April)	N/A	66.5	N/A	N/A	N/A	N/A
Cull rate (% pa)	4	3	N/A	N/A	N/A	N/A
Death rate (% pa)	4	3	Refer to Table 1 in section 2.2.2			

* Only ewe lambs were assumed to have been shorn.

Not all lambs have their wool shorn before they are sold. It is generally later lambs (sold after January) that get shorn before slaughter. To account for this only ewe lambs were assumed to produce saleable wool.

3.5 Linear Program Set Up

The Linear Program was linked to a number of background spreadsheets including the; 'Livestock Fertility and Demand'; 'Lamb Price Schedule'; 'Variable and Fixed Costs'; and 'Pasture Quality and Supply' to name but a few. The most pivotal spreadsheet (except for the Linear Program spreadsheet) was the 'Livestock Fertility and Demand' which took into account the energy requirements and performance of each class of stock depending on ewe prolificacy.

The ‘Livestock Fertility and Demand’ spreadsheet allowed ovulation rates to be estimated according to changes in the live weight of ewes 1 month prior to mating, the pasture allowance 1 month prior to mating and the genetic coefficient. The live weight at mating was calculated by dividing the excess (over maintenance) energy allowance of the ewes 1 month prior to mating by the energy required for adult ewe live weight gain. This was defined by (Nicol & Brooks (2007) as 55MJME /kg of live weight gain. Live weight gains were then added to the live weight 1 month prior to mating to calculate the live weight at mating.

Ovulation rates (OR) were based on the joining live weight/ovulation rate relationship defined by Rutherford et al. (2003) indicated in Equation 5.

Equation 5: Joining ewe live weight to ovulation rate formula. **From Rutherford et al. (2003).**
Equation 5: Ovulation rate= $1.06 + 0.0119 \times$ joining live weight (kg)

Ovulation rates were then multiplied by the ‘genetic coefficient’. The purpose of the genetic coefficient was to alter the ovulation rate from the standard equation stated by Rutherford et al. (2003). This was to allow variation in ovulation rates which exist between breeds and flocks. In the ‘base’ model the genetic coefficient was set at 0.86 to make each mated ewe on average produce 1.24 lambs sold. 1.24 lambs sold per mated ewe (or 124%) was the MAF average shown in Table 9. For simplicity the ‘lambs sold per mated ewe’, lambing percentage was referred to as the ‘Survival to Sale’ lambing percentage (% s.t.s).

No ewe prolificacy percentage was available from MAF, however the ‘Livestock Fertility and Demand’ spreadsheet extrapolated the 124% s.t.s as being equivalent to 152% ewe prolificacy. Four other levels of ewe prolificacy were chosen to provide a trend in profitability across a range of ewe prolificacy. A 139% ewe prolificacy (13% below the ‘base’ EP %) was chosen to show the effect of a below average ewe prolificacy on farm profits. Three net profit figures above the ‘base’ ewe prolificacy were used to show the effect of above average ewe prolificacy. The net profit results above the ‘base’ ewe prolificacy were at 190%, 252% and

280%. The differences between the ewe prolificacy's used were not constant. For example the lowest ewe prolificacy was 13% lower than the 'base' (152%). The next highest ewe prolificacy above the 'base' ewe prolificacy was 38% higher (at 190%). Because the net profits were plotted on a graph (Figure 8), it did not require the net profits to be done at regular intervals of ewe prolificacy to illustrate the relationship.

The range of ewe prolificacy used in the research would encompass most sheep and beef farms (excluding low (<129% EP) fertility flocks such as Merino in the High Country) in New Zealand.

The final ovulation rate figure was then multiplied by the average embryo survival (0.927) from scanning to birth as measured by (Nicol, Dodds, & Alderton (1999). This gave the number of 'lambs born per ewe mated'. Lamb deaths from birth to weaning were differentiated between the lamb birth ranks as reported by Amer et al. (1999) shown in Table 1 (Section 2.2.2). This was to provide the Linear Program with a realistic loss of lambs from mating to sale. Differentiating LWG's (shown in Table 10) for the different lamb birth rankings also aimed to allow the Linear Program to provide a realistic indication of the effects of ewe prolificacy on farm profits.

The Linear Program was set over a 12 month period. It altered the numbers in each class of stock to not only conform to a (self replacing) steady state flock, but to adjust the stock numbers to maximise the model farm's net profit figure. Changing the; ewe live weights prior to mating; pasture allowances prior to mating; or the genetic coefficient, changed not only the ewe prolificacy but also the energy requirements of the ewes. The Linear Program adjusted livestock numbers each time ewe prolificacy was altered to provide a net profit trend over a range of ewe prolificacy. The farm's stocking rate changed as a consequence of the change in per ewe energy requirements. It also altered the number of lambs slaughtered and their slaughter weights owing to changes in the proportion of the litter as the different birth rankings (with different survival, birth weights and LWG's for each birth ranking).

Chapter Four

Validation of Results

4.1 Introduction

Validating a computer model puts confidence in intended users of the information that the results being taken out of the model would occur in real life. Validating the Linear Program model through full farm trials would be too time consuming and expensive given the modest research budget. Even if full farm trials were feasible, a myriad of uncontrollable influences such as weather and product price changes could lead to variations in results between the Linear Program model and the trials. An alternative way to validate a computer model is to compare its results to that of another computer model. A feed profiling model designed by AgResearch scientists called Farmax Pro (Farmax, 2008) was used in this case to validate the Linear Program. MAF average data was also used to provide a financial comparison. Explanations and discussion on the comparisons for validating the Linear Program are present in this chapter.

4.2 Pasture Cover Feasibility

Livestock levels of production, livestock numbers and other relevant farm parameters such as pasture growth rates from the 'Base' scenario Linear Program were put into the Farmax Pro model. This was intended to ensure that the numbers of livestock the Linear Program calculated for optimal net profits were actually feasible in terms of monthly pasture covers.

The pasture cover output from the Farmax model (Figure 6) shows the pasture cover and the minimum pasture cover. Farmax Pro calculates the pasture cover levels by taking into account the supply and demand of pasture each month. If for example pasture growth rates were lower than that consumed by livestock, the pasture cover would reduce. Such a reduction is shown in Figure 6 between June and August in the 'cover' trend line.

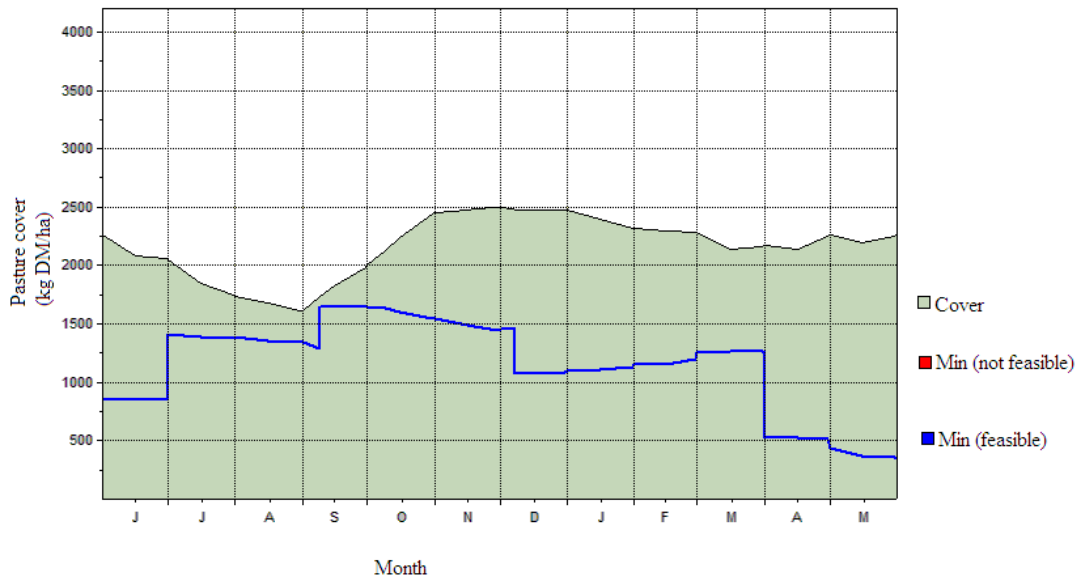

Figure 6: Pasture cover feasibility of Linear Program feed supply and demand validated in the Farmax model.

The minimum pasture cover (indicated by the bold blue line on Figure 6) was calculated by Farmax as the minimum pasture cover that would be needed to meet the livestock production and performance targets. Farmax utilises the relationship between the pasture cover and minimum cover to indicate whether the farm system would be feasible in terms of pasture supply and demand. If the minimum pasture cover exceeded that of the average pasture cover at any point in the year then Farmax Pro would describe the Linear Program livestock numbers as being infeasible.

The drop in the minimum pasture cover at the end of March was due to the fact that most of the lambs and finishing steers were sold by that stage and supplements were starting to be fed out. In addition the livestock that remained over winter did not need high pasture covers, as their energy intakes were being satisfied by supplements such as the 10.2 tonnes (DM) of silage and 20 ha of winter forage crops (swede and kale). If a red minimum pasture cover was present on Figure 6 it would have indicated that the actual pasture covers were not adequate for maintaining the intended livestock production and performance levels. When the Linear Program data were entered into the Farmax model it was found that at no stage through the year did the pasture covers become too low to support the livestock. Thus no red minimum pasture cover line was present on Figure 6. Therefore the numbers of stock the Linear Program calculated were in fact feasible.

The gap between the actual pasture cover and the minimum cover suggest that the Linear Program could have possibly lifted the stocking rate in March and June. Unfortunately the

Linear Program was not intended to provide livestock figures to optimise pasture covers (instead it was for optimising net profit) which could explain why there was such a gap.

The average pasture cover levels calculated in the Linear Program aligned similarly to the pasture covers stipulated by the Farmax model. For most of the year the Linear Program pasture cover levels were within ± 500kg DM/ha of the pasture covers calculated by Farmax. This is shown by the black Farmax pasture cover line being within the 500kg DM/ha ‘range’ that went from the Linear Program’s pasture cover line in Figure 7. The main discrepancies were in the months of May and June. The reduction in stock (through the sales of lambs and steers) in combination with the winter forage crops becoming available at this time were the causes for the increase in average pasture cover. An increase in pasture cover over those months may be unlikely in reality. This may highlight a limitation to the Linear Program in its ability to calculate livestock numbers that create realistic pasture cover levels. However, the Linear Program’s primary purpose was set to optimise net profits rather than pasture cover levels. Nonetheless the Linear Program average pasture levels were at levels throughout the year that would be reasonably consistent with a Canterbury dry land sheep and beef farm. Another possible explanation for variations in the pasture covers of the two models could be due to the equations by which they were calculated. The Linear Program assumed for example that winter forage crops did not contribute to the average pasture cover until the time they were grazed. This explains the rapid increase in average pasture cover in May and June in the Linear Program. The Farmax model may in contrast have calculated a gradual increase in contribution of winter feeds to the farms average pasture cover as the crop grew.

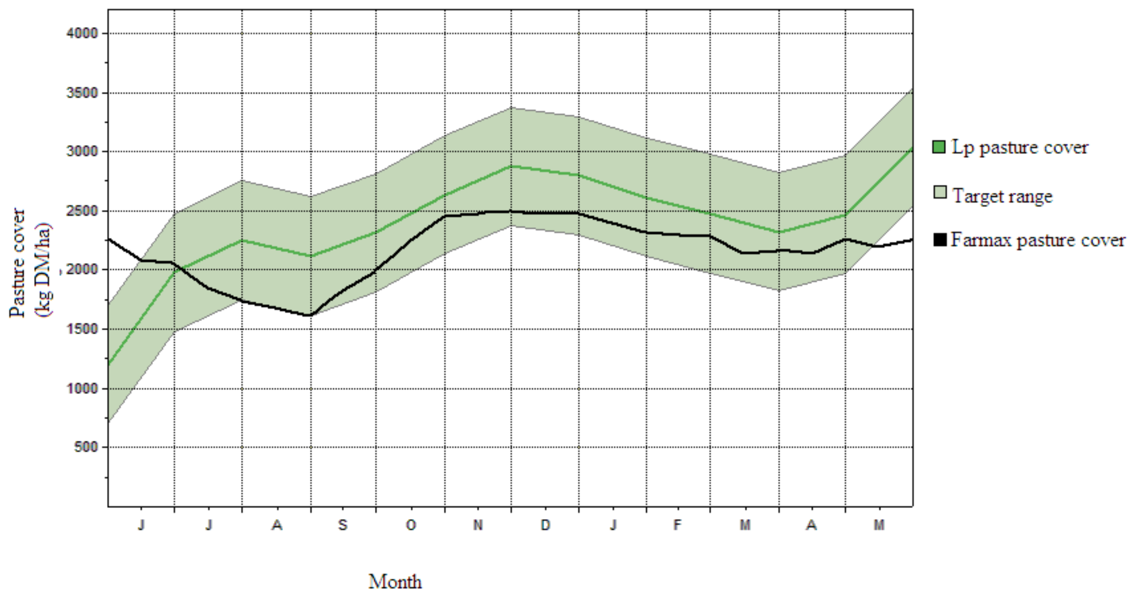

Figure 7: Comparison of the average pasture cover levels calculated by the Linear Program and Farmax model.

4.3 Financial Indices

MAF Canterbury/Marlborough Breeding and Finishing Sheep and Beef farm data (Ministry of Agriculture and Forestry, 2007) were used in addition to Farmax Pro financial output data for a comparison with the Linear Program.

Farmax Pro and MAF took into account capital value changes to assets such as sheep, cattle and crops for taxation purposes when calculating the farm's net profit. Capital value adjustments were not calculated in the Linear Program model. To provide a fair comparison of profitability required the capital value adjustments to be reversed. A brief summary of the Farmax Pro and Linear Program financial details is included in Table 11. Once capital value adjustments were taken into account the net profit figures aligned closely between the three sources. This is shown in Table 11 by the Linear Program net profit (b) being $7902 above that of the MAF average data, and $2172 less than that calculated by Farmax Pro. What must be noted is that expenditure adjustments were made to the MAF data making it more comparable ie. expenses not included in the Linear Program such as rent on land were subtracted from the MAF data when calculating the MAF Net Profit. The MAF data for revenue assumed the farm sold 25% of lambs as store and 75% as prime, leading to an average lamb price of $47.60. This compared to the Linear Program which sold all lambs as prime. Yet the average lamb price was similar at $47.74, which could explain the similarity

(+7.4% variation) between the revenue (excluding value adjustments) of the Linear Program and MAF data.

Table 11: Financial result comparison between; Farmax Pro; the Linear Program; and MAF average data at a ewe prolificacy of 152%.

Financial indice	Farmax Pro	Linear Program	MAF Canty/Marl 06/07 average data
Revenue- purchases(with livestock revalue adjustments (a))	146076	265891	262190
add/subtract adjustment reversals			
Sheep value change adj reversal	-592	0	-15992
Cattle value change adj reversal	59992	0	0
Crop value change adj reversal	-479	0	0
Revenue -purchases after asset value adjustment reversals (b)	204997	265891	246198
Expenditure	155059	218124	206333
Net Profit using (a) (including livestock revaluations)	-8983	47767	55857
Net Profit using (b) (excl livestock revaluations)	49938	47767	39865

Farmax Pro data were significantly lower both for revenue and expenditure than that calculated by the Linear Program, but still produced a similar net profit result to the Linear Program ($49938 compared to the Linear Program's $47767). Farmax Pro assumed lower lamb prices per head ($34.14/lamb) which could explain the $119815 lower revenue than the Linear Program. The cause for the lower Farmax Pro expenditure is due to the fact that it focussed its expenditure on feed costs and animal health. It excluded many general farm working expenses such as repairs and maintenance, ACC, and Electricity etc which the Linear Program did include. However, Farmax Pro is primarily used as a tool for feed budgeting rather than financial budgeting so the emphasised use of Farmax Pro was to validate the feed component of the Linear Program rather than the financial output.

In validating the Linear Program, it is important to highlight whether the model produces realistic results. There was some variation in net profit figures between the Farmax Pro, Linear Program and MAF average data. However, it would be naive to believe that three different models with some variations in assumptions would actually produce identical net profit figures. If the Farmax Pro model and MAF average data were assumed to provide a realistic indication of how a typical Canterbury dry land sheep and beef farm would perform financially, then it would appear that the Linear Program has been validated. This is due to the relative proximity of the Linear Program financial results to the results of Farmax Pro and MAF average data at a ewe prolificacy of 152%.

4.4 Conclusions

Validating a computer model requires proof that the model calculates realistic results that could be attained on a real farm. Livestock numbers the Linear Program calculated were validated by Farmax Pro as it calculated the average pasture covers/minimum pasture covers as being feasible. Average monthly pasture covers calculated in the Linear Program and that of the Farmax Pro output showed a variation of less than ± 500kg DM/ha over most months of the year. Pasture covers from the Linear Program were in general higher than that calculated by Farmax Pro. This would suggest that although the Linear Program livestock numbers and pasture covers were feasible they may not have been the optimum in terms of pasture covers. Higher stocking rates or more silage making could have been options to manage pasture covers to their optimum. However, the Linear Program was focussed on optimising net profits, and the cost of making more silage or increasing the stocking rate was obviously too high to be justified.

Some variations in financial indices between the three sources were present. Most of the variations in the data were explained by different product price or expenditure assumptions. The Linear Program net profit after livestock revaluations were reversed was $7902 above that of the MAF average data, and $2172 less than that calculated by Farmax Pro. The comparison of the Linear Program with Farmax Pro and MAF net profit figures would suggest that the Linear Program gave a realistic result, validating the financial aspect of the Linear Program.

Chapter Five

Results

5.1 Introduction

This chapter details the results of the Linear Program model. It relates increasing ewe prolificacy to the net farm profits and the energy to meat conversion efficiency of the model 378ha, Canterbury dry land sheep and beef farm. A range of net profit figures according to ewe prolificacy is plotted to highlight the trend that occurs and the point at which increasing ewe prolificacy may become less profitable. The energy to meat conversion efficiency data are also plotted against ewe prolificacy. Scenario analysis of the net farm profits is then made at five levels of ewe prolificacy.

5.2 Linear Program Key Data According to Ewe prolificacy

Table 12 details the changes to the optimal number of livestock on the Linear Program's model farm as ewe prolificacy was changed. A ewe prolificacy of 152% (equivalent to the 124% s.t.s) reflected the average performance on Canterbury sheep farms. The average scenario is the highlighted column in Table 12. The scenario with average ewe prolificacy (152%) was calculated to produce the highest net profit when 1789 ewes, 335 hoggets and 122 cattle were carried. This gave an effective stocking rate of 9.10 SU/ha.

Reducing the ewe prolificacy below the average to 129% resulted in higher numbers of ewes, hoggets and cattle, leading to a higher stocking rate (9.15 SU/ha compared to 9.10 SU/ha).

Table 12: Key livestock data over a range of ewe prolificacy for the Linear Program's model farm.

	Ewe Prolificacy (s.t.s % in brackets)				
Parameter	129% (99%)	152% (124%)	190% (153%)	252% (180%)	280% (192%)
No. ewes	1898	1789	1661	1478	1410
No. hoggets	355	335	311	277	264
No. lambs born	2450	2720	3154	3731	3955
No. lambs sold*	1870	2213	2545	2660	2702
No. cattle	130	122	114	101	96
Stocking rate (SU/ha)	9.15	9.10	9.09	8.96	8.91

* includes ewe lambs kept as replacements

Increasing ewe prolificacy above the Canterbury average figure lead to a decline in the number of capital stock the model farm could carry. Increasing ewe prolificacy from 152% to 190% resulted in 128 fewer ewes being necessary to optimise the net profit. This was to accommodate the increased per head energy requirements of the ewes and the increased energy requirements of the 434 additional lambs born. From a ewe prolificacy of 129% to 280% the model calculated a 0.24 SU/ha reduction was necessary to optimise net profits. Over a 378ha area this equates to a 90 SU reduction.

5.3 Profitability Trend

There was an increasing trend in net profitability when ewe prolificacy increased from 129% to approximately 190% (Figure 8). At a ewe prolificacy of 129% a net profit of $19557 was calculated, while at 190% the profit was $68282. Above 190% ewe prolificacy, a nearly linear reduction in net profitability occurred. At 252% ewe prolificacy, the net profit was $47114, this compared to the $38426 net profit calculated at 280% ewe prolificacy. As a consequence it could be suggested that optimal ewe prolificacy for Canterbury dry land sheep and beef farms (with the farm assumptions mentioned in Chapter 3) is at approximately 190%.

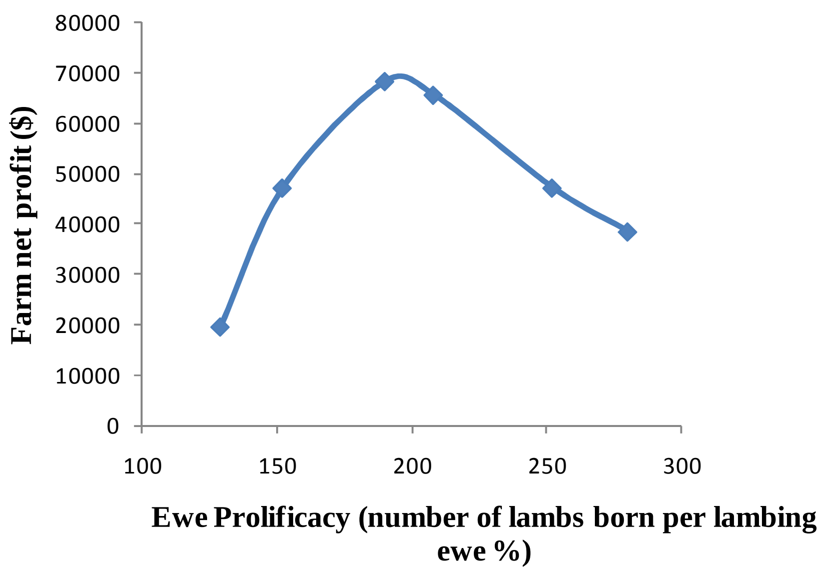

Figure 8: Net profit of a typical Canterbury dry land sheep and beef farm with increasing ewe prolificacy.

The reduction in the number of cattle with increasing ewe prolificacy shown in Table 12 did not have an influence on the overall ewe prolificacy/ net profit trend depicted in Figure 8. When the Linear Program had the option of carrying cattle on the model farm taken away, the general profitability trend shown in Figure 8 remained.

5.4 Biological Efficiency

Biological efficiency was defined as the quantity of energy expressed in units of MJME to produce each kilogram of sold lamb carcass. High energy to lamb meat efficiency figures would therefore be indicative of low levels of biological efficiency. Conversely, low amounts of energy required to produce a kilogram of lamb meat would be indicative of high biological efficiency. At low ewe prolificacy (135%) in the 'base' model, the energy required to produce a kilogram of lamb carcass was 848MJME/kg lamb carcass. At 152%, and 208% the conversion efficiencies were 703 MJME and 596 MJME/kg lamb carcass respectively. This is shown by the negative trend in the energy required to produce each kilogram of lamb carcass from 135% to 208% ewe prolificacy in Figure 9 (plain blue trend line). Thereon, there became a gradual increase in the energy required to produce each kilogram of lamb carcass. At a ewe prolificacy of 252% for the 'base' model the energy required to produce a kilogram of lamb carcass rose to 625MJME.

Figure 9 shows that in the 'base' model, increasing ewe prolificacy from 135% to 208% increased the farm system's biological efficiency. 208% ewe prolificacy was approximately where the biological efficiency was highest. Increasing ewe prolificacy beyond 208% then lead to reductions in biological efficiency.

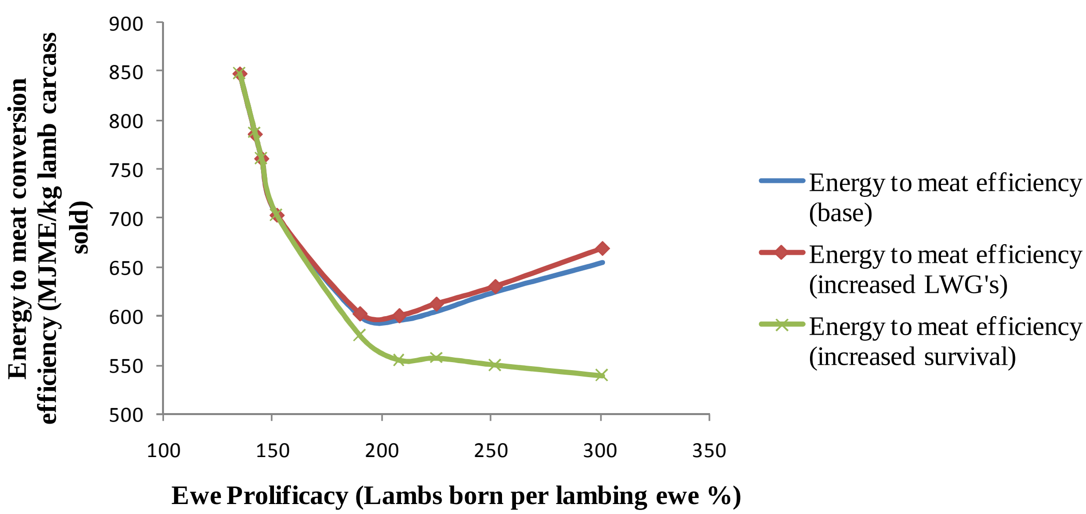

Figure 9: Energy to meat conversion efficiency for a typical Canterbury sheep and beef farm across a range of ewe prolificacy and when triplet and quadruplet lamb survival and post weaning live weight gains became equivalent to that of twin lambs.

The red (with 'diamond' markers) and green (with 'X' markers) trend lines were included in Figure 9 to highlight the factors that could be influencing the biological efficiency of the farm system over the range of ewe prolificacy. The green trend line indicates the energy to meat conversion efficiency if triplet and quadruplet lamb survival rates were increased to that of twin lambs (increased to 85%, from 65% and 55% respectively). This trend line shows a significantly lower quantity of energy required to produce 1kg of lamb carcass above a ewe prolificacy of approximately 175%, thus having higher biological efficiency. The increase in triplet and quadruplet lamb survival allowed an increase in the farm system's biological efficiency (indicated by the negative slope). This occurred even above 208% ewe prolificacy, when the 'base' model trend line showed a reduction in biological efficiency. This highlights the importance of triplet and quadruplet lamb survival rates as a driver for biological efficiency especially at high ewe prolificacy.

The red trend line indicates the effect increasing the triplet and quadruplet lamb weaning to sale live weight gains to that of twins (from 104 grams/ day and 83.2 grams/day respectively to 130g/day) had on biological efficiency. As is shown in Figure 9 increasing the live weight gains of the triplets and quadruplets had no significant impact on the energy required to produce 1 kilogram of lamb carcass across all levels of ewe prolificacy. However, above 200% ewe prolificacy the increased live weight gain trend line was slightly higher than the 'base'. This could indicate that the increased LWG's may have reduced the biological efficiency slightly compared to the 'base' scenario.

5.5 Scenario Analysis

Scenario analysis of the model farm's net profitability is contained in Table 13. Five different scenarios were made at each of the five levels of ewe prolificacy. The 'Base scenarios' were the net profits calculated by the Linear Program, assuming all the farm parameters discussed in Chapter 3 including selling policy, lamb survival and live weight gains remained constant. The only variable to change was the 'genetic coefficient' for ewe ovulation rates. This of course altered the ewe prolificacy. The 'base' scenario farm net profit figures were plotted in Figure 8 and explained in section 5.3.

Table 13: Net profitability of the model Canterbury sheep and beef farm over 5 levels of ewe prolificacy and farm scenarios.

Scenario	'Base' scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Variable changes	No changes to farm assumptions	Triplet and quad lambs survival increase to that of twins (85%)	Triplet and quad lamb post wean LWG's increased to equal twins	Sell all Triplet and quad lambs as store in December	Sell half Triplet and quad lambs as prime in May, half in June	All lamb post weaning LWG's increase by 20%
Ewe Prolificacy			Farm Net Profit ($ pa)			
129%	19577	N/C	N/C	N/C	N/C	18328
152%	47767	N/C	N/C	N/C	N/C	45828
190%	68282	71908	68439	70178	78362	72675
252%	47114	60453	47268	53799	80640	50841
280%	38426	55455	37847	46634	77215	41703

N/C means no change in farm net profit from the 'base' net profit

At each of the five levels of ewe prolificacy (129-280%), scenarios which altered the farm model were made. Scenario 1 aimed to quantify the significance of triplet and quadruplet lamb survival rates to net farm profits. This scenario assumed the triplet and quadruplet lambs were able to attain birth to sale survival rates equivalent to twins (85%) compared to their ‘base’, 65% and 55% survival rates respectively.

No changes to the farm net profits were calculated in Scenario 1 at a ewe prolificacy of 129% or 152%. This was due to the fact that the model assumed no triplet or quadruplet lambs were born on the farm at that level of ewe fertility. Therefore the increased survival rates had no effect on any lambs. However, above a ewe prolificacy of 190%, increasing the survival rates did increase net profits above that of the 190% ‘base’ scenario. At a ewe prolificacy of 190% (scenario 1) the net profit increased to $71908 or 5% above that of the 190% ‘base’ scenario. At 252% ewe prolificacy, the increased survival accounted for a 28% increase in the net profit compared to the ‘base’ scenario (from $47114 to $60453). In addition, at the highest level of ewe prolificacy (280%) the net profit increased 44% with the increase in triplet and quadruplet (birth to weaning) survival in relation to the 280% ‘base’ scenario.

Scenario 2 altered the live weight gains of the triplet and quadruplet lambs to quantify the relative importance of that variable for net profits. Live weight gains in the triplet and quadruplet lambs were assumed to have increased from the ‘base’ model’s figures of 104 and

83.2 grams/day (post weaning) (respectively) to being equivalent to the twin lambs 130 grams/day post weaning live weight gains.

As with scenario 1, scenario 2 had net profit figures no different to that of the ‘base’ scenario at 129% or 152% ewe prolificacy as no triplet or quadruplet lambs were assumed to have been born. Above a ewe prolificacy of 152% there were only marginally higher net profit figures for scenario 2 compared to the ‘base’ scenario, except at 280% ewe prolificacy where the net profit was actually $579 less than the ‘base’ scenario. The lower stocking rate (0.13 SU/ha) to accommodate the increased triplet and quadruplet lamb LWG’s contributed to the lower net profit.

The impacts of two different lamb selling policies on farm profits were detailed in scenario’s 3 and 4. Scenario 3 assumed all triplet and quadruplet lambs were sold as stores in December. Store lamb live weights in December for the triplets and quadruplets were 22.3kg and 21.2kg respectively. Scenario 4 withheld the triplet and quadruplet lamb sales until late in the killing season (May and June) to capture the rising price schedule of that period. Average carcass weights for the triplet and quadruplet lambs were 17.1 kg and 15.19 kg respectively in May, and 18.55 kg and 16.35 kg respectively in June.

Selectively selling the triplet and quadruplet lambs as store in December or as prime at the end of the killing season resulted in higher net profit results across most levels of ewe prolificacy. The exception to this rule was for the scenarios below 152% ewe prolificacy owing to no triplet or quadruplet lambs assumed to having been born. The percentage increase in the net profit (relative to the ‘base’ scenario) in scenario 3 increased at a higher ewe prolificacy. For example at 190% ewe prolificacy the increase in net profit due to triplet and quadruplet lambs being sold store in December was 2.8% greater ($70178 compared to the base scenario of $68282) than the ‘base’ scenario. This compared to a 14% increase at 252% ewe prolificacy and a 21% net profit increase above that of the ‘base’ scenario at a ewe prolificacy of 280%.

Waiting to sell the triplet and quadruplet lambs prime in May and June (Scenario 4) was shown in Table 13 to have the most significant impact on net profits (except at the two lowest levels of ewe prolificacy). Selling only prime triplet and quadruplet lambs in May and June gave a 12% increase in net profit compared to the ‘base’ scenario which had the typical distribution of lamb sales for Canterbury (outlined in Table 7, section 3.3.3). This scenario increased net profit by 49% compared to the ‘base’ scenario at a ewe prolificacy of 252%. Further, there was a significant net profit margin between selling the triplet and quadruplets as store in December compared to selling them prime in May and June. At 190% ewe prolificacy this margin was $8184 (12% higher) in favour of selling the lambs prime in May and June. At 252% ewe prolificacy this margin rose to $26841 or a 49% increase in net profit compared to if the lambs were sold store in December.

The final scenario (5) aimed to highlight the relative importance of an increase in live weight gains over lambs of all birth ranks. As is shown in Table 13 increasing all lamb post weaning live weight gains by 20% actually reduced the farm net profits compared to the ‘base’ scenario at 129% and 152% ewe prolificacy. Above 152% ewe prolificacy, the increased live weight gain scenarios all attained net profits above that of the ‘base’ scenario.

At a ewe prolificacy of 190%, the net profit from increasing all lamb live weight gains was similar to that of increasing the survival of triplet and quadruplet lambs to 85% ($72675 compared to $71908). By 252% ewe prolificacy, the triplet and quadruplet lamb survival scenario exceeded that of increasing all lamb live weights gains ($60453 compared to $50841).

Chapter six

Discussion

6.1 Introduction

This chapter examines how ewe prolificacy impacts on farm profitability and biological efficiency for a typical Canterbury dry land sheep and beef farm. Also included is a discussion of scenarios that highlight the effect various drivers of profitability such as lamb live weight gains, survival rates and selling policies have on a farm.

6.2 Ewe Prolificacy and Farm Profitability

Figure 8 showed an increasing trend in farm profitability above a ewe prolificacy of 129% which eventually peaked at approximately 190-200%. Increasing profitability between 129-190% EP arose from the revenue from lambs being sold increasing at a rate greater than the costs of producing those lambs. As the model assumed the flock was self replacing, when more lambs were born, a smaller proportion of the total lamb crop for instance had to be held as replacements. Thus a larger proportion of the lamb crop was available for sale.

Net profit reductions after the ‘optimum’ EP range were a consequence of the increased per ewe energy requirements requiring a lower overall stocking rate. In addition the cost of a higher proportion of triplet and quadruplet lambs resulting in lower survival rates and post weaning live weight gains surpassed the benefits of a larger number of lambs sold. At 152% ewe prolificacy for example, the number of lambs weaned was 81.4% of those born, at 190% this proportion remained the same. By 252% and 280% the proportion of lambs born that made it to weaning reduced to 71% and 68% respectively. This represented a significant cost to ewes in the form of wasted pregnancy and lactational energy in order for them to bear extra lambs which did not survive until slaughter.

The Linear Program’s trend in profitability contrasts previous research by Morel & Kenyon (2006) which still recorded increases in farm gross margins when 220-230% ewe prolificacy was exceeded (shown in Figure 3, section 2.3). However, Morel & Kenyon's (2006) data did show a reduction in the rate of increase in gross margin between 180 and 200% EP. The reduced rate of gross margin increase between 180% and 200% was attributed by Morel & Kenyon (2006) as more triplet lambs being born with greater mortality and lower LWG’s. Reasons for the difference in profitability trends (shown in Figures 3 and 8) measured by the

Linear Program and Morel & Kenyon (2006) could be attributed to the 'profit' methods of calculation as well as differences in farm system assumptions.

Gross margin 'Profits' by Morel & Kenyon (2006) were calculated by putting a $0.08/kg DM cost on herbage. Fixed costs were set at $7.50/ewe. In terms of revenue the lambs were valued at $2/kg of live weight at weaning. Farm gross margins were calculated by subtracting the herbage and fixed costs from the lamb, wool and cull ewe revenue. This presents limitations in the ability of the calculated gross margins to provide a realistic relationship between ewe prolificacy and farm profitability.

Firstly, weighting fixed costs on a per ewe basis may cause an overestimation of profitability at high ewe prolificacy. As was mentioned in section 5.2 increasing the ewe prolificacy above 129% required a reduction in the number of ewes in order to optimise net profits. In Morel & Kenyon's (2006) gross margin analysis, when the total number of ewes on a farm reduced (due to higher per head energy requirements with higher ewe prolificacy), the fixed costs reduced in proportion to the drop in ewe numbers. In reality most fixed costs such as council rates, interest, managerial labour etc. would remain the same regardless of the number of ewes on a set area of land. In contrast, the Linear Program had higher fixed costs per ewe at higher ewe prolificacy when the number of ewes reduced due to its fixed costs being weighted according to the area of land. (Appendix B provides a breakdown of the variable and fixed costs of the Linear Program-note that some labour costs do increase in terms of casual labour with increasing stock numbers). This could be partially responsible for why the Linear Program recorded a negative Net Profit trend above 190-200% EP, while Morel & Kenyon (2006) still recorded a positive trend in gross margins even above 220% EP.

Different lamb selling policies may have also contributed to the different farm profitability trends between the Linear Program and Morel & Kenyon (2006). Although Morel & Kenyon (2006) differentiated birth to weaning live weight gains between the birth ranks, it assumed the lambs were sold before the cost of lower post weaning live weight gains (between birth ranks) were taken into account. Morel & Kenyon (2006) sold lambs at weaning time based on a figure of $2/kg live weight. The Linear Program on the other hand forced lambs from each birth ranking to be sold prime at a fixed proportion each month (as was deemed to be typical of Canterbury dry land farms). Post weaning live-weight gains and birth weights for lambs in the Linear Program were differentiated between birth ranks. This would have caused differentiated carcass weights between birth rank lambs. In addition, the lighter lambs in the

Linear Program would have been further disadvantaged through being classed into different grades of lamb. If the lambs did not fit the optimal grade, then their price per kilogram of carcass weight would have been reduced according to the Agridata (2008) price schedule. In effect the gross margin by Morel & Kenyon (2006) disadvantaged smaller triplet and quadruplet lambs once, based on live weight, whereas the Linear Program disadvantaged them twice in the form of reduced carcass weights and a lower per kilogram carcass prices.

6.2.1 Scenario Analysis

Scenario analysis in this section aimed to prove whether the factors stated in section 6.2 actually explain the ewe prolificacy/ net profit trend reported in this dissertation. The main drivers of profitability at varying levels of ewe prolificacy could then be distinguished.

The scenario analysis table (Table 13 section 5.5) indicates that at 190% ewe prolificacy, similar increases in net profits (compared to the base scenario) can be achieved between increasing lamb survival and lamb LWG's. If triplet and quadruplet lamb survival rates were to increase to that of twins it resulted in a similar net profit compared to if all lambs were to have 20% higher live weight gains ($71908 compared to $72675 respectively). This would seem to suggest that survival rates of triplet and quadruplet lambs and live weight gains of all lambs would have similar effects on farm profits. In reality the ease by which a farmer could attain either of these scenarios would be different. Increases of triplet and quadruplet survival rates from 65% and 55% (respectively) to 85% would be more difficult to achieve than a 20% increase in all lamb live weight gains. A significant increase in survival rates would require increased lamb birth weights. Lamb birth weights can be increased through pregnancy nutrition but there are limits to how high multiple lamb birth weights can increase. Constraints on the amount of energy a triplet or quadruplet bearing ewe can actually consume (discussed in section 2.2.1) in pregnancy will be a limiting factor for improving triplet and quadruplet lamb survival to that of twins. Lambs on the other hand would unlikely be physiologically limited to the extent of multiple bearing ewes in pregnancy especially to only achieve a modest 20% increase in live weight gains. For example increasing the live weight gains of a triplet from 0.104kg/day to 0.125kg/day (20% increase) would require an additional 0.0079kg DM/day to achieve. This assumed every kilogram of LWG required an extra 40MJME (Nicol & Brooks, 2007) and that pasture quality was 10.5MJME/kg DM.

The increase in energy requirements for a triplet bearing ewe (in the final 2 weeks of pregnancy) to maintain an extra 2kg of lambs (increased weight to improve the lamb survival) would require approximately an extra 0.3kg DM/day assuming every kilogram of lamb (birth weight) required an extra 1.5MJME/day (Table 3 Chapter 3) and pasture quality was 10.5MJME/kg DM. Increasing the live weight gains of the lambs would likely be easier since the increase in ewe dry matter consumption to maintain the 2 kg higher lamb birth weight to increase lamb survival would be equivalent to 0.46% of the ewes 65kg live weight compared to only 0.053% of the lambs (15 kg) live weight.

However, the relative influence of triplet and quadruplet lamb survival on farm net profits increased with increasing ewe prolificacy. For example at 252% EP, increasing lamb survival in scenario 1 increased the net profit from $47114 to $60453, compared to the live weight gain scenario (5) which recorded a $50841 net profit. This is due to the greater proportion of lambs being born as triplet and quadruplets at higher ewe prolificacy, thus making the increased survival rates affect more lambs. Although, increasing triplet and quadruplet lamb survival would be harder to achieve than increasing the live weights gains, the scenario analysis highlights the fact that survival of triplet and quadruplet lambs becomes increasingly important compared to live weight gains (in all lambs) as ewe prolificacy increases.

Increasing the LWG's of triplet and quadruplet lambs in one case (at 280% EP) actually reduced the net profit of the farm relative to the 'base' scenario. The main cause of the reduced net profit at 280% EP was caused by the stocking rate reduction. This reduced from 8.91 SU/ha in the '280% base scenario' to 8.78 SU/ha when lambs achieved 20% higher LWG's. A reduction of 56 ewes was necessary to accommodate the increased lamb energy requirements over the finishing period. The increased meat production from the fewer lambs with greater LWG's thus did not overcome the opportunity cost of the production of 56 fewer ewes.

A factor not mentioned by Morel & Kenyon (2006) as being important for profits was the farmer's lamb selling policy. The inclusion of selling policy scenario's in section 5.5 was not focussed primarily on highlighting the optimum selling strategies at different ewe prolificacy. The intention was rather to highlight how influential selling policies could be on profits. Unfortunately, no recipe for selling lambs could be stated due to the uncertainty that surrounds lamb sales prices. But, the way lambs were sold had the most significant impacts on farms profits at most levels of ewe prolificacy. Selling triplet and quadruplet lambs at the end of the season for example was the scenario that achieved the highest net profits at all levels of ewe prolificacy above 152%.

This would suggest that farmers who aim for high ewe fertility should pay attention to selling strategies. However, this can be difficult as lamb prices are generally outside the influence of farmers. Volatile factors such as exchange rates can have a significant impact on lamb prices. Therefore the success of selling strategies could come down to a degree on luck.

Factors such as live weight gains and lamb survival rates can be controlled to a greater extent by the farmer. However, climatic variability such as storms, summer drought, etc still leave some of the success of the improvements down to chance. Benefits in net profits with increases in triplet and quadruplet survival rates and LWG's will also depend on the average ewe prolificacy of the farm. Between 129% EP and 152% EP, increases in triplet and quadruplet lamb survival and LWG's would not experience a net profit increase. This was due to no triplet or quadruplet lambs actually being born. If the single and twin lambs that made up all the birth ranks at 129-152% EP were to have LWG increases (Scenario 5 Table 13) profits actually reduced due to the necessary reductions in stocking rate. This would indicate that it would actually be better to concentrate on increasing ewe prolificacy rather than lamb LWG's between 129-152% EP (assuming average levels of LWG were being attained). Increasing ewe prolificacy from 152 to 190% would still lead to increased profits, making ewe prolificacy the main driver of profitability. Above the optimal ewe prolificacy of 190% any further increases in EP lead to reduced net profits. At 190% EP, profits could be increased instead by increasing lamb LWG's, lamb survival or through scenario 3 or 4's selling policies.

How triplet and quadruplet lambs were sold was found to be the most important driver of profitability at above average (152% +) ewe prolificacy. Getting the selling policy 'right', for example by selling all triplet and quadruplet lambs prime in May and June at a 190% EP (in the 2006/07 season) could have for example lead to a $10080 increase in profit (compared to the 190% EP 'base' scenario). Achieving an (arguably difficult to achieve) level of triplet and quadruplet survival (85%) in contrast would only lead to a $3626 increase in net profit at the same ewe prolificacy. The statement that selling policies are more important drivers of profitability at above average ewe prolificacy comes with an important admonishment. That is while selling policies were found to have the greatest effect on farm profits, implementing the right selling policy can be difficult since farmers have limited control over the prices they receive. Farmers may have a greater ability to influence triplet and quadruplet survival through management, but the success of doing so would still be dependent on the environment (eg. rainfall, temperatures) being favourable.

If a typical Canterbury sheep and beef farm was achieving above 190% EP then improving triplet and quadruplet lamb survival becomes increasingly important compared to increasing overall lamb live weight gains. This is indicated by the fact that at high (280% EP) ewe prolificacy the net profit from increasing the triplet and quadruplet lamb survival ($55455) exceeded that of when all lambs had 20% extra LWG's ($41703). Though, increases in net profits through improvements in lamb survival or LWG's when ewe prolificacy is over 190% will make up only part of the lost net profits that occurred due to the costs of increasing ewe prolificacy.

In summary, farmers should focus on increasing ewe prolificacy up until approximately 190%, at that point improvements in lamb LWG's and lamb selling policies can be made to improve net profits. Above 190% the survival of triplet and quadruplet lambs becomes an increasingly important driver to the farm's profits. However, the increases in profits will only partially offset the increased costs that high (190-280%) ewe prolificacy create.

6.3 Ewe Prolificacy and Biological Efficiency

It was stated in section 5.4 that the biological efficiency of the farm system increased when Ewe prolificacy increased from 135% to 208%. Above a ewe prolificacy of 208%, biological efficiency reduced. The fact that the maintenance energy requirements of the ewes got divided over an increasing quantity of lambs sold would attribute to the increasing biological efficiency trend between 135% and 208%. Furthermore, as ewe prolificacy increased, a smaller proportion of the total lamb crop had to be held (unavailable for slaughter) as replacements. Above 208% ewe prolificacy, the costs of additional energy requirements to ewes for pregnancy and lactation as well as a lower proportion of lambs born actually surviving until sale started to overcome the benefits of more lambs born per lambing ewe. Section 6.2 stated that the number of lambs born that actually survived until they were old enough to be sold (or defined as replacements) reduced from 81% at a ewe prolificacy of 152% to 71% at 252% EP and 68% at 280% EP. At ewe prolificacy levels above 152% therefore more of the ewe's pregnancy and lactational energy would effectively be wasted on lambs that did not make it to slaughter. Survival rates of the triplet and quadruplet lambs when those birth ranking lambs made up a greater proportion of the lamb crop were thus an important factor deciding the biological efficiency at high ewe prolificacy. Figure 9 (section 5.4) illustrates just how pivotal triplet and quadruplet lamb survival was for biological efficiency. If triplet and quadruplet lamb were to attain survival rates equivalent to that of twin lambs (shown on the X marked trend line on Figure 9) then increases in the farm system's biological efficiency could be still achieved above 208% EP, albeit at a lower rate.

Post weaning lamb live weight gains on the other hand did not show a significant effect on the biological efficiency of the farm system. Greater lamb carcass weights caused by increased lamb live weight gains required proportional increases in energy requirements- cancelling out the benefit of higher live weight gains. Alternatively, the live weight gain biological efficiency trend line may highlight a flaw to the Linear Program model.

Research by Brown (1990) would suggest that increasing live weight gains of lambs (through higher feed quality) should actually improve the biological efficiency of the farm system. As is illustrated in Figure 10 lambs with 250g/day LWG's were found to not only take 60 fewer days to achieve the set slaughter weight, but they also consumed 464MJME less to achieve the same slaughter weight than lambs growing at 100g/day. The Linear Program may not have adequately taken into account this cause of increased biological efficiency. This is because it did not assume lambs were sold when they reached the optimum live weight for slaughter. Instead a fixed proportion of the lambs in each birth ranking were sold each month according to what was considered typical of a Canterbury sheep and beef farm.

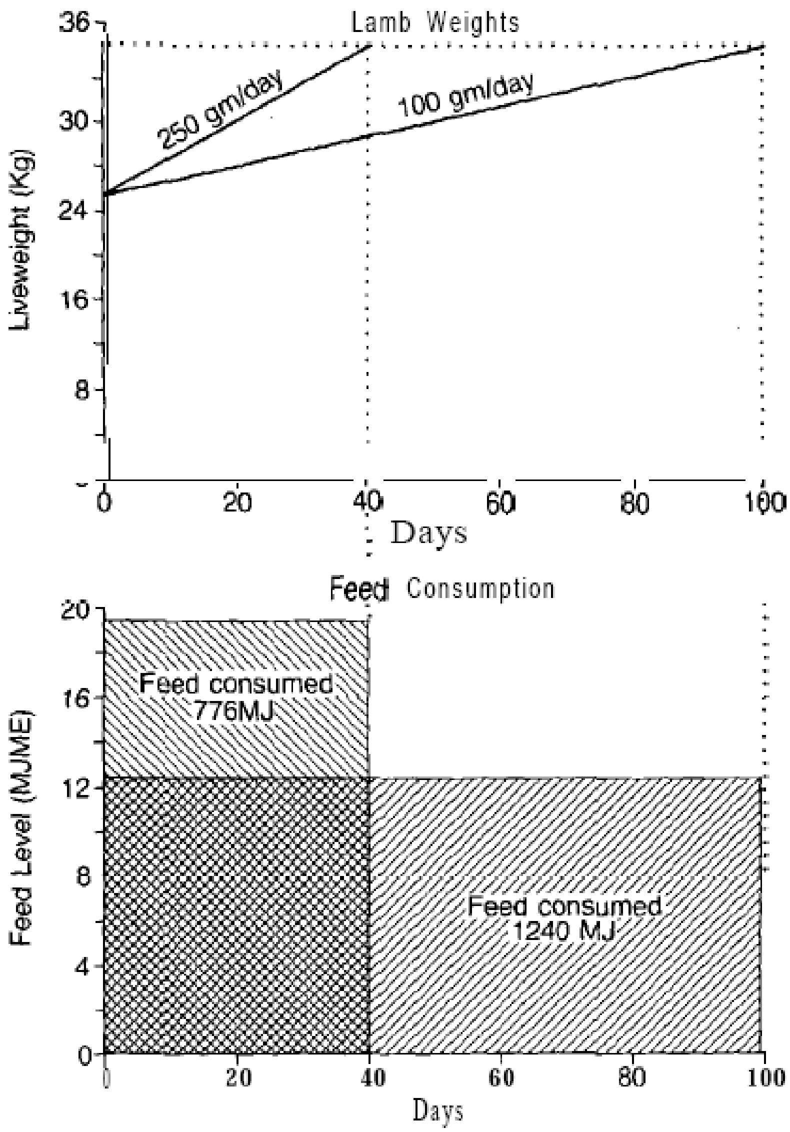

Figure 10: Comparative feed consumption with rate of lamb growth (feed consumption measured in megajoules of metabolisable energy). From Brown (1990).

The optimal economic ewe prolificacy was different to that of the biological optimum. The economic optimum of 190% was 18% less than that of the biological optimum (208%). The biological efficiency Linear Program had a set energy level forced on it. Instead of a typical monthly supply of energy for a dry land Canterbury farm, the Linear Program had an annual energy constraint. This allowed the Linear Program to distribute the energy across the months of the year as it saw fit as providing the optimum net profit. Therefore, it took away the seasonality of energy supply in the farm model. Thus supplements such as silage did not have to be made by the Linear Program, meaning energy losses (wastage) from feed transfer as silage did not occur. A larger proportion of energy grown on the farm could then be utilised by the stock to produce lambs allowing the optimum ewe prolificacy to be higher than that of the economic optimum.

6.4 Risk

It is important to discuss the risk involved in the scenarios mentioned in sections 5 and 6, as risk aversion will vary between farmers making for different 'optimal' scenarios. Also, risk was not quantified in the Linear Program. It is important for a farmer to understand the risks so that strategies can be implemented to reduce, mitigate or avoid them.

Increasing ewe prolificacy carries risk in that it may require better husbandry, feeding or genetics (which all come at a cost) to achieve higher levels of ewe prolificacy. Improved ewe prolificacy is not guaranteed even when the additional costs to aim for higher levels have been incurred. In saying this some risk adverse farmers may decide that the risk associated with increasing higher ewe prolificacy is too high. However, farm systems with lower than average (ie. 129%) ewe prolificacy could be faced with the financial risk of not being able to compete against other sheep and beef farmers, or alternative land uses. Further, at a lower ewe prolificacy the farm will require a higher stocking rate to achieve optimal net profits. This could increase the climatic risk of the system whereby it may come under more pressure if the pasture supply becomes limited by moisture or low temperatures.

The higher ewe prolificacy becomes, the greater the emphasis is needed on ensuring that the ewes actually achieve their target performance levels. Higher ewe prolificacy requires lower stocking rate. So the ewes have to perform better to make up for the loss of ewe numbers. It is thus important to ensure that there is a higher degree of disease management to minimise unnecessary abortions or ewe losses, as well as ensuring feed levels remain optimal at the right times (especially around mating) so the ewes have the ability to achieve their EP targets. Otherwise if per head performance targets are not met the farm would be left with a reduced number of ewes with lower per head feed demands that can not control the pasture quality. The number of lambs available for sale would also be reduced.

By far the greatest increases in net profits at ewe prolificacy levels above 152% were associated with implementing the right selling policy. The returns of doing so must be weighed up against the risks associated with it. It was mentioned in section 6.2.1 that an extra $10080 net profit could be made if the farm sold the triplet and quadruplet lambs (at 190% EP) later in the season as opposed to store in December. The benefits of the increased profits must be weighed up against the product and environmental risks associated with that scenario. It can be difficult for a farmer to anticipate lamb prices in advance (although the new 'backbone' contracts from Silver Fern Farms could reduce some of this uncertainty) and it will be the relative prices for store lambs versus prime lambs in May and June which would decide the actual benefits of such a selling policy. Also, retaining the triplet and quadruplet lambs over the summer on a dry land property would subject the farm to increased drought risk. Moisture limitations to pasture growth over the summer finishing period could end up causing lower than average LWG's for lambs. The farm could then be left with triplet and quadruplet lambs with low weights at the end of the season. The cost of carrying the lambs over the summer could have been saved, if the lambs were sold store in December.

The scenario analysis table (13) indicates that 190% is probably the safest level of ewe prolificacy as it had less variation in net profits between selling policy scenarios than at a higher ewe prolificacy. The difference in net profit between the 'right' selling policy (scenario 4) and 'wrong' selling policy (scenario 3) was only $8184 at a EP of 190%. At 252% the variation in net profit between getting the right selling policy (scenario 4) and the wrong selling policy (scenario 3) was $26841 net profit. At 252% the farm could achieve a higher net profit with selling lambs prime in May and June compared to at 190% ($80640 compared to $78362). However, a farmer would have to weigh up whether striving for the $2278 extra profit is worthwhile considering the extra variability that selling policies have at 252%.

Chapter Seven

Conclusions

7.1 Introduction

The original research questions listed below are answered in this chapter.

- How does increasing ewe prolificacy affect Canterbury dry land farm profitability?
- How does ewe prolificacy affect the efficiency of energy conversion to lamb meat?
- What are the most important drivers of profits across the range of ewe prolificacy?
- What are the most profitable management strategies for farming at high ewe prolificacy?
- Is increasing ewe prolificacy the best way to increase Canterbury dry land sheep and beef farm profitability?
- How well does the Linear Program perform as a tool for farmer decision making?

7.2 How does increasing ewe prolificacy affect Canterbury dry land farm profitability?

Ewe prolificacy had the greatest effect on Canterbury farm profitability between 129% and 190% EP. This arose from lamb revenue increasing at a rate greater than the costs of producing those lambs. As the model assumed the flock was self replacing, when more lambs were born, a smaller proportion of the total lamb crop for instance had to be held as replacements. Thus a larger proportion of the lamb crop was available for sale. Farm profitability was not measured for ewe prolificacy below 129% EP. Above 190% EP, farm profitability reduced with increasing ewe prolificacy. This was attributed to a greater proportion of the lamb crop being born as triplets and quadruplets with lower survival rates and live weight gains. The optimal level of ewe prolificacy is thus being set by the current average levels of lamb performance (in terms of survival and live weight gains) used in the Linear Program as well as the relationship between ewe fertility and the proportion of the ewe litter as each (lamb) birth ranking.

7.3 How does ewe prolificacy affect the efficiency of energy conversion to lamb meat?

A significant increase in the biological efficiency of the farm system resulted when ewe prolificacy increased from 135% to 208%. Energy requirements of ewes being divided over a greater number of saleable lambs attributed to the increased biological efficiency. A greater number of lambs were able to be sold as more lambs were born which reduced the proportion of lambs that had to be kept as replacements. Above 208% EP the biological efficiency reduced, attributed to a larger proportion of triplet and quadruplet lambs being born with lower survival. The stocking rate reduction caused by higher per ewe energy requirements also contributed to the reducing biological efficiency trend. Survival of the triplets and quadruplets was seen as a key factor in the level of biological efficiency. This was because if survival rates of those ‘birth ranking’ lambs were set to that of twins (85% survival from birth to sale) biological efficiencies could continue to increase above 208% EP, albeit at a lower rate than below 208% EP.

7.4 What are the most important drivers of profits across the range of ewe prolificacy?

Ewe prolificacy was the most important driver from 129-190% EP. Increasing ewe prolificacy above this point resulted in reduced profits. At 190% EP increases in triplet and quadruplet lamb survival and triplet and quadruplet lamb live weight gains had similar effects on profits. However, the levels of triplet and quadruplet survival to achieve similar levels of profit compared to 20% increases in live weight gains were 85% survival from birth to sale. This is a significant increase in survival rates and would require increased lamb birth weights. Lamb birth weights can be increased through pregnancy nutrition but there are limits to how high multiple lamb birth weights can be increased. Constraints on the amount of energy a triplet or quadruplet bearing ewe can actually consume is one such limitation. It was calculated in section 6.2.1 in relation to live weight the 20% increase in live weight gains would be more easily achieved by lambs compared to a triplet bearing ewe trying to maintain 2kg of additional lamb weight in order to achieve sufficient lamb survival. However, the importance of triplet and quadruplet survival did increase with increasing EP due to a larger proportion of the lamb crop as triplets and quadruplets.

The selling policy scenario of selling all triplet and quadruplet lambs in May and June was calculated to increase farm net profits by the most when ewe prolificacy was above 152% highlighting the importance of selling policies on farm profits at high ewe prolificacy.

Although this research highlighted the importance of a number of potential drivers of profitability, it did not include every possible driver. For example scenario analysis did not include changes to wool production, expenditure, product prices or any more than the 2 alternative selling policies. Therefore, the drivers left out of the analysis could have a greater impact on the profitability of the farm, but the purpose of the analysis was to highlight drivers that related specifically to ewe prolificacy, rather than general drivers of profitability.

7.5 What are the most profitable management strategies for farming at high ewe prolificacy?

According to the Linear Program the best strategy for a farmer who operates a typical Canterbury sheep and beef farm is to aim for a ewe prolificacy of 190%. At that point further increases in profits can be made through increases in lamb live weight gains of triplet and quadruplet lambs. Increasing survival rates of triplet and quadruplet lambs becomes more important at higher ewe prolificacy. However, changes in selling policies can have the greatest effect on farm profits. It must be noted that the Linear Program did not do justice to the benefits of a strategy in improving lamb LWG's owing to the way lamb sales were calculated in the model.

7.6 Is increasing ewe prolificacy the best way to increase Canterbury dry land sheep and beef farm profitability?

Whether or not increasing ewe prolificacy is the best way of increasing profits will depend on what ewe prolificacy the farm had previously achieved. In some cases (according to the Linear Program) a farm could actually improve profitability by reducing ewe prolificacy assuming the farm also achieves 'average' lamb survival rates and LWG's. This situation would occur if the farm was already achieving over the optimal (190%) ewe prolificacy. However, increasing ewe prolificacy between 129-190% EP was found to be one of the best ways of increasing profits.

At 190% ewe prolificacy focussing on lamb live weight gains became a better way of improving profits. Further, the higher the ewe prolificacy the greater the importance of triplet and quadruplet lamb survival as methods of improving profitability.

Selling policies were also important ways of improving farm profitability. However, farmers generally cannot influence their lamb sales prices so focussing on factors they can alter such as ewe prolificacy is recommended.

7.7 How well does the Linear Program perform as a tool for farmer decision making?

Instead of the user putting in the livestock numbers like Farmax, the Linear Program model uses all the farm parameters such as area, pasture growth etc. to decide what the optimal number of stock is.

A disadvantage to the Linear Program is the difficulty it has changing the timing of events such as mating time. Changing the timing of mating would take a lot of time rearranging livestock energy requirements and some parts of the Linear Program. The model also does not take into account risk, therefore a detailed analysis of risk involved in a Linear Program's output such as that in section 6.4 is vital for a farmer/researcher to make the right decisions. What makes up for this is the ease by which the user can change livestock weights and ewe prolificacy and the model will automatically calculate the per head energy requirements on per day and per month bases.

While the farm assumptions are based on a typical Canterbury sheep and beef farm, the; land area; product prices; farm variable; and fixed expenses can be easily changed. Once more, the pasture supply can be changed to suit any possible annual pasture growth profile. Changing the number in one cell in the 'Pasture Quality and Supply' spreadsheet can also change the topography of the farm which not only alters maintenance energy coefficients for each class of stock, but also changes the average lamb survival and LWG's according to topography as was reported by Amer et al. (1999). This would make it readily transferable to a range of sheep and beef farms around New Zealand.

Most computer literate farmers would be familiar with Excel used for the Linear Program making it easier for farmers or consultants to be trained to use it. The model was developed in a way so that only the background spreadsheets needed to have farm parameters entered into them. The actual Linear Program spreadsheet (which many farmers would be not familiar with) was linked to the background spreadsheets so that farmers did not have to understand how the Linear Program worked in order to use it.

Linear programming is less expensive and quicker than a full farm trial, and can control environmental effects. Linear Programs require assumptions which may not be 100% accurate, but provides useful output for analysis of trends, rather than absolute figures allowing for more informed decision making.

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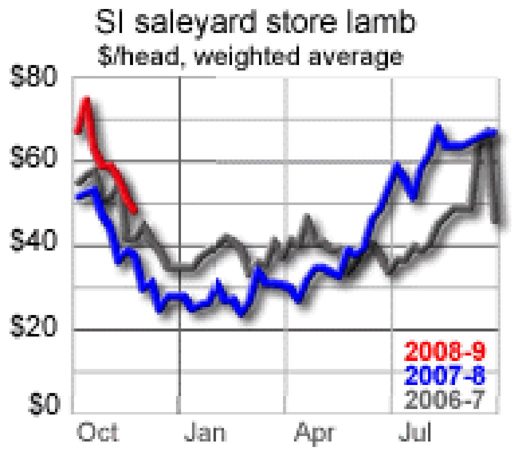
Appendices

Appendix A-South Island store lamb prices from Agridata (2008)



Appendix B-Variable and Fixed Costs for Linear Program

Class of stock	Dry ewe hogget	2th ewe	4th ewe	6th ewe	4yr ewe	5yr ewe	6yr ewe	Rams
Variable costs for animals	$/SU	$/SU	$/SU	$/SU	$/SU	$/SU	$/SU	$/SU
Shearing costs	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62
Animal health	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47
Breeding	0	0	0	0	0	0	0	0
Casual wages	3.50	4.62	4.62	4.62	4.62	4.62	4.62	4.62
R+M	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.99
Purchases	0	0	0	0	0	0	0	60.00
Other								
Total variable costs ($/SU)	15.6	16.7	16.7	16.7	16.7	16.7	16.7	76.7

Fixed costs	$/ha
Weed and pest control	13
Fertiliser	50
Lime	4
Seeds?	7
Vehicle expenses	14
Fuel?	18
Electricity	5
Administration	15
ACC levies	4
Insurance	6
Rates	14
Managerial salaries	4
Interest (excl interest on	80
Rent	
Irrigation	
Other	33
Other	
Total	267

Appendix C- 1 Livestock Fertility and Demand Spreadsheet

Livestock fertility and demand for: Ewe prolificacy and farm profits for Masters dissertation

Yellow or blue cells indicate formulae are in place or that they require no input data, white cells require input data from user, black cells indicate the cell is not applicable to that class of stock

No. days		Dry ewe hogget	Wet ewe hogget	Wether hogget	2th ewe	4th ewe	6th ewe	4yr	5yr	6yr	Rams	Ris 1 Cattle 1 year finish system
	Cull rate (% pa)	4%	5%	4%	3%	3%	3%	3%	3%	3%	10%	1%
	Death rate (% pa)	4%	7%	4%	3%	3%	3%	3%	3%	3%	10%	1%
	Liveweight (kg 1 month prior to tupping at start of March	35	35	0	65	65	65	65	65	65	90	
31	Maintenance energy requirement (MJME/day)	6.9	6.9	0.0	11.0	11.0	11.0	11.0	11.0	11.0	16.1	
	Average pasture allowance for 1 month pre tupping (March) (kg DM/day)	1.2	1.2	0	1.2	1.3	1.3	1.3	1.3	1.3	2	
	Energy of feed allowance (MJME/kg DM)	12.6	12.6	0.0	12.6	13.7	13.7	13.7	13.7	13.7	21.0	
	Energy requirement above maintenance (MJME/day)	5.7	5.7	0.0	1.6	2.7	2.7	2.7	2.7	2.7	4.9	
	Live weight gain	0.10	0.10	0.00	0.03	0.05	0.05	0.05	0.05	0.05	0.09	
	Total March energy requirement (MJME)	390.6	390.6	0.0	390.6	423.2	423.2	423.2	423.2	423.2	651.0	
	Genetic coefficient		0.6		0.86	0.86	0.86	0.86	0.86	0.86		
	Androvax effect		1		1	1	1	1	1	1		
	Ovulation rate		0.91		1.59	1.59	1.59	1.59	1.59	1.59		
	Max lambs per mated ewe		0.91		1.59	1.59	1.59	1.59	1.59	1.59		
	Embryos lost between tupping and scanning		0.05		0.06	0.06	0.06	0.06	0.06	0.06		
	Lamb survival from pregnancy diagnosis to birth		0.917		0.917	0.927	0.927	0.927	0.927	0.927		
	No. lambs born per ewe mated		0.78		1.4	1.4	1.4	1.4	1.4	1.4		
	No. lambs born per ewe lambing **(EP)**		0.86		1.5	1.5	1.5	1.5	1.5	1.5		
	Proportion of lambs as Singles		1.00		0.5	0.5	0.5	0.5	0.5	0.5		
	Proportion of lambs as Twins		0.00		0.5	0.5	0.5	0.5	0.5	0.5		
	Proportion of lambs as Triplets		0		0	0	0	0	0	0		
	Proportion of lambs as Quadruplets		0		0	0	0	0	0	0		
	Single lamb survival from birth to weaning		0.72		0.90	0.90	0.90	0.90	0.90	0.90		
	Twin lamb survival from birth to weaning		0.68		0.85	0.85	0.85	0.85	0.85	0.85		
	Triplet lamb survival from birth to weaning		0.52		0.65	0.65	0.65	0.65	0.65	0.65		
	Quadruplet lamb survival from birth to weaning		0.44		0.55	0.55	0.55	0.55	0.55	0.55		
	Single lamb birth weight (kg)		5.4		6	6	6	6	6	6		
	Twin lamb birth weight (kg)		4.5		5	5	5	5	5	5		
	Triplet lamb birth weight (kg)		3.69		4	4	4	4	4	4		
	Quadruplet lamb birth weight (kg)		2.7		3	3	3	3	3	3		
	Average total lamb birth weight per ewe weighted for the % of lambs with different birth rank and their different birth weights		4.6		8.3	8.3	8.3	8.3	8.3	8.3		
	% Barren after tupping		10%		5%	5%	5%	5%	5%	5%		
Activity coefficient		0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.62
April 30	Live weight	38.1	38.1	0.0	65.9	66.5	66.5	66.5	66.5	66.5	92.7	240
April 30	Live weight gain (kg/day)	0.1	0.1		0.0	0.0	0.0	0.0	0.0	0.0		0.67
April 30	Energy for maintenance (MJME/day)	7.6	7.6	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	39.0

	Ewe lambs from hoggets (singles)	Wether lambs from hoggets (singles)	Ewe lambs from hoggets (twins)	Wether lambs from hoggets (twins)	Ewe lambs from ewes (singles)	Ewe lambs from ewes (twins)	Ewe lambs from ewes (triplets)	Ewe lambs from ewes (quadruplets)	Wether lambs from ewes (singles)	Wether lambs from ewes (twins)	Wether lambs from ewes (triplets)	Wether lambs from ewes (quadruplets)	Ram lambs from ewes (singles)	Ram lambs from ewes (twins)	Ram lambs from ewes (triplets)	Ram lambs from ewes (quadruplets)	Cryptorchid lambs from ewes (singles)	Cryptorchid lambs from ewes (twins)	Cryptorchid lambs from ewes (triplets)	Cryptorchid lambs from ewes (quadruplets)
Activity coefficient	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
April 30 Live weight	0	0	0	0	0	0	0													
April 30 Live weight gain (kg/day)																				
April 30 Energy for maintenance (MJME/day)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix C- 2 Livestock Fertility and Demand Spreadsheet

April	30	Energy for LWG (MJME/day)	5.5	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0																					18.09
April	30	Energy for Pregnancy (MJME/day)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
April	30	Energy for lactation (MJME/day)																															
April	30	Total daily energy (MJME/day)	13.1	13.1	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57.1
April	30	Total April energy requirement (MJME/month)	392.4	392.4	0.0	333.1	335.3	335.3	335.3	335.3	335.3	494.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1712.3
May	31	Live weight	41.1	41.1	0.0	65.9	66.5	66.5	66.5	66.5	66.5	92.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	260.1
May	31	Live weight gain (kg/day)	0.2	0.3		0.0	0.0	0.0	0.0	0.0	0.0																						0.67
May	31	Energy for maintenance (MJME/day)	8.2	8.4	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	41.4
May	31	Energy for LWG (MJME/day)	11.0	16.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0																					18.09
May	31	Energy for Pregnancy (MJME/day)																															
May	31	Energy for lactation (MJME/day)																															
May	31	Total daily energy (MJME/day)	19.2	24.9	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	59.4
May	31	Total May energy requirement (MJME/month)	596.2	773.3	0.0	344.2	346.5	346.5	346.5	346.5	346.5	511.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1842.7
June	30	Live weight	47.3	50.4	0.0	65.9	66.5	66.5	66.5	66.5	66.5	92.7																					280.87
June	30	Live weight gain (kg/day)	0.1	0.1		0.0	0.0	0.0	0.0	0.0	0.0																						0.67
June	30	Energy for maintenance (MJME/day)	8.9	9.3	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43.7
June	30	Energy for LWG (MJME/day)	5.5	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0																					18.09
June	30	Energy for Pregnancy (MJME/day)																															
June	30	Energy for lactation (MJME/day)																															
June	30	Total daily energy (MJME/day)	14.4	14.8	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61.8
June	30	Total June energy requirement (MJME/month)	430.9	443.5	0.0	333.1	335.3	335.3	335.3	335.3	335.3	494.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1852.9
July	31	Live weight	50.3	53.4	0.0	65.9	66.5	66.5	66.5	66.5	66.5	92.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	301.0
July	31	Live weight gain (kg/day)	0.1	0.1		0.0	0.0	0.0	0.0	0.0	0.0																						0.5
July	31	Energy for maintenance (MJME/day)	9.3	9.7	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45.7
July	31	Energy for LWG (MJME/day)	5.5	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0																					16
July	31	Energy for Pregnancy (MJME/day)		2.3		4.1	4.2	4.2	4.2	4.2	4.2																						
July	31	Energy for lactation (MJME/day)																															
July	31	Total daily energy (MJME/day)	14.8	17.5	0.0	15.2	15.3	15.3	15.3	15.3	15.3	16.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61.7
July	31	Total July energy requirement (MJME/month)	458.1	543.0	0.0	472.7	475.8	475.8	475.8	475.8	475.8	511.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1911.6
August	31	Live weight	53.4	56.5	0.0	65.9	66.5	66.5	66.5	66.5	66.5	92.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	316.5
August	31	Live weight gain (kg/day)	0.1	0.1		0.0	0.0	0.0	0.0	0.0	0.0																						0.5
August	31	Energy for maintenance (MJME/day)	9.7	10.1	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	47.4
August	31	Energy for LWG (MJME/day)	5.5	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0																					16
August	31	Energy for Pregnancy (MJME/day)		3.9		6.9	7.0	7.0	7.0	7.0	7.0																						
August	31	Energy for lactation (MJME/day)																															
August	31	Total daily energy (MJME/day)	15.2	19.5	0.0	18.0	18.1	18.1	18.1	18.1	18.1	16.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63.4
August	31	Total August energy requirement (MJME/month)	470.9	603.6	0.0	558.4	562.0	562.0	562.0	562.0	562.0	511.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1964.5
September	30	Live weight	56.5	59.6	0.0	65.9	66.5	66.5	66.5	66.5	66.5	92.7	5.4	5.4	4.5	4.5	6	5	4.1	3	6	5	4.1	3	6	5	4.1	3	6	5	4.1	3	332.0
September	30	Live weight gain (kg/day)		0.0		0.0	0.0	0.0	0.0	0.0	0.0		0.18	0.18	0.18	0.18	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.5
September	30	Energy for maintenance (MJME/day)	9.9	10.3	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5																					49.0
September	30	Energy for LWG (MJME/day)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0							Lamb maintenance and LWG requirements are covered in the ewe requirements until after weaning after 12 weeks(in December)														16
September	30	Energy for Pregnancy (MJME/day)																															
September	30	Energy for lactation (MJME/day)		7.6		16.9	16.9	16.9	16.9	16.9	16.9																						

Appendix C- 3 Livestock Fertility and Demand Spreadsheet

September	30	Total daily energy (MJME/day)	9.9	17.9	0.0	28.0	28.1	28.1	28.1	28.1	28.1	16.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	65.0
September	30	Total September energy requirement (MJME/month)	296.8	537.2	0.0	841.1	843.4	843.4	843.4	843.4	843.4	494.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1951.0
October	31	Live weight	56.5	59.6	0.0	65.9	66.5	66.5	66.5	66.5	66.5	92.7	10.8	10.8	9.9	9.9	12	11	10.1	9	12	11	10.1	9	12	11	10.1	9	12	11	10.1	9	347.0
October	31	Live weight gain (kg/day)				0.0	0.0	0.0	0.0	0.0	0.0		0.18	0.18	0.18	0.18	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	1.21
October	31	Energy for maintenance (MJME/day)	9.9	10.3	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5																					51.9
October	31	Energy for LWG (MJME/day)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0								This energy requirement is covered in ewe energy until weaning at 12 weeks													47.19
October	31	Energy for Pregnancy (MJME/day)																															
October	31	Energy for lactation (MJME/day)		9.1		20.3	20.3	20.3	20.3	20.3	20.3																						
October	31	Total daily energy (MJME/day)	9.9	19.4	0.0	31.4	31.5	31.5	31.5	31.5	31.5	16.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	99.0
October	31	Total October energy requirement (MJME/month)	306.7	602.3	0.0	974.2	976.5	976.5	976.5	976.5	976.5	511.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3070.3
November	30	Live weight	56.5	59.6	0.0	65.9	66.5	66.5	66.5	66.5	66.5	92.7	16.38	16.38	15.48	15.48	18.2	17.2	16.3	15.2	18.2	17.2	16.3	15.2	18.2	17.2	16.3	15.2	18.2	17.2	16.3	15.2	384.48
November	30	Live weight gain (kg/day)				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.18	0.18	0.18	0.18	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	1.21
November	30	Energy for maintenance (MJME/day)	9.9	10.3	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5																					55.7
November	30	Energy for LWG (MJME/day)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0																					47.19
November	30	Energy for Pregnancy (MJME/day)																															
November	30	Energy for lactation (MJME/day)		10.2		22.7	22.7	22.7	22.7	22.7	22.7																						
November	30	Total daily energy (MJME/day)	9.9	20.5	0.0	33.8	33.9	33.9	33.9	33.9	33.9	16.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	102.9
November	30	Total November energy requirement (MJME/month)	296.8	614.8	0.0	1013.9	1016.1	1016.1	1016.1	1016.1	1016.1	494.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3087.5
December	31	Live weight	56.5	59.6	0.0	65.9	66.5	66.5	66.5	66.5	66.5	92.7	21.8	21.8	20.9	20.9	24.2	23.2	22.3	21.2	24.2	23.2	22.3	21.2	24.2	23.2	22.3	21.2	24.2	23.2	22.3	21.2	420.78
December	31	Live weight gain (kg/day)				0.0	0.0	0.0	0.0	0.0	0.0		0.14	0.14	0.12	0.12	0.16	0.13	0.10	0.08	0.16	0.13	0.10	0.08	0.19	0.16	0.12	0.10	0.22	0.19	0.15	0.12	1.21
December	31	Energy for maintenance (MJME/day)	9.9	10.3	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	4.9	4.9	4.7	4.7	5.3	5.1	4.9	4.6	5.3	5.1	4.9	4.6	5.9	5.7	5.5	5.2	6.0	5.8	5.5	5.3	59.5
December	31	Energy for LWG (MJME/day)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	5.6	4.7	4.7	6.2	5.2	4.2	3.3	6.2	5.2	4.2	3.3	5.6	4.7	3.7	3.0	6.7	5.6	4.5	3.6	47.2
December	31	Energy for Pregnancy (MJME/day)																															
December	31	Energy for lactation (MJME/day)																															
December	31	Total daily energy (MJME/day)	9.9	10.3	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	10.5	10.5	9.4	9.4	11.5	10.3	9.0	8.0	11.5	10.3	9.0	8.0	11.6	10.4	9.2	8.2	12.8	11.4	10.0	8.9	106.7
December	31	Total December energy requirement (MJME/month)	306.7	319.3	0.0	344.2	346.5	346.5	346.5	346.5	346.5	511.4	325.2	325.2	290.1	290.1	356.9	318.2	279.8	247.2	356.9	318.2	279.8	247.2	358.2	321.6	285.4	254.3	396.0	353.1	310.6	274.5	3307.9
January	31	Live weight	56.5	59.6	0.0	65.9	66.5	66.5	66.5	66.5	66.5	92.7	26.1	26.1	24.5	24.5	29.0	27.2	25.5	23.8	29.0	27.2	25.5	23.8	30.0	28.0	26.2	24.3	31.2	29.0	26.9	24.9	458.3
January	31	Live weight gain (kg/day)				0.0	0.0	0.0	0.0	0.0	0.0		0.14	0.14	0.12	0.12	0.16	0.13	0.10	0.08	0.16	0.13	0.10	0.08	0.19	0.16	0.12	0.10	0.22	0.19	0.15	0.12	1.21
January	31	Energy for maintenance (MJME/day)	9.9	10.3	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	5.5	5.5	5.2	5.2	6.0	5.7	5.4	5.0	6.0	5.7	5.4	5.0	6.9	6.5	6.1	5.7	7.1	6.7	6.3	5.9	63.3
January	31	Energy for LWG (MJME/day)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.3	6.3	5.3	5.3	7.0	5.9	4.7	3.7	7.0	5.9	4.7	3.7	6.6	5.5	4.4	3.5	7.9	6.6	5.2	4.2	47.2
January	31	Energy for Pregnancy (MJME/day)																															
January	31	Energy for lactation (MJME/day)																															
January	31	Total daily energy (MJME/day)	9.9	10.3	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	11.8	11.8	10.5	10.5	13.0	11.5	10.0	8.8	13.0	11.5	10.0	8.8	13.4	11.9	10.5	9.2	15.0	13.3	11.5	10.1	110.5
January	31	Total January energy requirement (MJME/month)	306.7	319.3	0.0	344.2	346.5	346.5	346.5	346.5	346.5	511.4	367.1	367.1	325.3	325.3	402.9	356.8	310.9	272.4	402.9	356.8	310.9	272.4	416.1	370.2	324.6	286.0	465.1	411.2	357.5	312.4	3424.8
February	28	Live weight	56.5	59.6	0.0	65.9	66.5	66.5	66.5	66.5	66.5	92.7	30.5	30.5	28.1	28.1	33.9	31.3	28.7	26.4	33.9	31.3	28.7	26.4	35.8	32.9	30.0	27.4	38.1	34.8	31.6	28.6	495.8
February	28	Live weight gain (kg/day)				0.0	0.0	0.0	0.0	0.0	0.0		0.14	0.14	0.12	0.12	0.16	0.13	0.10	0.08	0.16	0.13	0.10	0.08	0.19	0.16	0.12	0.10	0.22	0.19	0.15	0.12	0.77
February	28	Energy for maintenance (MJME/day)	9.9	10.3	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	6.1	6.1	5.7	5.7	6.6	6.2	5.8	5.4	6.6	6.2	5.8	5.4	7.7	7.2	6.7	6.2	8.1	7.6	7.0	6.5	66.2
February	28	Energy for LWG (MJME/day)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	7.0	5.9	5.9	7.8	6.5	5.2	4.2	7.8	6.5	5.2	4.2	6.6	5.5	4.4	3.5	7.9	6.6	5.2	4.2	39.3
February	28	Energy for Pregnancy (MJME/day)																															
February	28	Energy for lactation (MJME/day)																															
February	28	Total daily energy (MJME/day)	9.9	10.3	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	13.1	13.1	11.6	11.6	14.4	12.7	11.0	9.6	14.4	12.7	11.0	9.6	14.3	12.7	11.1	9.7	16.0	14.1	12.2	10.7	105.5
February	28	Total February energy requirement (MJME/month)	277.0	288.4	0.0	310.9	313.0	313.0	313.0	313.0	313.0	461.9	367.9	367.9	324.4	324.4	403.8	355.8	307.9	267.9	403.8	355.8	307.9	267.9	399.5	354.6	309.7	271.8	448.1	395.3	342.5	298.2	2953.2
March	31	Live weight	56.5	59.6	0.0	65.9	66.5	66.5	66.5	66.5	66.5	92.7	34.4	34.4	31.4	31.4	38.2	34.9	31.7	28.7	38.2	34.9	31.7	28.7	41.0	37.2	33.5	30.2	44.4	40.0	35.8	32.0	517.4

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March	31	Live weight gain (kg/day)				0.0	0.0	0.0	0.0	0.0	0.0		0.14	0.14	0.12	0.12	0.16	0.13	0.10	0.08	0.16	0.13	0.10	0.08	0.19	0.16	0.12	0.10	0.22	0.19	0.15	0.12	0.77
March	31	Energy for maintenance (MJME/day)	9.9	10.3	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	6.7	6.7	6.2	6.2	7.2	6.7	6.2	5.8	7.2	6.7	6.2	5.8	8.5	7.9	7.3	6.7	9.1	8.4	7.7	7.0	68.4
March	31	Energy for LWG (MJME/day)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	7.0	5.9	5.9	7.8	6.5	5.2	4.2	7.8	6.5	5.2	4.2	9.4	7.8	6.2	5.0	11.2	9.4	7.5	6.0	39.3
March	31	Energy for Pregnancy (MJME/day)																															
March	31	Energy for lactation (MJME/day)																															
March	31	Total daily energy (MJME/day)	9.9	10.3	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	13.7	13.7	12.1	12.1	15.0	13.2	11.4	9.9	15.0	13.2	11.4	9.9	17.9	15.7	13.5	11.7	20.3	17.7	15.2	13.0	107.7
March	31	Total March energy requirement (MJME/month)	306.7	319.3	0.0	344.2	346.5	346.5	346.5	346.5	346.5	511.4	425.2	425.2	374.4	374.4	466.4	410.4	354.5	307.7	466.4	410.4	354.5	307.7	554.7	486.8	418.7	362.0	630.4	550.2	469.8	403.2	3338.3
April	30	Live weight	56.5	59.6	0.0	65.9	66.5	66.5	66.5	66.5	66.5	92.7	38.8	38.8	35.0	35.0	43.1	38.9	34.9	31.3	43.1	38.9	34.9	31.3	46.9	42.1	37.4	33.3	51.4	45.9	40.4	35.7	240.0
April	30	Live weight gain (kg/day)				0.0	0.0	0.0	0.0	0.0	0.0		0.14	0.14	0.12	0.12	0.16	0.13	0.10	0.08	0.16	0.13	0.10	0.08	0.19	0.16	0.12	0.10	0.22	0.19	0.15	0.12	0.67
April	30	Energy for maintenance (MJME/day)	9.9	10.3	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	7.3	7.3	6.7	6.7	7.9	7.3	6.7	6.1	7.9	7.3	6.7	6.1	9.4	8.6	7.8	7.2	10.1	9.2	8.3	7.6	39.0
April	30	Energy for LWG (MJME/day)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	7.0	5.9	5.9	7.8	6.5	5.2	4.2	7.8	6.5	5.2	4.2	9.4	7.8	6.2	5.0	11.2	9.4	7.5	6.0	18.1
April	30	Energy for Pregnancy (MJME/day)																															
April	30	Energy for lactation (MJME/day)																															
April	30	Total daily energy (MJME/day)	9.9	10.3	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	14.3	14.3	12.6	12.6	15.7	13.8	11.9	10.3	15.7	13.8	11.9	10.3	18.7	16.4	14.1	12.2	21.3	18.6	15.8	13.6	57.1
April	30	Total April energy requirement (MJME/month)	296.8	309.0	0.0	333.1	335.3	335.3	335.3	335.3	335.3	494.9	428.8	428.8	377.2	377.2	470.2	413.3	356.2	308.6	470.2	413.3	356.2	308.6	561.4	492.1	422.5	364.6	638.9	557.2	475.1	407.0	1712.3
May	31	Live weight	56.5	59.6	0.0	65.9	66.5	66.5	66.5	66.5	66.5	92.7	43.0	43.0	38.5	38.5	47.8	42.8	38.0	33.8	47.8	42.8	38.0	33.8	52.5	46.8	41.1	36.3	58.1	51.5	44.9	39.3	260.1
May	31	Live weight gain (kg/day)				0.0	0.0	0.0	0.0	0.0	0.0		0.14	0.14	0.12	0.12	0.16	0.13	0.10	0.08	0.16	0.13	0.10	0.08	0.19	0.16	0.12	0.10	0.22	0.19	0.15	0.12	0.67
May	31	Energy for maintenance (MJME/day)	9.9	10.3	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	7.8	7.8	7.2	7.2	8.5	7.8	7.1	6.5	8.5	7.8	7.1	6.5	10.1	9.3	8.4	7.6	11.0	10.0	9.0	8.1	41.4
May	31	Energy for LWG (MJME/day)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	7.0	5.9	5.9	7.8	6.5	5.2	4.2	7.8	6.5	5.2	4.2	9.4	7.8	6.2	5.0	11.2	9.4	7.5	6.0	18.1
May	31	Energy for Pregnancy (MJME/day)																															
May	31	Energy for lactation (MJME/day)																															
May	31	Total daily energy (MJME/day)	9.9	10.3	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	14.9	14.9	13.1	13.1	16.3	14.3	12.3	10.6	16.3	14.3	12.3	10.6	19.5	17.1	14.6	12.6	22.2	19.4	16.5	14.1	59.4
May	31	Total May energy requirement (MJME/month)	306.7	319.3	0.0	344.2	346.5	346.5	346.5	346.5	346.5	511.4	460.6	460.6	404.7	404.7	504.8	443.2	381.5	329.9	504.8	443.2	381.5	329.9	604.8	529.6	454.1	391.2	689.0	600.5	511.4	437.5	1842.7
June	30	Live weight	56.5	59.6	0.0	65.9	66.5	66.5	66.5	66.5	66.5	92.7	47.3	47.3	42.2	42.2	52.6	46.9	41.2	36.3	52.6	46.9	41.2	36.3	58.3	51.6	45.0	39.4	65.1	57.3	49.6	43.0	280.9
June	30	Live weight gain (kg/day)				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.14	0.14	0.12	0.12	0.16	0.13	0.10	0.08	0.16	0.13	0.10	0.08	0.19	0.16	0.12	0.10	0.22	0.19	0.15	0.12	0.67
June	30	Energy for maintenance (MJME/day)	9.9	10.3	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	8.4	8.4	7.7	7.7	9.1	8.3	7.5	6.8	9.1	8.3	7.5	6.8	10.9	10.0	9.0	8.1	11.9	10.8	9.7	8.7	43.7
June	30	Energy for LWG (MJME/day)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	7.0	5.9	5.9	7.8	6.5	5.2	4.2	7.8	6.5	5.2	4.2	9.4	7.8	6.2	5.0	11.2	9.4	7.5	6.0	18.1
June	30	Energy for Pregnancy (MJME/day)																															
June	30	Energy for lactation (MJME/day)																															
June	30	Total daily energy (MJME/day)	9.9	10.3	0.0	11.1	11.2	11.2	11.2	11.2	11.2	16.5	15.4	15.4	13.5	13.5	16.9	14.8	12.7	11.0	16.9	14.8	12.7	11.0	20.3	17.8	15.2	13.1	23.1	20.1	17.1	14.6	61.8
June	30	Total June energy requirement (MJME/month)	296.8	309.0	0.0	333.1	335.3	335.3	335.3	335.3	335.3	494.9	462.3	462.3	405.9	405.9	506.4	444.3	381.9	329.7	506.4	444.3	381.9	329.7	608.5	532.5	456.0	392.2	693.9	604.5	514.3	439.5	1852.9
Total annual energy requirement			4446.0	5756.1	0.0	6214.2	6243.5	6243.5	6243.5	6243.5	6243.5	6021.4	1485.3	1485.3	1314.2	1314.2	1630.0	1441.2	1253.1	1095.2	1630.0	1441.2	1253.1	1095.2	1728.5	1533.1	1338.4	1174.1	1939.6	1709.8	1480.4	1288.3	30417.0
MJME per Stock unit	6000																																
Annual equivalent stock units			0.74	0.96	0.00	1.04	1.04	1.04	1.04	1.04	1.04	1.00	0.25	0.25	0.22	0.22	0.27	0.24	0.21	0.18	0.27	0.24	0.21	0.18	0.29	0.26	0.22	0.20	0.32	0.28	0.25	0.21	5.07

Appendix D Set up of pages

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Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

Appendix D: Linear Program fo Ewe prolificacy and farm profits for Masters dissertation

Put a 1 beside the box that will represent the male lambs(otherwise use a 0) | Wether | 1 | Ram | 0 | Cryptorchid | 0 | 0/1?

Put a 1 above the class of lambs that are sold prime otherwise leave as 0 if sold store | 1

	Constraint	Reltnshp	Demand	Dry hgt/2th tie	Wet ewe hogget	Dry/wet hogget tie	2th	4th	6th	4yr	5yr	6yr	Rams	Ewe lambs from hoggets (singles)	Wether lambs from hoggets (singles)	Ewe lambs from hoggets (twins)	Wether lambs from hoggets (twins)	Ewe lambs from ewe (singles)	Ewe lambs from ewes (twins)	Ewe lambs from ewes (triplets)	Ewe lambs from ewes (quadruplets)	Wether lambs from ewes (singles)	Wether lambs from ewes (twins)	Wether lambs from ewes (triplets)	Wether lambs from ewes (Quadruplets)	Ram lambs from ewes (singles)	Ram lambs from ewes (twins)	Ram lambs from ewes (triplets)	Ram lambs from ewes (quadruplets)	Cryptorchid lambs from ewes (singles)	Cryptorchid lambs from ewes (twins)	Cryptorchid lambs from ewes (triplets)	Cryptorchid lambs from ewes (quadruplets)	Cattle	Triplet ewe lambs sold November
Area of land (ha)	378	≤	378																																
Silage	0	≤	0																																
Livestock Energy	0	≤	0																																
June	0	≤	0	431	444		333	335	335	335	335	335	495	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1853	
July	0	≤	0	458	543		473	476	476	476	476	476	511	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1912	
August	0	≤	0	471	604		558	562	562	562	562	562	511	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1965	
September	0	≤	0	297	537		841	843	843	843	843	843	495	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1951	
October	0	≤	0	307	602		974	976	976	976	976	976	511	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3070	
November	0	≤	0	297	615		1014	1016	1016	1016	1016	1016	495	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3088	
December	0	≤	0	307	319		344	347	347	347	347	347	511	325	325	290	290	357	318	280	247	357	318	280	247	358	322	285	254	396	353	311	275	3308	
January	0	≤	0	307	319		344	347	347	347	347	347	511	367	367	325	325	403	357	311	272	403	357	311	272	416	370	325	286	465	411	358	312	3425	
February	0	≤	0	277	288		311	313	313	313	313	313	462	368	368	324	324	404	356	308	268	404	356	308	268	400	355	310	272	448	395	343	298	2953	
March	0	≤	0	391	391		391	423	423	423	423	423	651	425	425	374	374	466	410	354	308	466	410	354	308	555	487	419	362	630	550	470	403	3338	
April	0	≤	0	392	392		333	335	335	335	335	335	495	429	429	377	377	470	413	356	309	470	413	356	309	561	492	423	365	639	557	475	407	1712	
May	0	≤	0	596	773		344	347	347	347	347	347	511	461	461	405	405	505	443	381	330	505	443	381	330	605	530	454	391	689	601	511	438	1843	
Ram Tie	0	≤	0	0.00	0.02		0.01	0.01	0.01	0.01	0.01	0.01	-1.00																						
0	0	≤	0				-0.39	-0.39	-0.39	-0.39	-0.39	-0.39							1.00																
Twin ewe lambs from ewes/Hgt tie	0	≤	0	1	1.00														-1.00																
	0	≤	0																																
Single ewe lambs from ewes born	0	≤	0				-0.37	-0.37	-0.37	-0.37	-0.37	-0.37						1.00																	
Single ewe lambs from ewes sold November	0	≤	0															-0.09																	
Single ewe lambs from ewes sold December	0	≤	0															-0.18																	
Single ewe lambs from ewes sold January	0	≤	0															-0.27																	
Single ewe lambs from ewes sold February	0	≤	0															-0.18																	
Single ewe lambs from ewes sold March	0	≤	0															-0.09																	
Single ewe lambs from ewes sold April	0	≤	0															-0.05																	
Single ewe lambs from ewes sold May	0	≤	0															-0.02																	
Single ewe lambs from ewes sold June	0	≤	0															-0.02																	
Triplet ewe lambs from ewes sold	0	≤	0				0.00	0.00	0.00	0.00	0.00	0.00								1.00															
Triplet ewe lambs from ewes sold Nov	0	≤	0																	-0.07															1.00
Triplet ewe lambs from ewes sold Dec	0	≤	0																	-0.13															
Triplet ewe lambs from ewes sold January	0	≤	0																	-0.20															
Triplet ewe lambs from ewes sold February	0	≤	0																	-0.13															
Triplet ewe lambs from ewes sold March	0	≤	0																	-0.07															
Triplet ewe lambs from ewes sold April	0	≤	0																	-0.03															
Triplet ewe lambs from ewes sold May	0	≤	0																	-0.02															
Triplet ewe lambs from ewes sold June	0	≤	0																	-0.02															
Quadruplet ewe lambs from ewes sold	0	≤	0				0.00	0.00	0.00	0.00	0.00	0.00									1														
Quadruplet ewe lambs from ewes sold November	0	≤	0																		-0.06														
Quadruplet ewe lambs from ewes sold December	0	≤	0																		-0.11														
Quadruplet ewe lambs from ewes sold January	0	≤	0																		-0.17														
Quadruplet ewe lambs from ewes sold February	0	≤	0																		-0.11														
Quadruplet ewe lambs from ewes sold March	0	≤	0																		-0.06														
Quadruplet ewe lambs from ewes sold April	0	≤	0																		-0.03														
Quadruplet ewe lambs from ewes sold May	0	≤	0																		-0.01														
Quadruplet ewe lambs from ewes sold June	0	≤	0																		-0.01														
Single wether lambs from ewes sold	0	≤	0				-0.37	-0.37	-0.37	-0.37	-0.37	-0.37										1.00													
Single wether lambs from ewes sold November	0	≤	0																			-0.09													
Single wether lambs from ewes sold December	0	≤	0																			-0.18													
Single wether lambs from ewes sold January	0	≤	0																			-0.27													
Single wether lambs from ewes sold February	0	≤	0																			-0.18													
Single wether lambs from ewes sold March	0	≤	0																			-0.09													
Single wether lambs from ewes sold April	0	≤	0																			-0.05													
Single wether lambs from ewes sold May	0	≤	0																			-0.02													
Single wether lambs from ewes sold June	0	≤	0																			-0.02													

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Dry hgt/2th tie	Wet ewe hogget	Dry/wet hogget tie	2th	4th	6th	4yr	5yr	6yr	Rams	Ewe lambs from hoggets (singles)	Wether lambs from hoggets (singles)	Ewe lambs from hoggets (twins)	Wether lambs from hoggets (twins)	Ewe lambs from ewe (singles)	Ewe lambs from ewes (twins)	Ewe lambs from ewes (triplets)	Ewe lambs from ewes (quadruplets)	Wether lambs from ewes (singles)	Wether lambs from ewes (twins)	Wether lambs from ewes (triplets)	Wether lambs from ewes (Quadruplets)	Ram lambs from ewes (singles)	Ram lambs from ewes (twins)	Ram lambs from ewes (triplets)	Ram lambs from ewes (quadruplets)	Cryptorchid lambs from ewes (singles)	Cryptorchid lambs from ewes (twins)	Cryptorchid lambs from ewes (triplets)	Cryptorchid lambs from ewes (quadruplets)	Cattle	Triplet ewe lambs sold November
Twin wether lambs from ewes sold	0	≤	0				-0.39	-0.39	-0.39	-0.39	-0.39	-0.39											1.00												
Twin wether lambs from ewes sold November	0	≤	0																				-0.09												
Twin wether lambs from ewes sold December	0	≤	0																				-0.17												
Twin wether lambs from ewes sold January	0	≤	0																				-0.26												
Twin wether lambs from ewes sold February	0	≤	0																				-0.17												
Twin wether lambs from ewes sold March	0	≤	0																				-0.09												
Twin wether lambs from ewes sold April	0	≤	0																				-0.04												
Twin wether lambs from ewes sold May	0	≤	0																				-0.02												
Twin wether lambs from ewes sold June	0	≤	0																				-0.02												
Triplet wether lambs from ewes sold	0	≤	0				0.00	0.00	0.00	0.00	0.00	0.00												1.00											
Triplet wether lambs from ewes sold November	0	≤	0																					-0.07											
Triplet wether lambs from ewes sold December	0	≤	0																					-0.13											
Triplet wether lambs from ewes sold January	0	≤	0																					-0.20											
Triplet wether lambs from ewes sold February	0	≤	0																					-0.13											
Triplet wether lambs from ewes sold March	0	≤	0																					-0.07											
Triplet wether lambs from ewes sold April	0	≤	0																					-0.03											
Triplet wether lambs from ewes sold May	0	≤	0																					-0.02											
Triplet wether lambs from ewes sold June	0	≤	0																					-0.02											
Quadruplet wether lambs from ewes sold	0	≤	0				0.00	0.00	0.00	0.00	0.00	0.00													1.00										
Quadruplet wether lambs from ewes sold November	0	≤	0																						-0.06										
Quadruplet wether lambs from ewes sold December	0	≤	0																						-0.11										
Quadruplet wether lambs from ewes sold January	0	≤	0																						-0.17										
Quadruplet wether lambs from ewes sold February	0	≤	0																						-0.11										
Quadruplet wether lambs from ewes sold March	0	≤	0																						-0.06										
Quadruplet wether lambs from ewes sold April	0	≤	0																						-0.03										
Quadruplet wether lambs from ewes sold May	0	≤	0																						-0.01										
Quadruplet wether lambs from ewes sold June	0	≤	0																						-0.01										
Single ram lambs from ewes sold	0	≤	0				0.00	0.00	0.00	0.00	0.00	0.00														1.00									
Single ram lambs from ewes sold November	0	≤	0																							-0.09									
Single ram lambs from ewes sold December	0	≤	0																							-0.18									
Single ram lambs from ewes sold January	0	≤	0																							-0.27									
Single ram lambs from ewes sold February	0	≤	0																							-0.18									
Single ram lambs from ewes sold March	0	≤	0																							-0.09									
Single ram lambs from ewes sold April	0	≤	0																							-0.05									
Single ram lambs from ewes sold May	0	≤	0																							-0.02									
Single ram lambs from ewes sold June	0	≤	0																							-0.02									
Twin ram lambs from ewes sold	0	≤	0				0.00	0.00	0.00	0.00	0.00	0.00															1.00								
Twin ram lambs from ewes sold November	0	≤	0																								-0.09								
Twin ram lambs from ewes sold December	0	≤	0																								-0.17								
Twin ram lambs from ewes sold January	0	≤	0																								-0.26								
Twin ram lambs from ewes sold February	0	≤	0																								-0.17								
Twin ram lambs from ewes sold March	0	≤	0																								-0.09								
Twin ram lambs from ewes sold April	0	≤	0																								-0.04								
Twin ram lambs from ewes sold May	0	≤	0																								-0.02								
Twin ram lambs from ewes sold June	0	≤	0																								-0.02								
Triplet ram lambs from ewes sold	0	≤	0				0.00	0.00	0.00	0.00	0.00	0.00																1.00							
Triplet ram lambs from ewes sold November	0	≤	0																									-0.07							
Triplet ram lambs from ewes sold December	0	≤	0																									-0.13							
Triplet ram lambs from ewes sold January	0	≤	0																									-0.20							
Triplet ram lambs from ewes sold February	0	≤	0																									-0.13							
Triplet ram lambs from ewes sold March	0	≤	0																									-0.07							
Triplet ram lambs from ewes sold April	0	≤	0																									-0.03							

	Constraint	Reltnshp	Demand	Dry hgt/2th tie	Wet ewe hogget	Dry/wet hogget tie	2th	4th	6th	4yr	5yr	6yr	Rams	Ewe lambs from hoggets (singles)	Wether lambs from hoggets (singles)	Ewe lambs from hoggets (twins)	Wether lambs from hoggets (twins)	Ewe lambs from ewe (singles)	Ewe lambs from ewes (twins)	Ewe lambs from ewes (triplets)	Ewe lambs from ewes (quadruplets)	Wether lambs from ewes (singles)	Wether lambs from ewes (twins)	Wether lambs from ewes (triplets)	Wether lambs from ewes (Quadruplets)	Ram lambs from ewes (singles)	Ram lambs from ewes (twins)	Ram lambs from ewes (triplets)	Ram lambs from ewes (quadruplets)	Cryptorchid lambs from ewes (singles)	Cryptorchid lambs from ewes (twins)	Cryptorchid lambs from ewes (triplets)	Cryptorchid lambs from ewes (quadruplets)	Cattle	Triplet ewe lambs sold November
Triplet ram lambs from ewes sold May	0	≤	0																									-0.02							
Triplet ram lambs from ewes sold June	0	≤	0																									-0.02							
Quadruplet ram lambs from ewes sold	0	≤	0				0.00	0.00	0.00	0.00	0.00	0.00																	1.00						
Quadruplet ram lambs from ewes sold November	0	≤	0																										-0.06						
Quadruplet ram lambs from ewes sold December	0	≤	0																										-0.11						
Quadruplet ram lambs from ewes sold January	0	≤	0																										-0.17						
Quadruplet ram lambs from ewes sold February	0	≤	0																										-0.11						
Quadruplet ram lambs from ewes sold March	0	≤	0																										-0.06						
Quadruplet ram lambs from ewes sold April	0	≤	0																										-0.03						
Quadruplet ram lambs from ewes sold May	0	≤	0																										-0.01						
Quadruplet ram lambs from ewes sold June	0	≤	0																										-0.01						
Single cryptorchid lambs from ewes sold	0	≤	0				0.00	0.00	0.00	0.00	0.00	0.00																		1.00					
Single cryptorchid lambs from ewes sold November	0	≤	0																											-0.09					
Single cryptorchid lambs from ewes sold December	0	≤	0																											-0.18					
Single cryptorchid lambs from ewes sold January	0	≤	0																											-0.27					
Single cryptorchid lambs from ewes sold February	0	≤	0																											-0.18					
Single cryptorchid lambs from ewes sold March	0	≤	0																											-0.09					
Single cryptorchid lambs from ewes sold April	0	≤	0																											-0.05					
Single cryptorchid lambs from ewes sold May	0	≤	0																											-0.02					
Single cryptorchid lambs from ewes sold June	0	≤	0																											-0.02					
Twin cryptorchid lambs from ewes sold	0	≤	0				0.00	0.00	0.00	0.00	0.00	0.00																			1.00				
Twin cryptorchid lambs from ewes sold November	0	≤	0																												-0.09				
Twin cryptorchid lambs from ewes sold December	0	≤	0																												-0.17				
Twin cryptorchid lambs from ewes sold January	0	≤	0																												-0.26				
Twin cryptorchid lambs from ewes sold February	0	≤	0																												-0.17				
Twin cryptorchid lambs from ewes sold March	0	≤	0																												-0.09				
Twin cryptorchid lambs from ewes sold April	0	≤	0																												-0.04				
Twin cryptorchid lambs from ewes sold May	0	≤	0																												-0.02				
Twin cryptorchid lambs from ewes sold June	0	≤	0																												-0.02				
Triplet cryptorchid lambs from ewes sold	0	≤	0				0.00	0.00	0.00	0.00	0.00	0.00																				1.00			
Triplet cryptorchid lambs from ewes sold November	0	≤	0																													-0.07			
Triplet cryptorchid lambs from ewes sold December	0	≤	0																													-0.13			
Triplet cryptorchid lambs from ewes sold January	0	≤	0																													-0.20			
Triplet cryptorchid lambs from ewes sold February	0	≤	0																													-0.13			
Triplet cryptorchid lambs from ewes sold March	0	≤	0																													-0.07			
Triplet cryptorchid lambs from ewes sold April	0	≤	0																													-0.03			
Triplet cryptorchid lambs from ewes sold May	0	≤	0																													-0.02			
Triplet cryptorchid lambs from ewes sold June	0	≤	0																													-0.02			
Quadruplet cryptorchid lambs from ewes sold	0	≤	0				0.00	0.00	0.00	0.00	0.00	0.00																					1.00		
Quadruplet cryptorchid lambs from ewes sold November	0	≤	0																														-0.06		
Quadruplet cryptorchid lambs from ewes sold December	0	≤	0																														-0.11		
Quadruplet cryptorchid lambs from ewes sold January	0	≤	0																														-0.17		
Quadruplet cryptorchid lambs from ewes sold February	0	≤	0																														-0.11		
Quadruplet cryptorchid lambs from ewes sold March	0	≤	0																														-0.06		
Quadruplet cryptorchid lambs from ewes sold April	0	≤	0																														-0.03		
Quadruplet cryptorchid lambs from ewes sold May	0	≤	0																														-0.01		
Quadruplet cryptorchid lambs from ewes sold June	0	≤	0																														-0.01		
Single ewe lambs from hoggets sold	0	≤	0		-0.43									1.00																					
Single ewe lambs from hoggets sold November	0	≤	0											-0.07																					
Single ewe lambs from hoggets sold December	0	≤	0											-0.14																					

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Dry hgt/2th tie	Wet ewe hogget	Dry/wet hogget tie	2th	4th	6th	4yr	5yr	6yr	Rams	Ewe lambs from hoggets (singles)	Wether from hoggets (singles)	Ewe lambs from hoggets (twins)	Wether lambs from hoggets (twins)	Ewe lambs from ewe (singles)	Ewe lambs from ewes (twins)	Ewe lambs from ewes (triplets)	Ewe lambs from ewes (quadruplets)	Wether lambs from ewes (singles)	Wether lambs from ewes (twins)	Wether lambs from ewes (triplets)	Wether lambs from ewes (Quadruplets)	Ram lambs from ewes (singles)	Ram lambs from ewes (twins)	Ram lambs from ewes (triplets)	Ram lambs from ewes (quadruplets)	Cryptorchid lambs from ewes (singles)	Cryptorchid lambs from ewes (twins)	Cryptorchid lambs from ewes (triplets)	Cryptorchid lambs from ewes (quadruplets)	Cattle	Triplet ewe lambs sold November
Single ewe lambs from hoggets sold January	0	≤	0											-0.22																					
Single ewe lambs from hoggets sold February	0	≤	0											-0.14																					
Single ewe lambs from hoggets sold March	0	≤	0											-0.07																					
Single ewe lambs from hoggets sold April	0	≤	0											-0.04																					
Single ewe lambs from hoggets sold May	0	≤	0											-0.02																					
Single ewe lambs from hoggets sold June	0	≤	0											-0.02																					
Single wether lambs from hoggets sold	0	≤	0		-0.43										1.00																				
Single wether lambs from hoggets sold November	0	≤	0												-0.07																				
Single wether lambs from hoggets sold December	0	≤	0												-0.14																				
Single wether lambs from hoggets sold January	0	≤	0												-0.22																				
Single wether lambs from hoggets sold February	0	≤	0												-0.14																				
Single wether lambs from hoggets sold March	0	≤	0												-0.07																				
Single wether lambs from hoggets sold April	0	≤	0												-0.04																				
Single wether lambs from hoggets sold May	0	≤	0												-0.02																				
Single wether lambs from hoggets sold June	0	≤	0												-0.02																				
Twin ewe lambs from hoggets sold	0	≤	0		0.00											1.00																			
Twin ewe lambs from hoggets sold November	0	≤	0													-0.07																			
Twin ewe lambs from hoggets sold December	0	≤	0													-0.14																			
Twin ewe lambs from hoggets sold January	0	≤	0													-0.20																			
Twin ewe lambs from hoggets sold February	0	≤	0													-0.14																			
Twin ewe lambs from hoggets sold March	0	≤	0													-0.07																			
Twin ewe lambs from hoggets sold April	0	≤	0													-0.03																			
Twin ewe lambs from hoggets sold May	0	≤	0													-0.02																			
Twin ewe lambs from hoggets sold June	0	≤	0													-0.02																			
Twin wether lambs from hoggets sold	0	≤	0		0.00												1.00																		
Twin wether lambs from hoggets sold November	0	≤	0														-0.07																		
Twin wether lambs from hoggets sold December	0	≤	0														-0.14																		
Twin wether lambs from hoggets sold January	0	≤	0														-0.20																		
Twin wether lambs from hoggets sold February	0	≤	0														-0.14																		
Twin wether lambs from hoggets sold March	0	≤	0														-0.07																		
Twin wether lambs from hoggets sold April	0	≤	0														-0.03																		
Twin wether lambs from hoggets sold May	0	≤	0														-0.02																		
Twin wether lambs from hoggets sold June	0	≤	0														-0.02																		
	0	≤	0																																
	0	≤	0																																
	0	≤	0																																
Dry Hgt Tie	0	≤	0	-0.96		1.00																													
Hgt/2th Tie	0	≤	0		-0.93	-1.00	1.00																												
2th/4th tie	0	≤	0				-0.97	1																											
4th/6th tie	0	≤	0					-0.97	1.00																										
6th/4yr tie	0	≤	0						-0.97	1.00																									
4yr/5yr tie	0	≤	0							-0.97	1.00																								
5 yr/ sale tie	0	≤	0								-0.97	1.00																							
6yr/sale tie	0	≤	0									-0.97																							
Age cull	0	≤	0				-0.03	-0.03	-0.03	-0.03	-0.03																								
Dry hogget cull	0	≤	0	-0.04																															
Wet hogget cull	0	≤	0		-0.05																														
Wool from dry hogget	0	≤	0	-3.5																															
Wool from wet hogget	0	≤	0		-3.1																														
Wool from 2th	0	≤	0				-4																												
Wool from 4th	0	≤	0					-4																											
Wool from 6th	0	≤	0						-4																										
Wool from 4yr	0	≤	0							-4																									
Wool from 5yr	0	≤	0								-4																								
Wool from 6yr	0	≤	0									-4																							
Wool from Rams	0	≤	0										-6																						
	0	≤	0																																
Wool from Ewe lambs (singles)	0	≤	0															-1																	
Wool from Ewe lambs (twins)	0	≤	0																-1																
Wool from Ewe lambs (triplets)	0	≤	0																	-1															
Wool from Ewe lambs (quadruplets)	0	≤	0																		0														

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Dry hgt/2th tie	Wet ewe hogget	Dry/wet hogget tie	2th	4th	6th	4yr	5yr	6yr	Rams
Wool from wether lambs (singles)	0	≤	0										
Wool from wether lambs (twins)	0	≤	0										
Wool from wether lambs (triplets)	0	≤	0										
Wool from wether lambs (quadruplets)	0	≤	0										
Cattle	0	≤	0	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	
Stock units total	6006000	≤	3441	0.74	0.96		1.04	1.04	1.04	1.04	1.04	1.04	1.00
Switch	0		0	0	1		0						0
Variable costs	-1000000		47767	-11.54	-16.87		-17.30	-17.38	-17.38	-17.38	-17.38	-17.38	-76.97
Number of stock	0		0	335	0	321	321	312	302	293	285	276	18

	Ewe lambs from hoggets (singles)	Wether lambs from hoggets (singles)	Ewe lambs from hoggets (twins)	Wether lambs from hoggets (twins)	Ewe lambs from ewe (singles)	Ewe lambs from ewes (twins)	Ewe lambs from ewes (triplets)	Ewe lambs from ewes (quadruplets)	Wether lambs from ewes (singles)	Wether lambs from ewes (twins)	Wether lambs from ewes (triplets)	Wether lambs from ewes (Quadruplets)	Ram lambs from ewes (singles)	Ram lambs from ewes (twins)	Ram lambs from ewes (triplets)	Ram lambs from ewes (quadruplets)	Cryptorchid lambs from ewes (singles)	Cryptorchid lambs from ewes (twins)	Cryptorchid lambs from ewes (triplets)	Cryptorchid lambs from ewes (quadruplets)	Cattle	Triplet ewe lambs sold November
Wool from wether lambs (singles)									0													
Wool from wether lambs (twins)										0												
Wool from wether lambs (triplets)											0											
Wool from wether lambs (quadruplets)												0										
Cattle																					1	
Stock units total	0.25	0.25	0.22	0.22	0.27	0.24	0.21	0.18	0.27	0.24	0.21	0.18	0.29	0.26	0.22	0.20	0.32	0.28	0.25	0.21	5.07	
Switch		0																			0	
Variable costs	-2.99	-2.99	-2.65	-2.65	-3.28	-2.90	-2.52	-2.20	-3.28	-2.90	-2.52	-2.20	-3.48	-3.09	-2.69	-2.36	-3.91	-3.44	-2.98	-2.59	377.88	27.29
Number of stock	0	0	0	0	657	703	0	0	657	703	0	0	0	0	0	0	0	0	0	0	122	0

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Triplet ewe lambs sold December	Triplet ewe lambs sold January	Triplet ewe lambs sold February	Triplet ewe lambs sold March	Triplet ewe lambs sold April	Triplet ewe lambs sold May	Triplet ewe lambs sold June	Quadruplet ewe lambs from ewes sold November	Quadruplet ewe lambs from ewes sold December	Quadruplet ewe lambs from ewes sold January	Quadruplet ewe lambs from ewes sold February	Quadruplet ewe lambs from ewes sold March	Quadruplet ewe lambs from ewes sold April	Quadruplet ewe lambs from ewes sold May	Quadruplet ewe lambs from ewes sold June	Single wether lamb from ewes sold November	Single wether lamb from ewes sold December	Single wether lamb from ewes sold January	Single wether lamb from ewes sold February	Single wether lamb from ewes sold March	Single wether lamb from ewes sold April	Single wether lamb from ewes sold May	Single wether lamb from ewes sold June	Twin wether lamb from ewes sold November	Twin wether lamb from ewes sold December	Twin wether lamb from ewes sold January	Twin wether lamb from ewes sold February	Twin wether lamb from ewes sold March	Twin wether lamb from ewes sold April	Twin wether lamb from ewes sold May	Twin wether lamb from ewes sold June	Triplet wether lamb from ewes sold November	Triplet wether lamb from ewes sold December	Triplet wether lamb from ewes sold January	Triplet wether lamb from ewes sold February	Triplet wether lamb from ewes sold March	Triplet wether lamb from ewes sold April
Appendix D: Linear Program fo	Ewe prolificacy and farm prof																																							
Put a 1 beside the box that will represent the male lambs(otherwise use a 0)	Wether	1	Ram	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?
Put a 1 above the class of lambs that are sold prime otherwise leave as 0 if sold store				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Area of land (ha)	378	≤	378																																					
Silage	0	≤	0																																					
Livestock Energy	0	≤	0																																					
June	0	≤	0																																					
July	0	≤	0																																					
August	0	≤	0																																					
September	0	≤	0																																					
October	0	≤	0																																					
November	0	≤	0																																					
December	0	≤	0																																					
January	0	≤	0																																					
February	0	≤	0																																					
March	0	≤	0																																					
April	0	≤	0																																					
May	0	≤	0																																					
Ram Tie	0	≤	0																																					
0	0	≤	0																																					
Twin ewe lambs from ewes/Hgt tie	0	≤	0																																					
	0	≤	0																																					
Single ewe lambs from ewes born	0	≤	0																																					
Single ewe lambs from ewes sold November	0	≤	0																																					
Single ewe lambs from ewes sold December	0	≤	0																																					
Single ewe lambs from ewes sold January	0	≤	0																																					
Single ewe lambs from ewes sold February	0	≤	0																																					
Single ewe lambs from ewes sold March	0	≤	0																																					
Single ewe lambs from ewes sold April	0	≤	0																																					
Single ewe lambs from ewes sold May	0	≤	0																																					
Single ewe lambs from ewes sold June	0	≤	0																																					
Triplet ewe lambs from ewes sold	0	≤	0																																					
Triplet ewe lambs from ewes sold Nov	0	≤	0																																					
Triplet ewe lambs from ewes sold Dec	0	≤	0	1.00																																				
Triplet ewe lambs from ewes sold January	0	≤	0		1.00																																			
Triplet ewe lambs from ewes sold February	0	≤	0			1.00																																		
Triplet ewe lambs from ewes sold March	0	≤	0				1.00																																	
Triplet ewe lambs from ewes sold April	0	≤	0					1.00																																
Triplet ewe lambs from ewes sold May	0	≤	0						1.00																															
Triplet ewe lambs from ewes sold June	0	≤	0							1																														
Quadruplet ewe lambs from ewes sold	0	≤	0																																					
Quadruplet ewe lambs from ewes sold November	0	≤	0								1																													
Quadruplet ewe lambs from ewes sold December	0	≤	0									1																												
Quadruplet ewe lambs from ewes sold January	0	≤	0										1																											
Quadruplet ewe lambs from ewes sold February	0	≤	0											1																										
Quadruplet ewe lambs from ewes sold March	0	≤	0												1																									
Quadruplet ewe lambs from ewes sold April	0	≤	0													1																								
Quadruplet ewe lambs from ewes sold May	0	≤	0														1																							
Quadruplet ewe lambs from ewes sold June	0	≤	0															1																						
Single wether lambs from ewes sold	0	≤	0																																					
Single wether lambs from ewes sold November	0	≤	0																1																					
Single wether lambs from ewes sold December	0	≤	0																	1																				
Single wether lambs from ewes sold January	0	≤	0																		1																			
Single wether lambs from ewes sold February	0	≤	0																			1																		
Single wether lambs from ewes sold March	0	≤	0																				1																	
Single wether lambs from ewes sold April	0	≤	0																					1																
Single wether lambs from ewes sold May	0	≤	0																						1															
Single wether lambs from ewes sold June	0	≤	0																							1														

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Triplet ewe lambs sold December	Triplet ewe lambs sold January	Triplet ewe lambs sold February	Triplet ewe lambs sold March	Triplet ewe lambs sold April	Triplet ewe lambs sold May	Triplet ewe lambs sold June	Quadruplet ewe lambs from ewes sold November	Quadruplet ewe lambs from ewes sold December	Quadruplet ewe lambs from ewes sold January	Quadruplet ewe lambs from ewes sold February	Quadruplet ewe lambs from ewes sold March	Quadruplet ewe lambs from ewes sold April	Quadruplet ewe lambs from ewes sold May	Quadruplet ewe lambs from ewes sold June	Single wether lamb from ewes sold November	Single wether lamb from ewes sold December	Single wether lamb from ewes sold January	Single wether lamb from ewes sold February	Single wether lamb from ewes sold March	Single wether lamb from ewes sold April	Single wether lamb from ewes sold May	Single wether lamb from ewes sold June	Twin wether lamb from ewes sold November	Twin wether lamb from ewes sold December	Twin wether lamb from ewes sold January	Twin wether lamb from ewes sold February	Twin wether lamb from ewes sold March	Twin wether lamb from ewes sold April	Twin wether lamb from ewes sold May	Twin wether lamb from ewes sold June	Triplet wether lamb from ewes sold November	Triplet wether lamb from ewes sold December	Triplet wether lamb from ewes sold January	Triplet wether lamb from ewes sold February	Triplet wether lamb from ewes sold March	Triplet wether lamb from ewes sold April
Twin wether lambs from ewes sold	0	≤	0																																					
Twin wether lambs from ewes sold November	0	≤	0																								1													
Twin wether lambs from ewes sold December	0	≤	0																									1												
Twin wether lambs from ewes sold January	0	≤	0																										1											
Twin wether lambs from ewes sold February	0	≤	0																											1										
Twin wether lambs from ewes sold March	0	≤	0																												1									
Twin wether lambs from ewes sold April	0	≤	0																													1								
Twin wether lambs from ewes sold May	0	≤	0																														1							
Twin wether lambs from ewes sold June	0	≤	0																															1						
Triplet wether lambs from ewes sold	0	≤	0																																					
Triplet wether lambs from ewes sold November	0	≤	0																																1					
Triplet wether lambs from ewes sold December	0	≤	0																																	1				
Triplet wether lambs from ewes sold January	0	≤	0																																		1			
Triplet wether lambs from ewes sold February	0	≤	0																																			1		
Triplet wether lambs from ewes sold March	0	≤	0																																				1	
Triplet wether lambs from ewes sold April	0	≤	0																																					1
Triplet wether lambs from ewes sold May	0	≤	0																																					
Triplet wether lambs from ewes sold June	0	≤	0																																					
Quadruplet wether lambs from ewes sold	0	≤	0																																					
Quadruplet wether lambs from ewes sold November	0	≤	0																																					
Quadruplet wether lambs from ewes sold December	0	≤	0																																					
Quadruplet wether lambs from ewes sold January	0	≤	0																																					
Quadruplet wether lambs from ewes sold February	0	≤	0																																					
Quadruplet wether lambs from ewes sold March	0	≤	0																																					
Quadruplet wether lambs from ewes sold April	0	≤	0																																					
Quadruplet wether lambs from ewes sold May	0	≤	0																																					
Quadruplet wether lambs from ewes sold June	0	≤	0																																					
Single ram lambs from ewes sold	0	≤	0																																					
Single ram lambs from ewes sold November	0	≤	0																																					
Single ram lambs from ewes sold December	0	≤	0																																					
Single ram lambs from ewes sold January	0	≤	0																																					
Single ram lambs from ewes sold February	0	≤	0																																					
Single ram lambs from ewes sold March	0	≤	0																																					
Single ram lambs from ewes sold April	0	≤	0																																					
Single ram lambs from ewes sold May	0	≤	0																																					
Single ram lambs from ewes sold June	0	≤	0																																					
Twin ram lambs from ewes sold	0	≤	0																																					
Twin ram lambs from ewes sold November	0	≤	0																																					
Twin ram lambs from ewes sold December	0	≤	0																																					
Twin ram lambs from ewes sold January	0	≤	0																																					
Twin ram lambs from ewes sold February	0	≤	0																																					
Twin ram lambs from ewes sold March	0	≤	0																																					
Twin ram lambs from ewes sold April	0	≤	0																																					
Twin ram lambs from ewes sold May	0	≤	0																																					
Twin ram lambs from ewes sold June	0	≤	0																																					
Triplet ram lambs from ewes sold	0	≤	0																																					
Triplet ram lambs from ewes sold November	0	≤	0																																					
Triplet ram lambs from ewes sold December	0	≤	0																																					
Triplet ram lambs from ewes sold January	0	≤	0																																					
Triplet ram lambs from ewes sold February	0	≤	0																																					
Triplet ram lambs from ewes sold March	0	≤	0																																					
Triplet ram lambs from ewes sold April	0	≤	0																																					

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Triplet ewe lambs sold December	Triplet ewe lambs sold January	Triplet ewe lambs sold February	Triplet ewe lambs sold March	Triplet ewe lambs sold April	Triplet ewe lambs sold May	Triplet ewe lambs sold June	Quadruplet ewe lambs from ewes sold November	Quadruplet ewe lambs from ewes sold December	Quadruplet ewe lambs from ewes sold January	Quadruplet ewe lambs from ewes sold February	Quadruplet ewe lambs from ewes sold March	Quadruplet ewe lambs from ewes sold April	Quadruplet ewe lambs from ewes sold May	Quadruplet ewe lambs from ewes sold June	Single wether lamb from ewes sold November	Single wether lamb from ewes sold December	Single wether lamb from ewes sold January	Single wether lamb from ewes sold February	Single wether lamb from ewes sold March	Single wether lamb from ewes sold April	Single wether lamb from ewes sold May	Single wether lamb from ewes sold June	Twin wether lamb from ewes sold November	Twin wether lamb from ewes sold December	Twin wether lamb from ewes sold January	Twin wether lamb from ewes sold February	Twin wether lamb from ewes sold March	Twin wether lamb from ewes sold April	Twin wether lamb from ewes sold May	Twin wether lamb from ewes sold June	Triplet wether lamb from ewes sold November	Triplet wether lamb from ewes sold December	Triplet wether lamb from ewes sold January	Triplet wether lamb from ewes sold February	Triplet wether lamb from ewes sold March	Triplet wether lamb from ewes sold April
Triplet ram lambs from ewes sold May	0	≤	0																																					
Triplet ram lambs from ewes sold June	0	≤	0																																					
Quadruplet ram lambs from ewes sold	0	≤	0																																					
Quadruplet ram lambs from ewes sold November	0	≤	0																																					
Quadruplet ram lambs from ewes sold December	0	≤	0																																					
Quadruplet ram lambs from ewes sold January	0	≤	0																																					
Quadruplet ram lambs from ewes sold February	0	≤	0																																					
Quadruplet ram lambs from ewes sold March	0	≤	0																																					
Quadruplet ram lambs from ewes sold April	0	≤	0																																					
Quadruplet ram lambs from ewes sold May	0	≤	0																																					
Quadruplet ram lambs from ewes sold June	0	≤	0																																					
Single cryptorchid lambs from ewes sold	0	≤	0																																					
Single cryptorchid lambs from ewes sold November	0	≤	0																																					
Single cryptorchid lambs from ewes sold December	0	≤	0																																					
Single cryptorchid lambs from ewes sold January	0	≤	0																																					
Single cryptorchid lambs from ewes sold February	0	≤	0																																					
Single cryptorchid lambs from ewes sold March	0	≤	0																																					
Single cryptorchid lambs from ewes sold April	0	≤	0																																					
Single cryptorchid lambs from ewes sold May	0	≤	0																																					
Single cryptorchid lambs from ewes sold June	0	≤	0																																					
Twin cryptorchid lambs from ewes sold	0	≤	0																																					
Twin cryptorchid lambs from ewes sold November	0	≤	0																																					
Twin cryptorchid lambs from ewes sold December	0	≤	0																																					
Twin cryptorchid lambs from ewes sold January	0	≤	0																																					
Twin cryptorchid lambs from ewes sold February	0	≤	0																																					
Twin cryptorchid lambs from ewes sold March	0	≤	0																																					
Twin cryptorchid lambs from ewes sold April	0	≤	0																																					
Twin cryptorchid lambs from ewes sold May	0	≤	0																																					
Twin cryptorchid lambs from ewes sold June	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold November	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold December	0	≤	0																																					
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Triplet cryptorchid lambs from ewes sold February	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold March	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold April	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold May	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold June	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold November	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold December	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold January	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold February	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold March	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold April	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold May	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold June	0	≤	0																																					
Single ewe lambs from hoggets sold	0	≤	0																																					
Single ewe lambs from hoggets sold November	0	≤	0																																					
Single ewe lambs from hoggets sold December	0	≤	0																																					

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Triplet ewe lambs sold December	Triplet ewe lambs sold January	Triplet ewe lambs sold February	Triplet ewe lambs sold March	Triplet ewe lambs sold April	Triplet ewe lambs sold May	Triplet ewe lambs sold June	Quadruplet ewe lambs from ewes sold November	Quadruplet ewe lambs from ewes sold December	Quadruplet ewe lambs from ewes sold January	Quadruplet ewe lambs from ewes sold February	Quadruplet ewe lambs from ewes sold March	Quadruplet ewe lambs from ewes sold April	Quadruplet ewe lambs from ewes sold May	Quadruplet ewe lambs from ewes sold June	Single wether lamb from ewes sold November	Single wether lamb from ewes sold December	Single wether lamb from ewes sold January	Single wether lamb from ewes sold February	Single wether lamb from ewes sold March	Single wether lamb from ewes sold April	Single wether lamb from ewes sold May	Single wether lamb from ewes sold June	Twin wether lamb from ewes sold November	Twin wether lamb from ewes sold December	Twin wether lamb from ewes sold January	Twin wether lamb from ewes sold February	Twin wether lamb from ewes sold March	Twin wether lamb from ewes sold April	Twin wether lamb from ewes sold May	Twin wether lamb from ewes sold June	Triplet wether lamb from ewes sold November	Triplet wether lamb from ewes sold December	Triplet wether lamb from ewes sold January	Triplet wether lamb from ewes sold February	Triplet wether lamb from ewes sold March	Triplet wether lamb from ewes sold April
Single ewe lambs from hoggets sold January	0	≤	0																																					
Single ewe lambs from hoggets sold February	0	≤	0																																					
Single ewe lambs from hoggets sold March	0	≤	0																																					
Single ewe lambs from hoggets sold April	0	≤	0																																					
Single ewe lambs from hoggets sold May	0	≤	0																																					
Single ewe lambs from hoggets sold June	0	≤	0																																					
Single wether lambs from hoggets sold	0	≤	0																																					
Single wether lambs from hoggets sold November	0	≤	0																																					
Single wether lambs from hoggets sold December	0	≤	0																																					
Single wether lambs from hoggets sold January	0	≤	0																																					
Single wether lambs from hoggets sold February	0	≤	0																																					
Single wether lambs from hoggets sold March	0	≤	0																																					
Single wether lambs from hoggets sold April	0	≤	0																																					
Single wether lambs from hoggets sold May	0	≤	0																																					
Single wether lambs from hoggets sold June	0	≤	0																																					
Twin ewe lambs from hoggets sold	0	≤	0																																					
Twin ewe lambs from hoggets sold November	0	≤	0																																					
Twin ewe lambs from hoggets sold December	0	≤	0																																					
Twin ewe lambs from hoggets sold January	0	≤	0																																					
Twin ewe lambs from hoggets sold February	0	≤	0																																					
Twin ewe lambs from hoggets sold March	0	≤	0																																					
Twin ewe lambs from hoggets sold April	0	≤	0																																					
Twin ewe lambs from hoggets sold May	0	≤	0																																					
Twin ewe lambs from hoggets sold June	0	≤	0																																					
Twin wether lambs from hoggets sold	0	≤	0																																					
Twin wether lambs from hoggets sold November	0	≤	0																																					
Twin wether lambs from hoggets sold December	0	≤	0																																					
Twin wether lambs from hoggets sold January	0	≤	0																																					
Twin wether lambs from hoggets sold February	0	≤	0																																					
Twin wether lambs from hoggets sold March	0	≤	0																																					
Twin wether lambs from hoggets sold April	0	≤	0																																					
Twin wether lambs from hoggets sold May	0	≤	0																																					
Twin wether lambs from hoggets sold June	0	≤	0																																					
	0	≤	0																																					
	0	≤	0																																					
	0	≤	0																																					
Dry Hgt Tie	0	≤	0																																					
Hgt/2th Tie	0	≤	0																																					
2th/4th tie	0	≤	0																																					
4th/6th tie	0	≤	0																																					
6th/4yr tie	0	≤	0																																					
4yr/5yr tie	0	≤	0																																					
5 yr/ sale tie	0	≤	0																																					
6yr/sale tie	0	≤	0																																					
Age cull	0	≤	0																																					
Dry hogget cull	0	≤	0																																					
Wet hogget cull	0	≤	0																																					
Wool from dry hogget	0	≤	0																																					
Wool from wet hogget	0	≤	0																																					
Wool from 2th	0	≤	0																																					
Wool from 4th	0	≤	0																																					
Wool from 6th	0	≤	0																																					
Wool from 4yr	0	≤	0																																					
Wool from 5yr	0	≤	0																																					
Wool from 6yr	0	≤	0																																					
Wool from Rams	0	≤	0																																					
	0	≤	0																																					
Wool from Ewe lambs (singles)	0	≤	0																																					
Wool from Ewe lambs (twins)	0	≤	0																																					
Wool from Ewe lambs (triplets)	0	≤	0																																					
Wool from Ewe lambs (quadruplets)	0	≤	0																																					

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Triplet ewe lambs sold December	Triplet ewe lambs sold January	Triplet ewe lambs sold February	Triplet ewe lambs sold March	Triplet ewe lambs sold April	Triplet ewe lambs sold May	Triplet ewe lambs sold June	Quadruplet ewe lambs from ewes sold November	Quadruplet ewe lambs from ewes sold December	Quadruplet ewe lambs from ewes sold January	Quadruplet ewe lambs from ewes sold February	Quadruplet ewe lambs from ewes sold March	Quadruplet ewe lambs from ewes sold April	Quadruplet ewe lambs from ewes sold May	Quadruplet ewe lambs from ewes sold June	Single wether lamb from ewes sold November	Single wether lamb from ewes sold December	Single wether lamb from ewes sold January	Single wether lamb from ewes sold February	Single wether lamb from ewes sold March	Single wether lamb from ewes sold April	Single wether lamb from ewes sold May	Single wether lamb from ewes sold June	Twin wether lamb from ewes sold November	Twin wether lamb from ewes sold December	Twin wether lamb from ewes sold January	Twin wether lamb from ewes sold February	Twin wether lamb from ewes sold March	Twin wether lamb from ewes sold April	Twin wether lamb from ewes sold May	Twin wether lamb from ewes sold June	Triplet wether lamb from ewes sold November	Triplet wether lamb from ewes sold December	Triplet wether lamb from ewes sold January	Triplet wether lamb from ewes sold February	Triplet wether lamb from ewes sold March	Triplet wether lamb from ewes sold April
Wool from wether lambs (singles)	0	≤	0																																					
Wool from wether lambs (twins)	0	≤	0																																					
Wool from wether lambs (triplets)	0	≤	0																																					
Wool from wether lambs (quadruplets)	0	≤	0																																					
Cattle	0	≤	0																																					
Stock units total	6006000	≤	3441																																					
Switch	0		0																																					
Variable costs	-1000000		47767	31.96	25.41	25.23	41.67	45.52	50.02	65.45	25.44	30.38	23.68	23.13	29.95	40.80	44.44	57.70	30.47	34.68	28.91	45.73	50.33	56.21	71.12	94.91	28.79	33.25	27.11	42.20	45.94	50.80	56.37	84.57	27.29	31.96	25.41	25.23	41.67	45.52
Number of stock	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	59	118	177	118	59	30	15	15	60	120	179	120	60	30	15	15	0	0	0	0	0	0

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

Appendix D: Linear Program fo	Ewe prolificacy and farm profi																																							
Put a 1 beside the box that will represent the male lambs(otherwise use a 0)	Wether	1	Ram	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?
Put a 1 above the class of lambs that are sold prime otherwise leave as 0 if sold store				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Constraint	Reltnshp	Demand	Triplet wether lamb from ewes sold May	Triplet wether lamb from ewes sold June	Quadruplet wether lambs from ewes sold November	Quadruplet wether lambs from ewes sold December	Quadruplet wether lambs from ewes sold January	Quadruplet wether lambs from ewes sold February	Quadruplet wether lambs from ewes sold March	Quadruplet wether lambs from ewes sold April	Quadruplet wether lambs from ewes sold May	Quadruplet wether lambs from ewes sold June	Single ram lambs from ewes sold November	Single ram lambs from ewes sold December	Single ram lambs from ewes sold January	Single ram lambs from ewes sold February	Single ram lambs from ewes sold March	Single ram lambs from ewes sold April	Single ram lambs from ewes sold May	Single ram lambs from ewes sold June	Twin ram lambs from ewes sold November	Twin ram lambs from ewes sold December	Twin ram lambs from ewes sold January	Twin ram lambs from ewes sold February	Twin ram lambs from ewes sold March	Twin ram lambs from ewes sold April	Twin ram lambs from ewes sold May	Twin ram lambs from ewes sold June	Triplet ram lambs from ewes sold November	Triplet ram lambs from ewes sold December	Triplet ram lambs from ewes sold January	Triplet ram lambs from ewes sold February	Triplet ram lambs from ewes sold March	Triplet ram lambs from ewes sold April	Triplet ram lambs from ewes sold May	Triplet ram lambs from ewes sold June	Quadruplet ram lambs from ewes sold November	Quadruplet ram lambs from ewes sold December	Quadruplet ram lambs from ewes sold January
Area of land (ha)	378	≤	378																																					
Silage	0	≤	0																																					
Livestock Energy	0	≤	0																																					
June	0	≤	0																																					
July	0	≤	0																																					
August	0	≤	0																																					
September	0	≤	0																																					
October	0	≤	0																																					
November	0	≤	0																																					
December	0	≤	0																																					
January	0	≤	0																																					
February	0	≤	0																																					
March	0	≤	0																																					
April	0	≤	0																																					
May	0	≤	0																																					
Ram Tie	0	≤	0																																					
0	0	≤	0																																					
Twin ewe lambs from ewes/Hgt tie	0	≤	0																																					
	0	≤	0																																					
Single ewe lambs from ewes born	0	≤	0																																					
Single ewe lambs from ewes sold November	0	≤	0																																					
Single ewe lambs from ewes sold December	0	≤	0																																					
Single ewe lambs from ewes sold January	0	≤	0																																					
Single ewe lambs from ewes sold February	0	≤	0																																					
Single ewe lambs from ewes sold March	0	≤	0																																					
Single ewe lambs from ewes sold April	0	≤	0																																					
Single ewe lambs from ewes sold May	0	≤	0																																					
Single ewe lambs from ewes sold June	0	≤	0																																					
Triplet ewe lambs from ewes sold	0	≤	0																																					
Triplet ewe lambs from ewes sold Nov	0	≤	0																																					
Triplet ewe lambs from ewes sold Dec	0	≤	0																																					
Triplet ewe lambs from ewes sold January	0	≤	0																																					
Triplet ewe lambs from ewes sold February	0	≤	0																																					
Triplet ewe lambs from ewes sold March	0	≤	0																																					
Triplet ewe lambs from ewes sold April	0	≤	0																																					
Triplet ewe lambs from ewes sold May	0	≤	0																																					
Triplet ewe lambs from ewes sold June	0	≤	0																																					
Quadruplet ewe lambs from ewes sold	0	≤	0																																					
Quadruplet ewe lambs from ewes sold November	0	≤	0																																					
Quadruplet ewe lambs from ewes sold December	0	≤	0																																					
Quadruplet ewe lambs from ewes sold January	0	≤	0																																					
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Quadruplet ewe lambs from ewes sold March	0	≤	0																																					
Quadruplet ewe lambs from ewes sold April	0	≤	0																																					
Quadruplet ewe lambs from ewes sold May	0	≤	0																																					
Quadruplet ewe lambs from ewes sold June	0	≤	0																																					
Single wether lambs from ewes sold	0	≤	0																																					
Single wether lambs from ewes sold November	0	≤	0																																					
Single wether lambs from ewes sold December	0	≤	0																																					
Single wether lambs from ewes sold January	0	≤	0																																					
Single wether lambs from ewes sold February	0	≤	0																																					
Single wether lambs from ewes sold March	0	≤	0																																					
Single wether lambs from ewes sold April	0	≤	0																																					
Single wether lambs from ewes sold May	0	≤	0																																					
Single wether lambs from ewes sold June	0	≤	0																																					

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Triplet wether lamb from ewes sold May	Triplet wether lamb from ewes sold June	Quadruplet wether lambs from ewes sold November	Quadruplet wether lambs from ewes sold December	Quadruplet wether lambs from ewes sold January	Quadruplet wether lambs from ewes sold February	Quadruplet wether lambs from ewes sold March	Quadruplet wether lambs from ewes sold April	Quadruplet wether lambs from ewes sold May	Quadruplet wether lambs from ewes sold June	Single ram lambs from ewes sold November	Single ram lambs from ewes sold December	Single ram lambs from ewes sold January	Single ram lambs from ewes sold February	Single ram lambs from ewes sold March	Single ram lambs from ewes sold April	Single ram lambs from ewes sold May	Single ram lambs from ewes sold June	Twin ram lambs from ewes sold November	Twin ram lambs from ewes sold December	Twin ram lambs from ewes sold January	Twin ram lambs from ewes sold February	Twin ram lambs from ewes sold March	Twin ram lambs from ewes sold April	Twin ram lambs from ewes sold May	Twin ram lambs from ewes sold June	Triplet ram lambs from ewes sold November	Triplet ram lambs from ewes sold December	Triplet ram lambs from ewes sold January	Triplet ram lambs from ewes sold February	Triplet ram lambs from ewes sold March	Triplet ram lambs from ewes sold April	Triplet ram lambs from ewes sold May	Triplet ram lambs from ewes sold June	Quadruplet ram lambs from ewes sold November	Quadruplet ram lambs from ewes sold December	Quadruplet ram lambs from ewes sold January
Twin wether lambs from ewes sold	0	≤	0																																					
Twin wether lambs from ewes sold November	0	≤	0																																					
Twin wether lambs from ewes sold December	0	≤	0																																					
Twin wether lambs from ewes sold January	0	≤	0																																					
Twin wether lambs from ewes sold February	0	≤	0																																					
Twin wether lambs from ewes sold March	0	≤	0																																					
Twin wether lambs from ewes sold April	0	≤	0																																					
Twin wether lambs from ewes sold May	0	≤	0																																					
Twin wether lambs from ewes sold June	0	≤	0																																					
Triplet wether lambs from ewes sold	0	≤	0																																					
Triplet wether lambs from ewes sold November	0	≤	0																																					
Triplet wether lambs from ewes sold December	0	≤	0																																					
Triplet wether lambs from ewes sold January	0	≤	0																																					
Triplet wether lambs from ewes sold February	0	≤	0																																					
Triplet wether lambs from ewes sold March	0	≤	0																																					
Triplet wether lambs from ewes sold April	0	≤	0																																					
Triplet wether lambs from ewes sold May	0	≤	0	1																																				
Triplet wether lambs from ewes sold June	0	≤	0		1																																			
Quadruplet wether lambs from ewes sold	0	≤	0																																					
Quadruplet wether lambs from ewes sold November	0	≤	0			1																																		
Quadruplet wether lambs from ewes sold December	0	≤	0				1																																	
Quadruplet wether lambs from ewes sold January	0	≤	0					1																																
Quadruplet wether lambs from ewes sold February	0	≤	0						1																															
Quadruplet wether lambs from ewes sold March	0	≤	0							1																														
Quadruplet wether lambs from ewes sold April	0	≤	0								1																													
Quadruplet wether lambs from ewes sold May	0	≤	0									1																												
Quadruplet wether lambs from ewes sold June	0	≤	0										1																											
Single ram lambs from ewes sold	0	≤	0																																					
Single ram lambs from ewes sold November	0	≤	0											1																										
Single ram lambs from ewes sold December	0	≤	0												1																									
Single ram lambs from ewes sold January	0	≤	0													1																								
Single ram lambs from ewes sold February	0	≤	0														1																							
Single ram lambs from ewes sold March	0	≤	0															1																						
Single ram lambs from ewes sold April	0	≤	0																1																					
Single ram lambs from ewes sold May	0	≤	0																	1																				
Single ram lambs from ewes sold June	0	≤	0																		1																			
Twin ram lambs from ewes sold	0	≤	0																																					
Twin ram lambs from ewes sold November	0	≤	0																			1																		
Twin ram lambs from ewes sold December	0	≤	0																				1																	
Twin ram lambs from ewes sold January	0	≤	0																					1																
Twin ram lambs from ewes sold February	0	≤	0																						1															
Twin ram lambs from ewes sold March	0	≤	0																							1														
Twin ram lambs from ewes sold April	0	≤	0																								1													
Twin ram lambs from ewes sold May	0	≤	0																									1												
Twin ram lambs from ewes sold June	0	≤	0																										1											
Triplet ram lambs from ewes sold	0	≤	0																																					
Triplet ram lambs from ewes sold November	0	≤	0																											1										
Triplet ram lambs from ewes sold December	0	≤	0																												1									
Triplet ram lambs from ewes sold January	0	≤	0																													1								
Triplet ram lambs from ewes sold February	0	≤	0																														1							
Triplet ram lambs from ewes sold March	0	≤	0																															1						
Triplet ram lambs from ewes sold April	0	≤	0																																1					

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Triplet wether lamb from ewes sold May	Triplet wether lamb from ewes sold June	Quadruplet wether lambs from ewes sold November	Quadruplet wether lambs from ewes sold December	Quadruplet wether lambs from ewes sold January	Quadruplet wether lambs from ewes sold February	Quadruplet wether lambs from ewes sold March	Quadruplet wether lambs from ewes sold April	Quadruplet wether lambs from ewes sold May	Quadruplet wether lambs from ewes sold June	Single ram lambs from ewes sold November	Single ram lambs from ewes sold December	Single ram lambs from ewes sold January	Single ram lambs from ewes sold February	Single ram lambs from ewes sold March	Single ram lambs from ewes sold April	Single ram lambs from ewes sold May	Single ram lambs from ewes sold June	Twin ram lambs from ewes sold November	Twin ram lambs from ewes sold December	Twin ram lambs from ewes sold January	Twin ram lambs from ewes sold February	Twin ram lambs from ewes sold March	Twin ram lambs from ewes sold April	Twin ram lambs from ewes sold May	Twin ram lambs from ewes sold June	Triplet ram lambs from ewes sold November	Triplet ram lambs from ewes sold December	Triplet ram lambs from ewes sold January	Triplet ram lambs from ewes sold February	Triplet ram lambs from ewes sold March	Triplet ram lambs from ewes sold April	Triplet ram lambs from ewes sold May	Triplet ram lambs from ewes sold June	Quadruplet ram lambs from ewes sold November	Quadruplet ram lambs from ewes sold December	Quadruplet ram lambs from ewes sold January
Triplet ram lambs from ewes sold May	0	≤	0																																	1				
Triplet ram lambs from ewes sold June	0	≤	0																																		1			
Quadruplet ram lambs from ewes sold	0	≤	0																																					
Quadruplet ram lambs from ewes sold November	0	≤	0																																			1		
Quadruplet ram lambs from ewes sold December	0	≤	0																																				1	
Quadruplet ram lambs from ewes sold January	0	≤	0																																					1
Quadruplet ram lambs from ewes sold February	0	≤	0																																					
Quadruplet ram lambs from ewes sold March	0	≤	0																																					
Quadruplet ram lambs from ewes sold April	0	≤	0																																					
Quadruplet ram lambs from ewes sold May	0	≤	0																																					
Quadruplet ram lambs from ewes sold June	0	≤	0																																					
Single cryptorchid lambs from ewes sold	0	≤	0																																					
Single cryptorchid lambs from ewes sold November	0	≤	0																																					
Single cryptorchid lambs from ewes sold December	0	≤	0																																					
Single cryptorchid lambs from ewes sold January	0	≤	0																																					
Single cryptorchid lambs from ewes sold February	0	≤	0																																					
Single cryptorchid lambs from ewes sold March	0	≤	0																																					
Single cryptorchid lambs from ewes sold April	0	≤	0																																					
Single cryptorchid lambs from ewes sold May	0	≤	0																																					
Single cryptorchid lambs from ewes sold June	0	≤	0																																					
Twin cryptorchid lambs from ewes sold	0	≤	0																																					
Twin cryptorchid lambs from ewes sold November	0	≤	0																																					
Twin cryptorchid lambs from ewes sold December	0	≤	0																																					
Twin cryptorchid lambs from ewes sold January	0	≤	0																																					
Twin cryptorchid lambs from ewes sold February	0	≤	0																																					
Twin cryptorchid lambs from ewes sold March	0	≤	0																																					
Twin cryptorchid lambs from ewes sold April	0	≤	0																																					
Twin cryptorchid lambs from ewes sold May	0	≤	0																																					
Twin cryptorchid lambs from ewes sold June	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold November	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold December	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold January	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold February	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold March	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold April	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold May	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold June	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold November	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold December	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold January	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold February	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold March	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold April	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold May	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold June	0	≤	0																																					
Single ewe lambs from hoggets sold	0	≤	0																																					
Single ewe lambs from hoggets sold November	0	≤	0																																					
Single ewe lambs from hoggets sold December	0	≤	0																																					

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Triplet wether lamb from ewes sold May	Triplet wether lamb from ewes sold June	Quadruplet wether lambs from ewes sold November	Quadruplet wether lambs from ewes sold December	Quadruplet wether lambs from ewes sold January	Quadruplet wether lambs from ewes sold February	Quadruplet wether lambs from ewes sold March	Quadruplet wether lambs from ewes sold April	Quadruplet wether lambs from ewes sold May	Quadruplet wether lambs from ewes sold June	Single ram lambs from ewes sold November	Single ram lambs from ewes sold December	Single ram lambs from ewes sold January	Single ram lambs from ewes sold February	Single ram lambs from ewes sold March	Single ram lambs from ewes sold April	Single ram lambs from ewes sold May	Single ram lambs from ewes sold June	Twin ram lambs from ewes sold November	Twin ram lambs from ewes sold December	Twin ram lambs from ewes sold January	Twin ram lambs from ewes sold February	Twin ram lambs from ewes sold March	Twin ram lambs from ewes sold April	Twin ram lambs from ewes sold May	Twin ram lambs from ewes sold June	Triplet ram lambs from ewes sold November	Triplet ram lambs from ewes sold December	Triplet ram lambs from ewes sold January	Triplet ram lambs from ewes sold February	Triplet ram lambs from ewes sold March	Triplet ram lambs from ewes sold April	Triplet ram lambs from ewes sold May	Triplet ram lambs from ewes sold June	Quadruplet ram lambs from ewes sold November	Quadruplet ram lambs from ewes sold December	Quadruplet ram lambs from ewes sold January
Single ewe lambs from hoggets sold January	0	≤	0																																					
Single ewe lambs from hoggets sold February	0	≤	0																																					
Single ewe lambs from hoggets sold March	0	≤	0																																					
Single ewe lambs from hoggets sold April	0	≤	0																																					
Single ewe lambs from hoggets sold May	0	≤	0																																					
Single ewe lambs from hoggets sold June	0	≤	0																																					
Single wether lambs from hoggets sold	0	≤	0																																					
Single wether lambs from hoggets sold November	0	≤	0																																					
Single wether lambs from hoggets sold December	0	≤	0																																					
Single wether lambs from hoggets sold January	0	≤	0																																					
Single wether lambs from hoggets sold February	0	≤	0																																					
Single wether lambs from hoggets sold March	0	≤	0																																					
Single wether lambs from hoggets sold April	0	≤	0																																					
Single wether lambs from hoggets sold May	0	≤	0																																					
Single wether lambs from hoggets sold June	0	≤	0																																					
Twin ewe lambs from hoggets sold	0	≤	0																																					
Twin ewe lambs from hoggets sold November	0	≤	0																																					
Twin ewe lambs from hoggets sold December	0	≤	0																																					
Twin ewe lambs from hoggets sold January	0	≤	0																																					
Twin ewe lambs from hoggets sold February	0	≤	0																																					
Twin ewe lambs from hoggets sold March	0	≤	0																																					
Twin ewe lambs from hoggets sold April	0	≤	0																																					
Twin ewe lambs from hoggets sold May	0	≤	0																																					
Twin ewe lambs from hoggets sold June	0	≤	0																																					
Twin wether lambs from hoggets sold	0	≤	0																																					
Twin wether lambs from hoggets sold November	0	≤	0																																					
Twin wether lambs from hoggets sold December	0	≤	0																																					
Twin wether lambs from hoggets sold January	0	≤	0																																					
Twin wether lambs from hoggets sold February	0	≤	0																																					
Twin wether lambs from hoggets sold March	0	≤	0																																					
Twin wether lambs from hoggets sold April	0	≤	0																																					
Twin wether lambs from hoggets sold May	0	≤	0																																					
Twin wether lambs from hoggets sold June	0	≤	0																																					
	0	≤	0																																					
	0	≤	0																																					
	0	≤	0																																					
Dry Hgt Tie	0	≤	0																																					
Hgt/2th Tie	0	≤	0																																					
2th/4th tie	0	≤	0																																					
4th/6th tie	0	≤	0																																					
6th/4yr tie	0	≤	0																																					
4yr/5yr tie	0	≤	0																																					
5 yr/ sale tie	0	≤	0																																					
6yr/sale tie	0	≤	0																																					
Age cull	0	≤	0																																					
Dry hogget cull	0	≤	0																																					
Wet hogget cull	0	≤	0																																					
Wool from dry hogget	0	≤	0																																					
Wool from wet hogget	0	≤	0																																					
Wool from 2th	0	≤	0																																					
Wool from 4th	0	≤	0																																					
Wool from 6th	0	≤	0																																					
Wool from 4yr	0	≤	0																																					
Wool from 5yr	0	≤	0																																					
Wool from 6yr	0	≤	0																																					
Wool from Rams	0	≤	0																																					
	0	≤	0																																					
Wool from Ewe lambs (singles)	0	≤	0																																					
Wool from Ewe lambs (twins)	0	≤	0																																					
Wool from Ewe lambs (triplets)	0	≤	0																																					
Wool from Ewe lambs (quadruplets)	0	≤	0																																					

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Triplet wether lamb from ewes sold May	Triplet wether lamb from ewes sold June	Quadruplet wether lambs from ewes sold November	Quadruplet wether lambs from ewes sold December	Quadruplet wether lambs from ewes sold January	Quadruplet wether lambs from ewes sold February	Quadruplet wether lambs from ewes sold March	Quadruplet wether lambs from ewes sold April	Quadruplet wether lambs from ewes sold May	Quadruplet wether lambs from ewes sold June
Wool from wether lambs (singles)	0	≤	0										
Wool from wether lambs (twins)	0	≤	0										
Wool from wether lambs (triplets)	0	≤	0										
Wool from wether lambs (quadruplets)	0	≤	0										
Cattle	0	≤	0										
Stock units total	6006000	≤	3441										
Switch	0		0										
Variable costs	-1000000		47767	50.02	65.45	25.44	30.38	23.68	23.13	29.95	40.80	44.44	57.70
Number of stock	0		0	0	0	0	0	0	0	0	0	0	0

	Single ram lambs from ewes sold November	Single ram lambs from ewes sold December	Single ram lambs from ewes sold January	Single ram lambs from ewes sold February	Single ram lambs from ewes sold March	Single ram lambs from ewes sold April	Single ram lambs from ewes sold May	Single ram lambs from ewes sold June	Twin ram lambs from ewes sold November	Twin ram lambs from ewes sold December	Twin ram lambs from ewes sold January	Twin ram lambs from ewes sold February	Twin ram lambs from ewes sold March	Twin ram lambs from ewes sold April
Wool from wether lambs (singles)														
Wool from wether lambs (twins)														
Wool from wether lambs (triplets)														
Wool from wether lambs (quadruplets)														
Cattle														
Stock units total														
Switch														
Variable costs	30.47	34.68	43.04	48.34	54.03	69.08	78.14	105.16	28.79	33.25	27.91	44.38	49.02	54.91
Number of stock	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	Twin ram lambs from ewes sold May	Twin ram lambs from ewes sold June	Triplet ram lambs from ewes sold November	Triplet ram lambs from ewes sold December	Triplet ram lambs from ewes sold January	Triplet ram lambs from ewes sold February	Triplet ram lambs from ewes sold March	Triplet ram lambs from ewes sold April	Triplet ram lambs from ewes sold May	Triplet ram lambs from ewes sold June	Quadruplet ram lambs from ewes sold November	Quadruplet ram lambs from ewes sold December	Quadruplet ram lambs from ewes sold January
Wool from wether lambs (singles)													
Wool from wether lambs (twins)													
Wool from wether lambs (triplets)													
Wool from wether lambs (quadruplets)													
Cattle													
Stock units total													
Switch													
Variable costs	69.63	93.11	27.29	31.96	26.05	40.55	44.14	48.81	54.16	81.24	25.44	30.38	24.19
Number of stock	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

Appendix D: Linear Program fo	Ewe prolificacy and farm profi																																					
Put a 1 beside the box that will represent the male lambs(otherwise use a 0)	Wether	1	Ram	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?
Put a 1 above the class of lambs that are sold prime otherwise leave as 0 if sold store				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Constraint	Reltnshp	Demand	Quadruplet ram lambs from ewes sold February	Quadruplet ram lambs from ewes sold March	Quadruplet ram lambs from ewes sold April	Quadruplet ram lambs from ewes sold May	Quadruplet ram lambs from ewes sold June	Single cryptorchid lambs from ewes sold November	Single cryptorchid lambs from ewes sold December	Single cryptorchid lambs from ewes sold January	Single cryptorchid lambs from ewes sold February	Single cryptorchid lambs from ewes sold March	Single cryptorchid lambs from ewes sold April	Single cryptorchid lambs from ewes sold May	Single cryptorchid lambs from ewes sold June	Twin cryptorchid lambs from ewes sold November	Twin cryptorchid lambs from ewes sold December	Twin cryptorchid lambs from ewes sold January	Twin cryptorchid lambs from ewes sold February	Twin cryptorchid lambs from ewes sold March	Twin cryptorchid lambs from ewes sold April	Twin cryptorchid lambs from ewes sold May	Twin cryptorchid lambs from ewes sold June	Triplet cryptorchid lambs from ewes sold November	Triplet cryptorchid lambs from ewes sold December	Triplet cryptorchid lambs from ewes sold January	Triplet cryptorchid lambs from ewes sold February	Triplet cryptorchid lambs from ewes sold March	Triplet cryptorchid lambs from ewes sold April	Triplet cryptorchid lambs from ewes sold May	Triplet cryptorchid lambs from ewes sold June	Quadruplet cryptorchid lambs from ewes sold November	Quadruplet cryptorchid lambs from ewes sold December	Quadruplet cryptorchid lambs from ewes sold January	Quadruplet cryptorchid lambs from ewes sold February	Quadruplet cryptorchid lambs from ewes sold March	Quadruplet cryptorchid lambs from ewes sold April
Area of land (ha)	378	≤	378																																			
Silage	0	≤	0																																			
Livestock Energy	0	≤	0																																			
June	0	≤	0																																			
July	0	≤	0																																			
August	0	≤	0																																			
September	0	≤	0																																			
October	0	≤	0																																			
November	0	≤	0																																			
December	0	≤	0																																			
January	0	≤	0																																			
February	0	≤	0																																			
March	0	≤	0																																			
April	0	≤	0																																			
May	0	≤	0																																			
Ram Tie	0	≤	0																																			
0	0	≤	0																																			
Twin ewe lambs from ewes/Hgt tie	0	≤	0																																			
	0	≤	0																																			
Single ewe lambs from ewes born	0	≤	0																																			
Single ewe lambs from ewes sold November	0	≤	0																																			
Single ewe lambs from ewes sold December	0	≤	0																																			
Single ewe lambs from ewes sold January	0	≤	0																																			
Single ewe lambs from ewes sold February	0	≤	0																																			
Single ewe lambs from ewes sold March	0	≤	0																																			
Single ewe lambs from ewes sold April	0	≤	0																																			
Single ewe lambs from ewes sold May	0	≤	0																																			
Single ewe lambs from ewes sold June	0	≤	0																																			
Triplet ewe lambs from ewes sold	0	≤	0																																			
Triplet ewe lambs from ewes sold Nov	0	≤	0																																			
Triplet ewe lambs from ewes sold Dec	0	≤	0																																			
Triplet ewe lambs from ewes sold January	0	≤	0																																			
Triplet ewe lambs from ewes sold February	0	≤	0																																			
Triplet ewe lambs from ewes sold March	0	≤	0																																			
Triplet ewe lambs from ewes sold April	0	≤	0																																			
Triplet ewe lambs from ewes sold May	0	≤	0																																			
Triplet ewe lambs from ewes sold June	0	≤	0																																			
Quadruplet ewe lambs from ewes sold	0	≤	0																																			
Quadruplet ewe lambs from ewes sold November	0	≤	0																																			
Quadruplet ewe lambs from ewes sold December	0	≤	0																																			
Quadruplet ewe lambs from ewes sold January	0	≤	0																																			
Quadruplet ewe lambs from ewes sold February	0	≤	0																																			
Quadruplet ewe lambs from ewes sold March	0	≤	0																																			
Quadruplet ewe lambs from ewes sold April	0	≤	0																																			
Quadruplet ewe lambs from ewes sold May	0	≤	0																																			
Quadruplet ewe lambs from ewes sold June	0	≤	0																																			
Single wether lambs from ewes sold	0	≤	0																																			
Single wether lambs from ewes sold November	0	≤	0																																			
Single wether lambs from ewes sold December	0	≤	0																																			
Single wether lambs from ewes sold January	0	≤	0																																			
Single wether lambs from ewes sold February	0	≤	0																																			
Single wether lambs from ewes sold March	0	≤	0																																			
Single wether lambs from ewes sold April	0	≤	0																																			
Single wether lambs from ewes sold May	0	≤	0																																			
Single wether lambs from ewes sold June	0	≤	0																																			

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Quadruplet ram lambs from ewes sold February	Quadruplet ram lambs from ewes sold March	Quadruplet ram lambs from ewes sold April	Quadruplet ram lambs from ewes sold May	Quadruplet ram lambs from ewes sold June	Single cryptorchid lambs from ewes sold November	Single cryptorchid lambs from ewes sold December	Single cryptorchid lambs from ewes sold January	Single cryptorchid lambs from ewes sold February	Single cryptorchid lambs from ewes sold March	Single cryptorchid lambs from ewes sold April	Single cryptorchid lambs from ewes sold May	Single cryptorchid lambs from ewes sold June	Twin cryptorchid lambs from ewes sold November	Twin cryptorchid lambs from ewes sold December	Twin cryptorchid lambs from ewes sold January	Twin cryptorchid lambs from ewes sold February	Twin cryptorchid lambs from ewes sold March	Twin cryptorchid lambs from ewes sold April	Twin cryptorchid lambs from ewes sold May	Twin cryptorchid lambs from ewes sold June	Triplet cryptorchid lambs from ewes sold November	Triplet cryptorchid lambs from ewes sold December	Triplet cryptorchid lambs from ewes sold January	Triplet cryptorchid lambs from ewes sold February	Triplet cryptorchid lambs from ewes sold March	Triplet cryptorchid lambs from ewes sold April	Triplet cryptorchid lambs from ewes sold May	Triplet cryptorchid lambs from ewes sold June	Quadruplet cryptorchid lambs from ewes sold November	Quadruplet cryptorchid lambs from ewes sold December	Quadruplet cryptorchid lambs from ewes sold January	Quadruplet cryptorchid lambs from ewes sold February	Quadruplet cryptorchid lambs from ewes sold March	Quadruplet cryptorchid lambs from ewes sold April
Twin wether lambs from ewes sold	0	≤	0																																			
Twin wether lambs from ewes sold November	0	≤	0																																			
Twin wether lambs from ewes sold December	0	≤	0																																			
Twin wether lambs from ewes sold January	0	≤	0																																			
Twin wether lambs from ewes sold February	0	≤	0																																			
Twin wether lambs from ewes sold March	0	≤	0																																			
Twin wether lambs from ewes sold April	0	≤	0																																			
Twin wether lambs from ewes sold May	0	≤	0																																			
Twin wether lambs from ewes sold June	0	≤	0																																			
Triplet wether lambs from ewes sold	0	≤	0																																			
Triplet wether lambs from ewes sold November	0	≤	0																																			
Triplet wether lambs from ewes sold December	0	≤	0																																			
Triplet wether lambs from ewes sold January	0	≤	0																																			
Triplet wether lambs from ewes sold February	0	≤	0																																			
Triplet wether lambs from ewes sold March	0	≤	0																																			
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Triplet wether lambs from ewes sold June	0	≤	0																																			
Quadruplet wether lambs from ewes sold	0	≤	0																																			
Quadruplet wether lambs from ewes sold November	0	≤	0																																			
Quadruplet wether lambs from ewes sold December	0	≤	0																																			
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Quadruplet wether lambs from ewes sold March	0	≤	0																																			
Quadruplet wether lambs from ewes sold April	0	≤	0																																			
Quadruplet wether lambs from ewes sold May	0	≤	0																																			
Quadruplet wether lambs from ewes sold June	0	≤	0																																			
Single ram lambs from ewes sold	0	≤	0																																			
Single ram lambs from ewes sold November	0	≤	0																																			
Single ram lambs from ewes sold December	0	≤	0																																			
Single ram lambs from ewes sold January	0	≤	0																																			
Single ram lambs from ewes sold February	0	≤	0																																			
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Single ram lambs from ewes sold June	0	≤	0																																			
Twin ram lambs from ewes sold	0	≤	0																																			
Twin ram lambs from ewes sold November	0	≤	0																																			
Twin ram lambs from ewes sold December	0	≤	0																																			
Twin ram lambs from ewes sold January	0	≤	0																																			
Twin ram lambs from ewes sold February	0	≤	0																																			
Twin ram lambs from ewes sold March	0	≤	0																																			
Twin ram lambs from ewes sold April	0	≤	0																																			
Twin ram lambs from ewes sold May	0	≤	0																																			
Twin ram lambs from ewes sold June	0	≤	0																																			
Triplet ram lambs from ewes sold	0	≤	0																																			
Triplet ram lambs from ewes sold November	0	≤	0																																			
Triplet ram lambs from ewes sold December	0	≤	0																																			
Triplet ram lambs from ewes sold January	0	≤	0																																			
Triplet ram lambs from ewes sold February	0	≤	0																																			
Triplet ram lambs from ewes sold March	0	≤	0																																			
Triplet ram lambs from ewes sold April	0	≤	0																																			

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Quadruplet ram lambs from ewes sold February	Quadruplet ram lambs from ewes sold March	Quadruplet ram lambs from ewes sold April	Quadruplet ram lambs from ewes sold May	Quadruplet ram lambs from ewes sold June	Single cryptorchid lambs from ewes sold November	Single cryptorchid lambs from ewes sold December	Single cryptorchid lambs from ewes sold January	Single cryptorchid lambs from ewes sold February	Single cryptorchid lambs from ewes sold March	Single cryptorchid lambs from ewes sold April	Single cryptorchid lambs from ewes sold May	Single cryptorchid lambs from ewes sold June	Twin cryptorchid lambs from ewes sold November	Twin cryptorchid lambs from ewes sold December	Twin cryptorchid lambs from ewes sold January	Twin cryptorchid lambs from ewes sold February	Twin cryptorchid lambs from ewes sold March	Twin cryptorchid lambs from ewes sold April	Twin cryptorchid lambs from ewes sold May	Twin cryptorchid lambs from ewes sold June	Triplet cryptorchid lambs from ewes sold November	Triplet cryptorchid lambs from ewes sold December	Triplet cryptorchid lambs from ewes sold January	Triplet cryptorchid lambs from ewes sold February	Triplet cryptorchid lambs from ewes sold March	Triplet cryptorchid lambs from ewes sold April	Triplet cryptorchid lambs from ewes sold May	Triplet cryptorchid lambs from ewes sold June	Quadruplet cryptorchid lambs from ewes sold November	Quadruplet cryptorchid lambs from ewes sold December	Quadruplet cryptorchid lambs from ewes sold January	Quadruplet cryptorchid lambs from ewes sold February	Quadruplet cryptorchid lambs from ewes sold March	Quadruplet cryptorchid lambs from ewes sold April
Triplet ram lambs from ewes sold May	0	≤	0																																			
Triplet ram lambs from ewes sold June	0	≤	0																																			
Quadruplet ram lambs from ewes sold	0	≤	0																																			
Quadruplet ram lambs from ewes sold November	0	≤	0																																			
Quadruplet ram lambs from ewes sold December	0	≤	0																																			
Quadruplet ram lambs from ewes sold January	0	≤	0																																			
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Quadruplet ram lambs from ewes sold March	0	≤	0		1																																	
Quadruplet ram lambs from ewes sold April	0	≤	0			1																																
Quadruplet ram lambs from ewes sold May	0	≤	0				1																															
Quadruplet ram lambs from ewes sold June	0	≤	0					1																														
Single cryptorchid lambs from ewes sold	0	≤	0																																			
Single cryptorchid lambs from ewes sold November	0	≤	0						1																													
Single cryptorchid lambs from ewes sold December	0	≤	0							1																												
Single cryptorchid lambs from ewes sold January	0	≤	0								1																											
Single cryptorchid lambs from ewes sold February	0	≤	0									1																										
Single cryptorchid lambs from ewes sold March	0	≤	0										1																									
Single cryptorchid lambs from ewes sold April	0	≤	0											1																								
Single cryptorchid lambs from ewes sold May	0	≤	0												1																							
Single cryptorchid lambs from ewes sold June	0	≤	0													1																						
Twin cryptorchid lambs from ewes sold	0	≤	0																																			
Twin cryptorchid lambs from ewes sold November	0	≤	0														1																					
Twin cryptorchid lambs from ewes sold December	0	≤	0															1																				
Twin cryptorchid lambs from ewes sold January	0	≤	0																1																			
Twin cryptorchid lambs from ewes sold February	0	≤	0																	1																		
Twin cryptorchid lambs from ewes sold March	0	≤	0																		1																	
Twin cryptorchid lambs from ewes sold April	0	≤	0																			1																
Twin cryptorchid lambs from ewes sold May	0	≤	0																				1															
Twin cryptorchid lambs from ewes sold June	0	≤	0																					1														
Triplet cryptorchid lambs from ewes sold	0	≤	0																																			
Triplet cryptorchid lambs from ewes sold November	0	≤	0																						1													
Triplet cryptorchid lambs from ewes sold December	0	≤	0																							1												
Triplet cryptorchid lambs from ewes sold January	0	≤	0																								1											
Triplet cryptorchid lambs from ewes sold February	0	≤	0																									1										
Triplet cryptorchid lambs from ewes sold March	0	≤	0																										1									
Triplet cryptorchid lambs from ewes sold April	0	≤	0																											1								
Triplet cryptorchid lambs from ewes sold May	0	≤	0																												1							
Triplet cryptorchid lambs from ewes sold June	0	≤	0																													1						
Quadruplet cryptorchid lambs from ewes sold	0	≤	0																																			
Quadruplet cryptorchid lambs from ewes sold November	0	≤	0																														1					
Quadruplet cryptorchid lambs from ewes sold December	0	≤	0																															1				
Quadruplet cryptorchid lambs from ewes sold January	0	≤	0																																1			
Quadruplet cryptorchid lambs from ewes sold February	0	≤	0																																	1		
Quadruplet cryptorchid lambs from ewes sold March	0	≤	0																																		1	
Quadruplet cryptorchid lambs from ewes sold April	0	≤	0																																			1
Quadruplet cryptorchid lambs from ewes sold May	0	≤	0																																			
Quadruplet cryptorchid lambs from ewes sold June	0	≤	0																																			
Single ewe lambs from hoggets sold	0	≤	0																																			
Single ewe lambs from hoggets sold November	0	≤	0																																			
Single ewe lambs from hoggets sold December	0	≤	0																																			

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Quadruplet ram lambs from ewes sold February	Quadruplet ram lambs from ewes sold March	Quadruplet ram lambs from ewes sold April	Quadruplet ram lambs from ewes sold May	Quadruplet ram lambs from ewes sold June	Single cryptorchid lambs from ewes sold November	Single cryptorchid lambs from ewes sold December	Single cryptorchid lambs from ewes sold January	Single cryptorchid lambs from ewes sold February	Single cryptorchid lambs from ewes sold March	Single cryptorchid lambs from ewes sold April	Single cryptorchid lambs from ewes sold May	Single cryptorchid lambs from ewes sold June	Twin cryptorchid lambs from ewes sold November	Twin cryptorchid lambs from ewes sold December	Twin cryptorchid lambs from ewes sold January	Twin cryptorchid lambs from ewes sold February	Twin cryptorchid lambs from ewes sold March	Twin cryptorchid lambs from ewes sold April	Twin cryptorchid lambs from ewes sold May	Twin cryptorchid lambs from ewes sold June	Triplet cryptorchid lambs from ewes sold November	Triplet cryptorchid lambs from ewes sold December	Triplet cryptorchid lambs from ewes sold January	Triplet cryptorchid lambs from ewes sold February	Triplet cryptorchid lambs from ewes sold March	Triplet cryptorchid lambs from ewes sold April	Triplet cryptorchid lambs from ewes sold May	Triplet cryptorchid lambs from ewes sold June	Quadruplet cryptorchid lambs from ewes sold November	Quadruplet cryptorchid lambs from ewes sold December	Quadruplet cryptorchid lambs from ewes sold January	Quadruplet cryptorchid lambs from ewes sold February	Quadruplet cryptorchid lambs from ewes sold March	Quadruplet cryptorchid lambs from ewes sold April
Single ewe lambs from hoggets sold January	0	≤	0																																			
Single ewe lambs from hoggets sold February	0	≤	0																																			
Single ewe lambs from hoggets sold March	0	≤	0																																			
Single ewe lambs from hoggets sold April	0	≤	0																																			
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Single wether lambs from hoggets sold	0	≤	0																																			
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Single wether lambs from hoggets sold December	0	≤	0																																			
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Single wether lambs from hoggets sold April	0	≤	0																																			
Single wether lambs from hoggets sold May	0	≤	0																																			
Single wether lambs from hoggets sold June	0	≤	0																																			
Twin ewe lambs from hoggets sold	0	≤	0																																			
Twin ewe lambs from hoggets sold November	0	≤	0																																			
Twin ewe lambs from hoggets sold December	0	≤	0																																			
Twin ewe lambs from hoggets sold January	0	≤	0																																			
Twin ewe lambs from hoggets sold February	0	≤	0																																			
Twin ewe lambs from hoggets sold March	0	≤	0																																			
Twin ewe lambs from hoggets sold April	0	≤	0																																			
Twin ewe lambs from hoggets sold May	0	≤	0																																			
Twin ewe lambs from hoggets sold June	0	≤	0																																			
Twin wether lambs from hoggets sold	0	≤	0																																			
Twin wether lambs from hoggets sold November	0	≤	0																																			
Twin wether lambs from hoggets sold December	0	≤	0																																			
Twin wether lambs from hoggets sold January	0	≤	0																																			
Twin wether lambs from hoggets sold February	0	≤	0																																			
Twin wether lambs from hoggets sold March	0	≤	0																																			
Twin wether lambs from hoggets sold April	0	≤	0																																			
Twin wether lambs from hoggets sold May	0	≤	0																																			
Twin wether lambs from hoggets sold June	0	≤	0																																			
	0	≤	0																																			
	0	≤	0																																			
	0	≤	0																																			
Dry Hgt Tie	0	≤	0																																			
Hgt/2th Tie	0	≤	0																																			
2th/4th tie	0	≤	0																																			
4th/6th tie	0	≤	0																																			
6th/4yr tie	0	≤	0																																			
4yr/5yr tie	0	≤	0																																			
5 yr/ sale tie	0	≤	0																																			
6yr/sale tie	0	≤	0																																			
Age cull	0	≤	0																																			
Dry hogget cull	0	≤	0																																			
Wet hogget cull	0	≤	0																																			
Wool from dry hogget	0	≤	0																																			
Wool from wet hogget	0	≤	0																																			
Wool from 2th	0	≤	0																																			
Wool from 4th	0	≤	0																																			
Wool from 6th	0	≤	0																																			
Wool from 4yr	0	≤	0																																			
Wool from 5yr	0	≤	0																																			
Wool from 6yr	0	≤	0																																			
Wool from Rams	0	≤	0																																			
	0	≤	0																																			
Wool from Ewe lambs (singles)	0	≤	0																																			
Wool from Ewe lambs (twins)	0	≤	0																																			
Wool from Ewe lambs (triplets)	0	≤	0																																			
Wool from Ewe lambs (quadruplets)	0	≤	0																																			

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Quadruplet ram lambs from ewes sold February	Quadruplet ram lambs from ewes sold March	Quadruplet ram lambs from ewes sold April	Quadruplet ram lambs from ewes sold May	Quadruplet ram lambs from ewes sold June	Single cryptorchid lambs from ewes sold November	Single cryptorchid lambs from ewes sold December	Single cryptorchid lambs from ewes sold January	Single cryptorchid lambs from ewes sold February	Single cryptorchid lambs from ewes sold March	Single cryptorchid lambs from ewes sold April	Single cryptorchid lambs from ewes sold May	Single cryptorchid lambs from ewes sold June	Twin cryptorchid lambs from ewes sold November	Twin cryptorchid lambs from ewes sold December	Twin cryptorchid lambs from ewes sold January	Twin cryptorchid lambs from ewes sold February	Twin cryptorchid lambs from ewes sold March	Twin cryptorchid lambs from ewes sold April	Twin cryptorchid lambs from ewes sold May	Twin cryptorchid lambs from ewes sold June	Triplet cryptorchid lambs from ewes sold November	Triplet cryptorchid lambs from ewes sold December	Triplet cryptorchid lambs from ewes sold January	Triplet cryptorchid lambs from ewes sold February	Triplet cryptorchid lambs from ewes sold March	Triplet cryptorchid lambs from ewes sold April	Triplet cryptorchid lambs from ewes sold May	Triplet cryptorchid lambs from ewes sold June	Quadruplet cryptorchid lambs from ewes sold November	Quadruplet cryptorchid lambs from ewes sold December	Quadruplet cryptorchid lambs from ewes sold January	Quadruplet cryptorchid lambs from ewes sold February	Quadruplet cryptorchid lambs from ewes sold March	Quadruplet cryptorchid lambs from ewes sold April
Wool from wether lambs (singles)	0	≤	0																																			
Wool from wether lambs (twins)	0	≤	0																																			
Wool from wether lambs (triplets)	0	≤	0																																			
Wool from wether lambs (quadruplets)	0	≤	0																																			
Cattle	0	≤	0																																			
Stock units total	6006000	≤	3441																																			
Switch	0		0																																			
Variable costs	-1000000		47767	24.03	39.73	43.43	47.75	62.51	30.47	34.68	44.70	51.47	60.76	75.76	86.56	117.46	28.79	33.25	28.88	46.99	52.71	67.61	76.65	103.36	27.29	31.96	26.82	42.64	47.09	52.75	66.89	89.43	25.44	30.38	24.81	25.12	42.10	46.58
Number of stock	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

Appendix D: Linear Program fo	Ewe prolificacy and farm profi																																							
Put a 1 beside the box that will represent the male lambs(otherwise use a 0)	Wether	1	Ram	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?	0/1?
Put a 1 above the class of lambs that are sold prime otherwise leave as 0 if sold store				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Constraint	Reltnshp	Demand	Quadruplet cryptorchid lambs from ewes sold May	Quadruplet cryptorchid lambs from ewes sold June	Single ewe lambs from hoggets sold November	Single ewe lambs from hoggets sold December	Single ewe lambs from hoggets sold January	Single ewe lambs from hoggets sold February	Single ewe lambs from hoggets sold March	Single ewelambs from hoggets sold April	Single ewe lambs from hoggets sold May	Single ewelambs from hoggets sold June	Single wether lambs from hoggets sold November	Single wether lambs from hoggets sold December	Single wether lambs from hoggets sold January	Single wether lambs from hoggets sold February	Single wether lambs from hoggets sold March	Single wether lambs from hoggets sold April	Single wether lambs from hoggets sold May	Single wether lambs from hoggets sold June	Twin ewe lambs from hoggets sold November	Twin ewe lambs from hoggets sold December	Twin ewe lambs from hoggets sold January	Twin ewe lambs from hoggets sold February	Twin ewe lambs from hoggets sold March	Twin ewe lambs from hoggets sold April	Twin ewe lambs from hoggets sold May	Twin ewe lambs from hoggets sold June	Twin wether lambs from hoggets sold November	Twin wether lambs from hoggets sold December	Twin wether lambs from hoggets sold January	Twin wether lambs from hoggets sold February	Twin wether lambs from hoggets sold March	Twin wether lambs from hoggets sold April	Twin wether lambs from hoggets sold May	Twin wether lambs from hoggets sold June	Single ewe lambs from ewes sold November	Single ewe lambs from ewes sold December	Single ewe lambs from ewes sold January
Area of land (ha)	378	≤	378																																					
Silage	0	≤	0																																					
Livestock Energy	0	≤	0																																					
June	0	≤	0																																					
July	0	≤	0																																					
August	0	≤	0																																					
September	0	≤	0																																					
October	0	≤	0																																					
November	0	≤	0																																					
December	0	≤	0																																					
January	0	≤	0																																					
February	0	≤	0																																					
March	0	≤	0																																					
April	0	≤	0																																					
May	0	≤	0																																					
Ram Tie	0	≤	0																																					
0	0	≤	0																																					
Twin ewe lambs from ewes/Hgt tie	0	≤	0																																					
	0	≤	0																																					
Single ewe lambs from ewes born	0	≤	0																																					
Single ewe lambs from ewes sold November	0	≤	0																																		1.00		
Single ewe lambs from ewes sold December	0	≤	0																																			1.00	
Single ewe lambs from ewes sold January	0	≤	0																																				1.00
Single ewe lambs from ewes sold February	0	≤	0																																					
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Single ewe lambs from ewes sold April	0	≤	0																																					
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Triplet ewe lambs from ewes sold	0	≤	0																																					
Triplet ewe lambs from ewes sold Nov	0	≤	0																																					
Triplet ewe lambs from ewes sold Dec	0	≤	0																																					
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Quadruplet ewe lambs from ewes sold May	0	≤	0																																					
Quadruplet ewe lambs from ewes sold June	0	≤	0																																					
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Single wether lambs from ewes sold November	0	≤	0																																					
Single wether lambs from ewes sold December	0	≤	0																																					
Single wether lambs from ewes sold January	0	≤	0																																					
Single wether lambs from ewes sold February	0	≤	0																																					
Single wether lambs from ewes sold March	0	≤	0																																					
Single wether lambs from ewes sold April	0	≤	0																																					
Single wether lambs from ewes sold May	0	≤	0																																					
Single wether lambs from ewes sold June	0	≤	0																																					

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Quadruplet cryptorchid lambs from ewes sold May	Quadruplet cryptorchid lambs from ewes sold June	Single ewe lambs from hoggets sold November	Single ewe lambs from hoggets sold December	Single ewe lambs from hoggets sold January	Single ewe lambs from hoggets sold February	Single ewe lambs from hoggets sold March	Single ewelambs from hoggets sold April	Single ewe lambs from hoggets sold May	Single ewelambs from hoggets sold June	Single wether lambs from hoggets sold November	Single wether lambs from hoggets sold December	Single wether lambs from hoggets sold January	Single wether lambs from hoggets sold February	Single wether lambs from hoggets sold March	Single wether lambs from hoggets sold April	Single wether lambs from hoggets sold May	Single wether lambs from hoggets sold June	Twin ewe lambs from hoggets sold November	Twin ewe lambs from hoggets sold December	Twin ewe lambs from hoggets sold January	Twin ewe lambs from hoggets sold February	Twin ewe lambs from hoggets sold March	Twin ewe lambs from hoggets sold April	Twin ewe lambs from hoggets sold May	Twin ewe lambs from hoggets sold June	Twin wether lambs from hoggets sold November	Twin wether lambs from hoggets sold December	Twin wether lambs from hoggets sold January	Twin wether lambs from hoggets sold February	Twin wether lambs from hoggets sold March	Twin wether lambs from hoggets sold April	Twin wether lambs from hoggets sold May	Twin wether lambs from hoggets sold June	Single ewe lambs from ewes sold November	Single ewe lambs from ewes sold December	Single ewe lambs from ewes sold January
Twin wether lambs from ewes sold	0	≤	0																																					
Twin wether lambs from ewes sold November	0	≤	0																																					
Twin wether lambs from ewes sold December	0	≤	0																																					
Twin wether lambs from ewes sold January	0	≤	0																																					
Twin wether lambs from ewes sold February	0	≤	0																																					
Twin wether lambs from ewes sold March	0	≤	0																																					
Twin wether lambs from ewes sold April	0	≤	0																																					
Twin wether lambs from ewes sold May	0	≤	0																																					
Twin wether lambs from ewes sold June	0	≤	0																																					
Triplet wether lambs from ewes sold	0	≤	0																																					
Triplet wether lambs from ewes sold November	0	≤	0																																					
Triplet wether lambs from ewes sold December	0	≤	0																																					
Triplet wether lambs from ewes sold January	0	≤	0																																					
Triplet wether lambs from ewes sold February	0	≤	0																																					
Triplet wether lambs from ewes sold March	0	≤	0																																					
Triplet wether lambs from ewes sold April	0	≤	0																																					
Triplet wether lambs from ewes sold May	0	≤	0																																					
Triplet wether lambs from ewes sold June	0	≤	0																																					
Quadruplet wether lambs from ewes sold	0	≤	0																																					
Quadruplet wether lambs from ewes sold November	0	≤	0																																					
Quadruplet wether lambs from ewes sold December	0	≤	0																																					
Quadruplet wether lambs from ewes sold January	0	≤	0																																					
Quadruplet wether lambs from ewes sold February	0	≤	0																																					
Quadruplet wether lambs from ewes sold March	0	≤	0																																					
Quadruplet wether lambs from ewes sold April	0	≤	0																																					
Quadruplet wether lambs from ewes sold May	0	≤	0																																					
Quadruplet wether lambs from ewes sold June	0	≤	0																																					
Single ram lambs from ewes sold	0	≤	0																																					
Single ram lambs from ewes sold November	0	≤	0																																					
Single ram lambs from ewes sold December	0	≤	0																																					
Single ram lambs from ewes sold January	0	≤	0																																					
Single ram lambs from ewes sold February	0	≤	0																																					
Single ram lambs from ewes sold March	0	≤	0																																					
Single ram lambs from ewes sold April	0	≤	0																																					
Single ram lambs from ewes sold May	0	≤	0																																					
Single ram lambs from ewes sold June	0	≤	0																																					
Twin ram lambs from ewes sold	0	≤	0																																					
Twin ram lambs from ewes sold November	0	≤	0																																					
Twin ram lambs from ewes sold December	0	≤	0																																					
Twin ram lambs from ewes sold January	0	≤	0																																					
Twin ram lambs from ewes sold February	0	≤	0																																					
Twin ram lambs from ewes sold March	0	≤	0																																					
Twin ram lambs from ewes sold April	0	≤	0																																					
Twin ram lambs from ewes sold May	0	≤	0																																					
Twin ram lambs from ewes sold June	0	≤	0																																					
Triplet ram lambs from ewes sold	0	≤	0																																					
Triplet ram lambs from ewes sold November	0	≤	0																																					
Triplet ram lambs from ewes sold December	0	≤	0																																					
Triplet ram lambs from ewes sold January	0	≤	0																																					
Triplet ram lambs from ewes sold February	0	≤	0																																					
Triplet ram lambs from ewes sold March	0	≤	0																																					
Triplet ram lambs from ewes sold April	0	≤	0																																					

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Quadruplet cryptorchid lambs from ewes sold May	Quadruplet cryptorchid lambs from ewes sold June	Single ewe lambs from hoggets sold November	Single ewe lambs from hoggets sold December	Single ewe lambs from hoggets sold January	Single ewe lambs from hoggets sold February	Single ewe lambs from hoggets sold March	Single ewelambs from hoggets sold April	Single ewe lambs from hoggets sold May	Single ewelambs from hoggets sold June	Single wether lambs from hoggets sold November	Single wether lambs from hoggets sold December	Single wether lambs from hoggets sold January	Single wether lambs from hoggets sold February	Single wether lambs from hoggets sold March	Single wether lambs from hoggets sold April	Single wether lambs from hoggets sold May	Single wether lambs from hoggets sold June	Twin ewe lambs from hoggets sold November	Twin ewe lambs from hoggets sold December	Twin ewe lambs from hoggets sold January	Twin ewe lambs from hoggets sold February	Twin ewe lambs from hoggets sold March	Twin ewe lambs from hoggets sold April	Twin ewe lambs from hoggets sold May	Twin ewe lambs from hoggets sold June	Twin wether lambs from hoggets sold November	Twin wether lambs from hoggets sold December	Twin wether lambs from hoggets sold January	Twin wether lambs from hoggets sold February	Twin wether lambs from hoggets sold March	Twin wether lambs from hoggets sold April	Twin wether lambs from hoggets sold May	Twin wether lambs from hoggets sold June	Single ewe lambs from ewes sold November	Single ewe lambs from ewes sold December	Single ewe lambs from ewes sold January
Triplet ram lambs from ewes sold May	0	≤	0																																					
Triplet ram lambs from ewes sold June	0	≤	0																																					
Quadruplet ram lambs from ewes sold	0	≤	0																																					
Quadruplet ram lambs from ewes sold November	0	≤	0																																					
Quadruplet ram lambs from ewes sold December	0	≤	0																																					
Quadruplet ram lambs from ewes sold January	0	≤	0																																					
Quadruplet ram lambs from ewes sold February	0	≤	0																																					
Quadruplet ram lambs from ewes sold March	0	≤	0																																					
Quadruplet ram lambs from ewes sold April	0	≤	0																																					
Quadruplet ram lambs from ewes sold May	0	≤	0																																					
Quadruplet ram lambs from ewes sold June	0	≤	0																																					
Single cryptorchid lambs from ewes sold	0	≤	0																																					
Single cryptorchid lambs from ewes sold November	0	≤	0																																					
Single cryptorchid lambs from ewes sold December	0	≤	0																																					
Single cryptorchid lambs from ewes sold January	0	≤	0																																					
Single cryptorchid lambs from ewes sold February	0	≤	0																																					
Single cryptorchid lambs from ewes sold March	0	≤	0																																					
Single cryptorchid lambs from ewes sold April	0	≤	0																																					
Single cryptorchid lambs from ewes sold May	0	≤	0																																					
Single cryptorchid lambs from ewes sold June	0	≤	0																																					
Twin cryptorchid lambs from ewes sold	0	≤	0																																					
Twin cryptorchid lambs from ewes sold November	0	≤	0																																					
Twin cryptorchid lambs from ewes sold December	0	≤	0																																					
Twin cryptorchid lambs from ewes sold January	0	≤	0																																					
Twin cryptorchid lambs from ewes sold February	0	≤	0																																					
Twin cryptorchid lambs from ewes sold March	0	≤	0																																					
Twin cryptorchid lambs from ewes sold April	0	≤	0																																					
Twin cryptorchid lambs from ewes sold May	0	≤	0																																					
Twin cryptorchid lambs from ewes sold June	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold November	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold December	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold January	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold February	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold March	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold April	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold May	0	≤	0																																					
Triplet cryptorchid lambs from ewes sold June	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold November	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold December	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold January	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold February	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold March	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold April	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold May	0	≤	0	1																																				
Quadruplet cryptorchid lambs from ewes sold June	0	≤	0		1																																			
Single ewe lambs from hoggets sold	0	≤	0																																					
Single ewe lambs from hoggets sold November	0	≤	0			1																																		
Single ewe lambs from hoggets sold December	0	≤	0				1																																	

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Quadruplet cryptorchid lambs from ewes sold May	Quadruplet cryptorchid lambs from ewes sold June	Single ewe lambs from hoggets sold November	Single ewe lambs from hoggets sold December	Single ewe lambs from hoggets sold January	Single ewe lambs from hoggets sold February	Single ewe lambs from hoggets sold March	Single ewelambs from hoggets sold April	Single ewe lambs from hoggets sold May	Single ewelambs from hoggets sold June	Single wether lambs from hoggets sold November	Single wether lambs from hoggets sold December	Single wether lambs from hoggets sold January	Single wether lambs from hoggets sold February	Single wether lambs from hoggets sold March	Single wether lambs from hoggets sold April	Single wether lambs from hoggets sold May	Single wether lambs from hoggets sold June	Twin ewe lambs from hoggets sold November	Twin ewe lambs from hoggets sold December	Twin ewe lambs from hoggets sold January	Twin ewe lambs from hoggets sold February	Twin ewe lambs from hoggets sold March	Twin ewe lambs from hoggets sold April	Twin ewe lambs from hoggets sold May	Twin ewe lambs from hoggets sold June	Twin wether lambs from hoggets sold November	Twin wether lambs from hoggets sold December	Twin wether lambs from hoggets sold January	Twin wether lambs from hoggets sold February	Twin wether lambs from hoggets sold March	Twin wether lambs from hoggets sold April	Twin wether lambs from hoggets sold May	Twin wether lambs from hoggets sold June	Single ewe lambs from ewes sold November	Single ewe lambs from ewes sold December	Single ewe lambs from ewes sold January
Single ewe lambs from hoggets sold January	0	≤	0					1																																
Single ewe lambs from hoggets sold February	0	≤	0						1																															
Single ewe lambs from hoggets sold March	0	≤	0							1																														
Single ewe lambs from hoggets sold April	0	≤	0								1																													
Single ewe lambs from hoggets sold May	0	≤	0									1																												
Single ewe lambs from hoggets sold June	0	≤	0										1																											
Single wether lambs from hoggets sold	0	≤	0																																					
Single wether lambs from hoggets sold November	0	≤	0											1																										
Single wether lambs from hoggets sold December	0	≤	0												1																									
Single wether lambs from hoggets sold January	0	≤	0													1																								
Single wether lambs from hoggets sold February	0	≤	0														1																							
Single wether lambs from hoggets sold March	0	≤	0															1																						
Single wether lambs from hoggets sold April	0	≤	0																1																					
Single wether lambs from hoggets sold May	0	≤	0																	1																				
Single wether lambs from hoggets sold June	0	≤	0																		1																			
Twin ewe lambs from hoggets sold	0	≤	0																																					
Twin ewe lambs from hoggets sold November	0	≤	0																			1																		
Twin ewe lambs from hoggets sold December	0	≤	0																				1																	
Twin ewe lambs from hoggets sold January	0	≤	0																					1																
Twin ewe lambs from hoggets sold February	0	≤	0																						1															
Twin ewe lambs from hoggets sold March	0	≤	0																							1														
Twin ewe lambs from hoggets sold April	0	≤	0																								1													
Twin ewe lambs from hoggets sold May	0	≤	0																									1												
Twin ewe lambs from hoggets sold June	0	≤	0																										1											
Twin wether lambs from hoggets sold	0	≤	0																																					
Twin wether lambs from hoggets sold November	0	≤	0																											1										
Twin wether lambs from hoggets sold December	0	≤	0																												1									
Twin wether lambs from hoggets sold January	0	≤	0																													1								
Twin wether lambs from hoggets sold February	0	≤	0																														1							
Twin wether lambs from hoggets sold March	0	≤	0																															1						
Twin wether lambs from hoggets sold April	0	≤	0																																1					
Twin wether lambs from hoggets sold May	0	≤	0																																	1				
Twin wether lambs from hoggets sold June	0	≤	0																																		1			
	0	≤	0																																					
	0	≤	0																																					
	0	≤	0																																					
Dry Hgt Tie	0	≤	0																																					
Hgt/2th Tie	0	≤	0																																					
2th/4th tie	0	≤	0																																					
4th/6th tie	0	≤	0																																					
6th/4yr tie	0	≤	0																																					
4yr/5yr tie	0	≤	0																																					
5 yr/ sale tie	0	≤	0																																					
6yr/sale tie	0	≤	0																																					
Age cull	0	≤	0																																					
Dry hogget cull	0	≤	0																																					
Wet hogget cull	0	≤	0																																					
Wool from dry hogget	0	≤	0																																					
Wool from wet hogget	0	≤	0																																					
Wool from 2th	0	≤	0																																					
Wool from 4th	0	≤	0																																					
Wool from 6th	0	≤	0																																					
Wool from 4yr	0	≤	0																																					
Wool from 5yr	0	≤	0																																					
Wool from 6yr	0	≤	0																																					
Wool from Rams	0	≤	0																																					
	0	≤	0																																					
Wool from Ewe lambs (singles)	0	≤	0																																					
Wool from Ewe lambs (twins)	0	≤	0																																					
Wool from Ewe lambs (triplets)	0	≤	0																																					
Wool from Ewe lambs (quadruplets)	0	≤	0																																					

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Quadruplet cryptorchid lambs from ewes sold May	Quadruplet cryptorchid lambs from ewes sold June	Single ewe lambs from hoggets sold November	Single ewe lambs from hoggets sold December	Single ewe lambs from hoggets sold January	Single ewe lambs from hoggets sold February	Single ewe lambs from hoggets sold March	Single ewelambs from hoggets sold April	Single ewe lambs from hoggets sold May	Single ewelambs from hoggets sold June	Single wether lambs from hoggets sold November	Single wether lambs from hoggets sold December	Single wether lambs from hoggets sold January	Single wether lambs from hoggets sold February	Single wether lambs from hoggets sold March	Single wether lambs from hoggets sold April	Single wether lambs from hoggets sold May	Single wether lambs from hoggets sold June
Wool from wether lambs (singles)	0	≤	0																		
Wool from wether lambs (twins)	0	≤	0																		
Wool from wether lambs (triplets)	0	≤	0																		
Wool from wether lambs (quadruplets)	0	≤	0																		
Cattle	0	≤	0																		
Stock units total	6006000	≤	3441																		
Switch	0		0																		
Variable costs	-1000000		47767	51.72	68.27	27.42	31.22	26.02	41.15	45.30	50.59	56.57	85.42	27.42	31.22	26.02	41.15	45.30	50.59	56.57	85.42
Number of stock	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	Twin ewe lambs from hoggets sold November	Twin ewe lambs from hoggets sold December	Twin ewe lambs from hoggets sold January	Twin ewe lambs from hoggets sold February	Twin ewe lambs from hoggets sold March	Twin ewe lambs from hoggets sold April	Twin ewe lambs from hoggets sold May	Twin ewe lambs from hoggets sold June	Twin wether lambs from hoggets sold November	Twin wether lambs from hoggets sold December	Twin wether lambs from hoggets sold January	Twin wether lambs from hoggets sold February	Twin wether lambs from hoggets sold March	Twin wether lambs from hoggets sold April	Twin wether lambs from hoggets sold May	Twin wether lambs from hoggets sold June	Single ewe lambs from ewes sold November	Single ewe lambs from ewes sold December	Single ewe lambs from ewes sold January
Wool from wether lambs (singles)																			
Wool from wether lambs (twins)																			
Wool from wether lambs (triplets)																			
Wool from wether lambs (quadruplets)																			
Cattle																			
Stock units total																			
Switch																			
Variable costs	25.91	29.93	24.40	24.69	41.34	45.72	50.74	66.96	25.91	29.93	24.40	24.69	41.34	45.72	50.74	66.96	30.47	34.68	28.91
Number of stock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	59	118	177

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

Appendix D: Linear Program fo	Ewe prolificacy and farm prof																
Put a 1 beside the box that will represent the male lambs(otherwise use a 0)	Wether	1	Ram	0/1?	0/1?	0/1?	0/1?	0/1?									
Put a 1 above the class of lambs that are sold prime otherwise leave as 0 if sold store				1	1	1	1	1	1	1	1	1	1	1	1	1
	Constraint	Reltnshp	Demand	Single ewe lambs from ewes sold February	Single ewe lambs from ewes sold March	Single ewe lambs from ewes sold April	Single ewe lambs from ewes sold May	Single ewe lambs from ewes sold June	Twin ewe lamb from ewe sales November	Twin ewe lamb from ewe sales December	Twin ewe lamb from ewe sales January	Twin ewe lamb from ewe sales February	Twin ewe lamb from ewe sales March	Twin ewe lamb from ewe sales April	Twin ewe lamb from ewe sales May	Twin ewe lamb from ewe sales June
Area of land (ha)	378	≤	378													
Silage	0	≤	0													
Livestock Energy	0	≤	0													
June	0	≤	0													
July	0	≤	0													
August	0	≤	0													
September	0	≤	0													
October	0	≤	0													
November	0	≤	0													
December	0	≤	0													
January	0	≤	0													
February	0	≤	0													
March	0	≤	0													
April	0	≤	0													
May	0	≤	0													
Ram Tie	0	≤	0													
0	0	≤	0													
Twin ewe lambs from ewes/Hgt tie	0	≤	0						0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
	0	≤	0													
Single ewe lambs from ewes born	0	≤	0													
Single ewe lambs from ewes sold November	0	≤	0													
Single ewe lambs from ewes sold December	0	≤	0													
Single ewe lambs from ewes sold January	0	≤	0													
Single ewe lambs from ewes sold February	0	≤	0	1.00												
Single ewe lambs from ewes sold March	0	≤	0		1.00											
Single ewe lambs from ewes sold April	0	≤	0			1.00										
Single ewe lambs from ewes sold May	0	≤	0				1.00									
Single ewe lambs from ewes sold June	0	≤	0					1.00								
Triplet ewe lambs from ewes sold	0	≤	0													
Triplet ewe lambs from ewes sold Nov	0	≤	0													
Triplet ewe lambs from ewes sold Dec	0	≤	0													
Triplet ewe lambs from ewes sold January	0	≤	0													
Triplet ewe lambs from ewes sold February	0	≤	0													
Triplet ewe lambs from ewes sold March	0	≤	0													
Triplet ewe lambs from ewes sold April	0	≤	0													
Triplet ewe lambs from ewes sold May	0	≤	0													
Triplet ewe lambs from ewes sold June	0	≤	0													
Quadruplet ewe lambs from ewes sold	0	≤	0													
Quadruplet ewe lambs from ewes sold November	0	≤	0													
Quadruplet ewe lambs from ewes sold December	0	≤	0													
Quadruplet ewe lambs from ewes sold January	0	≤	0													
Quadruplet ewe lambs from ewes sold February	0	≤	0													
Quadruplet ewe lambs from ewes sold March	0	≤	0													
Quadruplet ewe lambs from ewes sold April	0	≤	0													
Quadruplet ewe lambs from ewes sold May	0	≤	0													
Quadruplet ewe lambs from ewes sold June	0	≤	0													
Single wether lambs from ewes sold	0	≤	0													
Single wether lambs from ewes sold November	0	≤	0													
Single wether lambs from ewes sold December	0	≤	0													
Single wether lambs from ewes sold January	0	≤	0													
Single wether lambs from ewes sold February	0	≤	0													
Single wether lambs from ewes sold March	0	≤	0													
Single wether lambs from ewes sold April	0	≤	0													
Single wether lambs from ewes sold May	0	≤	0													
Single wether lambs from ewes sold June	0	≤	0													

	Silage made in August	Silage made in September	Silage made in October	Silage made in November	Silage made in December	Silage made in January	Silage made in February	Silage fed out October	Silage fed out November	Silage fed out December	Silage fed out January	Silage fed out February	Silage fed out March	Silage fed out April	Silage fed out May	Silage fed out June	Silage fed out July	Silage fed out Aug	Silage fed out Sept	Cull ewes Sales	Aged ewes Sales	Dry hogget culls	Wet hogget culls	June
Area of land (ha)																								
Silage	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1					
Livestock Energy																								
June																0.85								-0.85
July																	0.85							
August																		0.85						
September																			0.85					
October								0.85																
November									0.85															
December										0.85														
January											0.85													
February												0.85												
March													0.85											
April														0.85										
May															0.85									1
Ram Tie																								
0																								
Twin ewe lambs from ewes/Hgt tie																								
Single ewe lambs from ewes born																								
Single ewe lambs from ewes sold November																								
Single ewe lambs from ewes sold December																								
Single ewe lambs from ewes sold January																								
Single ewe lambs from ewes sold February																								
Single ewe lambs from ewes sold March																								
Single ewe lambs from ewes sold April																								
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Single wether lambs from ewes sold May																								
Single wether lambs from ewes sold June																								

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Single ewe lambs from ewes sold February	Single ewe lambs from ewes sold March	Single ewe lambs from ewes sold April	Single ewe lambs from ewes sold May	Single ewe lambs from ewes sold June	Twin ewe lamb from ewe sales November	Twin ewe lamb from ewe sales December	Twin ewe lamb from ewe sales January	Twin ewe lamb from ewe sales February	Twin ewe lamb from ewe sales March	Twin ewe lamb from ewe sales April	Twin ewe lamb from ewe sales May	Twin ewe lamb from ewe sales June	Silage made in August	Silage made in September	Silage made in October	Silage made in November	Silage made in December	Silage made in January	Silage made in February	Silage fed out October	Silage fed out November	Silage fed out December	Silage fed out January	Silage fed out February	Silage fed out March	Silage fed out April	Silage fed out May	Silage fed out June	Silage fed out July	Silage fed out Aug	Silage fed out Sept	Cull ewes Sales	Aged ewes Sales	Dry hogget culls	Wet hogget culls	June
Twin wether lambs from ewes sold	0	≤	0																																					
Twin wether lambs from ewes sold November	0	≤	0																																					
Twin wether lambs from ewes sold December	0	≤	0																																					
Twin wether lambs from ewes sold January	0	≤	0																																					
Twin wether lambs from ewes sold February	0	≤	0																																					
Twin wether lambs from ewes sold March	0	≤	0																																					
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Twin wether lambs from ewes sold May	0	≤	0																																					
Twin wether lambs from ewes sold June	0	≤	0																																					
Triplet wether lambs from ewes sold	0	≤	0																																					
Triplet wether lambs from ewes sold November	0	≤	0																																					
Triplet wether lambs from ewes sold December	0	≤	0																																					
Triplet wether lambs from ewes sold January	0	≤	0																																					
Triplet wether lambs from ewes sold February	0	≤	0																																					
Triplet wether lambs from ewes sold March	0	≤	0																																					
Triplet wether lambs from ewes sold April	0	≤	0																																					
Triplet wether lambs from ewes sold May	0	≤	0																																					
Triplet wether lambs from ewes sold June	0	≤	0																																					
Quadruplet wether lambs from ewes sold	0	≤	0																																					
Quadruplet wether lambs from ewes sold November	0	≤	0																																					
Quadruplet wether lambs from ewes sold December	0	≤	0																																					
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Quadruplet wether lambs from ewes sold April	0	≤	0																																					
Quadruplet wether lambs from ewes sold May	0	≤	0																																					
Quadruplet wether lambs from ewes sold June	0	≤	0																																					
Single ram lambs from ewes sold	0	≤	0																																					
Single ram lambs from ewes sold November	0	≤	0																																					
Single ram lambs from ewes sold December	0	≤	0																																					
Single ram lambs from ewes sold January	0	≤	0																																					
Single ram lambs from ewes sold February	0	≤	0																																					
Single ram lambs from ewes sold March	0	≤	0																																					
Single ram lambs from ewes sold April	0	≤	0																																					
Single ram lambs from ewes sold May	0	≤	0																																					
Single ram lambs from ewes sold June	0	≤	0																																					
Twin ram lambs from ewes sold	0	≤	0																																					
Twin ram lambs from ewes sold November	0	≤	0																																					
Twin ram lambs from ewes sold December	0	≤	0																																					
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Twin ram lambs from ewes sold May	0	≤	0																																					
Twin ram lambs from ewes sold June	0	≤	0																																					
Triplet ram lambs from ewes sold	0	≤	0																																					
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Triplet ram lambs from ewes sold December	0	≤	0																																					
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Triplet ram lambs from ewes sold February	0	≤	0																																					
Triplet ram lambs from ewes sold March	0	≤	0																																					
Triplet ram lambs from ewes sold April	0	≤	0																																					

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Single ewe lambs from ewes sold February	Single ewe lambs from ewes sold March	Single ewe lambs from ewes sold April	Single ewe lambs from ewes sold May	Single ewe lambs from ewes sold June	Twin ewe lamb from ewe sales November	Twin ewe lamb from ewe sales December	Twin ewe lamb from ewe sales January	Twin ewe lamb from ewe sales February	Twin ewe lamb from ewe sales March	Twin ewe lamb from ewe sales April	Twin ewe lamb from ewe sales May	Twin ewe lamb from ewe sales June	Silage made in August	Silage made in September	Silage made in October	Silage made in November	Silage made in December	Silage made in January	Silage made in February	Silage fed out October	Silage fed out November	Silage fed out December	Silage fed out January	Silage fed out February	Silage fed out March	Silage fed out April	Silage fed out May	Silage fed out June	Silage fed out July	Silage fed out Aug	Silage fed out Sept	Cull ewes Sales	Aged ewes Sales	Dry hogget culls	Wet hogget culls	June
Triplet ram lambs from ewes sold May	0	≤	0																																					
Triplet ram lambs from ewes sold June	0	≤	0																																					
Quadruplet ram lambs from ewes sold	0	≤	0																																					
Quadruplet ram lambs from ewes sold November	0	≤	0																																					
Quadruplet ram lambs from ewes sold December	0	≤	0																																					
Quadruplet ram lambs from ewes sold January	0	≤	0																																					
Quadruplet ram lambs from ewes sold February	0	≤	0																																					
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Quadruplet ram lambs from ewes sold April	0	≤	0																																					
Quadruplet ram lambs from ewes sold May	0	≤	0																																					
Quadruplet ram lambs from ewes sold June	0	≤	0																																					
Single cryptorchid lambs from ewes sold	0	≤	0																																					
Single cryptorchid lambs from ewes sold November	0	≤	0																																					
Single cryptorchid lambs from ewes sold December	0	≤	0																																					
Single cryptorchid lambs from ewes sold January	0	≤	0																																					
Single cryptorchid lambs from ewes sold February	0	≤	0																																					
Single cryptorchid lambs from ewes sold March	0	≤	0																																					
Single cryptorchid lambs from ewes sold April	0	≤	0																																					
Single cryptorchid lambs from ewes sold May	0	≤	0																																					
Single cryptorchid lambs from ewes sold June	0	≤	0																																					
Twin cryptorchid lambs from ewes sold	0	≤	0																																					
Twin cryptorchid lambs from ewes sold November	0	≤	0																																					
Twin cryptorchid lambs from ewes sold December	0	≤	0																																					
Twin cryptorchid lambs from ewes sold January	0	≤	0																																					
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Triplet cryptorchid lambs from ewes sold	0	≤	0																																					
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Triplet cryptorchid lambs from ewes sold June	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold November	0	≤	0																																					
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Quadruplet cryptorchid lambs from ewes sold April	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold May	0	≤	0																																					
Quadruplet cryptorchid lambs from ewes sold June	0	≤	0																																					
Single ewe lambs from hoggets sold	0	≤	0																																					
Single ewe lambs from hoggets sold November	0	≤	0																																					
Single ewe lambs from hoggets sold December	0	≤	0																																					

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Single ewe lambs from ewes sold February	Single ewe lambs from ewes sold March	Single ewe lambs from ewes sold April	Single ewe lambs from ewes sold May	Single ewe lambs from ewes sold June	Twin ewe lamb from ewe sales November	Twin ewe lamb from ewe sales December	Twin ewe lamb from ewe sales January	Twin ewe lamb from ewe sales February	Twin ewe lamb from ewe sales March	Twin ewe lamb from ewe sales April	Twin ewe lamb from ewe sales May	Twin ewe lamb from ewe sales June	Silage made in August	Silage made in September	Silage made in October	Silage made in November	Silage made in December	Silage made in January	Silage made in February	Silage fed out October	Silage fed out November	Silage fed out December	Silage fed out January	Silage fed out February	Silage fed out March	Silage fed out April	Silage fed out May	Silage fed out June	Silage fed out July	Silage fed out Aug	Silage fed out Sept	Cull ewes Sales	Aged ewes Sales	Dry hogget culls	Wet hogget culls	June
Single ewe lambs from hoggets sold January	0	≤	0																																					
Single ewe lambs from hoggets sold February	0	≤	0																																					
Single ewe lambs from hoggets sold March	0	≤	0																																					
Single ewe lambs from hoggets sold April	0	≤	0																																					
Single ewe lambs from hoggets sold May	0	≤	0																																					
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Single wether lambs from hoggets sold June	0	≤	0																																					
Twin ewe lambs from hoggets sold	0	≤	0																																					
Twin ewe lambs from hoggets sold November	0	≤	0																																					
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Twin wether lambs from hoggets sold December	0	≤	0																																					
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Twin wether lambs from hoggets sold March	0	≤	0																																					
Twin wether lambs from hoggets sold April	0	≤	0																																					
Twin wether lambs from hoggets sold May	0	≤	0																																					
Twin wether lambs from hoggets sold June	0	≤	0																																					
	0	≤	0																																					
	0	≤	0																																					
	0	≤	0																																					
Dry Hgt Tie	0	≤	0																																					
Hgt/2th Tie	0	≤	0																																					
2th/4th tie	0	≤	0																																					
4th/6th tie	0	≤	0																																					
6th/4yr tie	0	≤	0																																					
4yr/5yr tie	0	≤	0																																					
5 yr/ sale tie	0	≤	0																																	0.00			
6yr/sale tie	0	≤	0																																	1.00			
Age cull	0	≤	0																																1.00				
Dry hogget cull	0	≤	0																																		1.00		
Wet hogget cull	0	≤	0																																			1.00	
Wool from dry hogget	0	≤	0																																					
Wool from wet hogget	0	≤	0																																					
Wool from 2th	0	≤	0																																					
Wool from 4th	0	≤	0																																					
Wool from 6th	0	≤	0																																					
Wool from 4yr	0	≤	0																																					
Wool from 5yr	0	≤	0																																					
Wool from 6yr	0	≤	0																																					
Wool from Rams	0	≤	0																																					
	0	≤	0																																					
Wool from Ewe lambs (singles)	0	≤	0																																					
Wool from Ewe lambs (twins)	0	≤	0																																					
Wool from Ewe lambs (triplets)	0	≤	0																																					
Wool from Ewe lambs (quadruplets)	0	≤	0																																					

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	Single ewe lambs from ewes sold February	Single ewe lambs from ewes sold March	Single ewe lambs from ewes sold April	Single ewe lambs from ewes sold May	Single ewe lambs from ewes sold June	Twin ewe lamb from ewe sales November	Twin ewe lamb from ewe sales December	Twin ewe lamb from ewe sales January	Twin ewe lamb from ewe sales February	Twin ewe lamb from ewe sales March	Twin ewe lamb from ewe sales April	Twin ewe lamb from ewe sales May	Twin ewe lamb from ewe sales June
Wool from wether lambs (singles)	0	≤	0													
Wool from wether lambs (twins)	0	≤	0													
Wool from wether lambs (triplets)	0	≤	0													
Wool from wether lambs (quadruplets)	0	≤	0													
Cattle	0	≤	0													
Stock units total	6006000	≤	3441													
Switch	0		0													
Variable costs	-1000000		47767	45.73	50.33	56.21	71.12	94.91	28.79	33.25	24.51	42.20	45.94	50.80	56.37	84.57
Number of stock	0		0	118	59	30	15	15	0	0	0	0	0	0	0	433

	Silage made in August	Silage made in September	Silage made in October	Silage made in November	Silage made in December	Silage made in January	Silage made in February	Silage fed out October	Silage fed out November	Silage fed out December	Silage fed out January	Silage fed out February	Silage fed out March	Silage fed out April	Silage fed out May	Silage fed out June	Silage fed out July	Silage fed out Aug	Silage fed out Sept
Wool from wether lambs (singles)																			
Wool from wether lambs (twins)																			
Wool from wether lambs (triplets)																			
Wool from wether lambs (quadruplets)																			
Cattle																			
Stock units total																			
Switch																			
Variable costs	-0.02	-0.02	-0.01	-0.01	-0.01	-0.01	-0.02												
Number of stock	70494	6190	6257	6244	6249	6249	6182	31599	11346	19014	7471	9836	12622	0	0	0	838	8688	6831

	Cull ewes Sales	Aged ewes Sales	Dry hogget culls	Wet hogget culls	June
Wool from wether lambs (singles)					
Wool from wether lambs (twins)					
Wool from wether lambs (triplets)					
Wool from wether lambs (quadruplets)					
Cattle					
Stock units total					
Switch					
Variable costs	40.00	40.00	50.00	50.00	
Number of stock	45	268	13	0	3078087

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

Appendix D: Linear Program fo Ewe prolificacy and farm profi

Put a 1 beside the box that will represent the male lambs(otherwise use a 0)	Wether	1	Ram

Put a 1 above the class of lambs that are sold prime otherwise leave as 0 if sold store

	Constraint	Reltnshp	Demand	July	August	September	October	November	December	January	February	March	April	May	Total	Stock units	Wool sales dry hogget	Wool sales wet hogget	Wool sales 2th	Wool sales 4th	Wool sales 6th	Wool sales 4yr	Wool sales 5yr	Wool sales 6 yr	Wool sales Rams	Wool sales ewe lambs (singles)	Wool sales ewe lambs (twins)	Wool sales ewe lambs (triplets	Wool sales ewe lambs (quadruplets)	Wool sales wether lambs (singles)	Wool sales wether lambs (twins)	Wool sales wether lambs (triplets	Wool sales wether lambs (quadruplets)
Area of land (ha)	378	≤	378												1																		
Silage	0	≤	0												1																		
Livestock Energy	0	≤	0																														
June	0	≤	0	1											-10957.2																		
July	0	≤	0	-0.85	1										-6124.32																		
August	0	≤	0		-0.85	1									-2240.74																		
September	0	≤	0			-0.85	1								-7920																		
October	0	≤	0				-0.85	1							-10049.9																		
November	0	≤	0					-0.85	1						-6624																		
December	0	≤	0						-0.85	1					-4797.39																		
January	0	≤	0							-0.85	1				-3282.42																		
February	0	≤	0								-0.85	1			-3163.13																		
March	0	≤	0									-0.85	1		-3945.96																		
April	0	≤	0										-0.85	1	-8447.72																		
May	0	≤	0											-0.85	-11840																		
Ram Tie	0	≤	0																														
0	0	≤	0																														
Twin ewe lambs from ewes/Hgt tie	0	≤	0																														
	0	≤	0																														
Single ewe lambs from ewes born	0	≤	0																														
Single ewe lambs from ewes sold November	0	≤	0																														
Single ewe lambs from ewes sold December	0	≤	0																														
Single ewe lambs from ewes sold January	0	≤	0																														
Single ewe lambs from ewes sold February	0	≤	0																														
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Single ewe lambs from ewes sold June	0	≤	0																														
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Single wether lambs from ewes sold May	0	≤	0																														
Single wether lambs from ewes sold June	0	≤	0																														

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	July	August	September	October	November	December	January	February	March	April	May	Total	Stock units	Wool sales dry hogget	Wool sales wet hogget	Wool sales 2th	Wool sales 4th	Wool sales 6th	Wool sales 4yr	Wool sales 5yr	Wool sales 6 yr	Wool sales Rams	Wool sales ewe lambs (singles)	Wool sales ewe lambs (twins)	Wool sales ewe lambs (triplets	Wool sales ewe lambs (quadruplets)	Wool sales wether lambs (singles)	Wool sales wether lambs (twins)	Wool sales wether lambs (triplets	Wool sales wether lambs (quadruplets)
Twin wether lambs from ewes sold	0	≤	0																														
Twin wether lambs from ewes sold November	0	≤	0																														
Twin wether lambs from ewes sold December	0	≤	0																														
Twin wether lambs from ewes sold January	0	≤	0																														
Twin wether lambs from ewes sold February	0	≤	0																														
Twin wether lambs from ewes sold March	0	≤	0																														
Twin wether lambs from ewes sold April	0	≤	0																														
Twin wether lambs from ewes sold May	0	≤	0																														
Twin wether lambs from ewes sold June	0	≤	0																														
Triplet wether lambs from ewes sold	0	≤	0																														
Triplet wether lambs from ewes sold November	0	≤	0																														
Triplet wether lambs from ewes sold December	0	≤	0																														
Triplet wether lambs from ewes sold January	0	≤	0																														
Triplet wether lambs from ewes sold February	0	≤	0																														
Triplet wether lambs from ewes sold March	0	≤	0																														
Triplet wether lambs from ewes sold April	0	≤	0																														
Triplet wether lambs from ewes sold May	0	≤	0																														
Triplet wether lambs from ewes sold June	0	≤	0																														
Quadruplet wether lambs from ewes sold	0	≤	0																														
Quadruplet wether lambs from ewes sold November	0	≤	0																														
Quadruplet wether lambs from ewes sold December	0	≤	0																														
Quadruplet wether lambs from ewes sold January	0	≤	0																														
Quadruplet wether lambs from ewes sold February	0	≤	0																														
Quadruplet wether lambs from ewes sold March	0	≤	0																														
Quadruplet wether lambs from ewes sold April	0	≤	0																														
Quadruplet wether lambs from ewes sold May	0	≤	0																														
Quadruplet wether lambs from ewes sold June	0	≤	0																														
Single ram lambs from ewes sold	0	≤	0																														
Single ram lambs from ewes sold November	0	≤	0																														
Single ram lambs from ewes sold December	0	≤	0																														
Single ram lambs from ewes sold January	0	≤	0																														
Single ram lambs from ewes sold February	0	≤	0																														
Single ram lambs from ewes sold March	0	≤	0																														
Single ram lambs from ewes sold April	0	≤	0																														
Single ram lambs from ewes sold May	0	≤	0																														
Single ram lambs from ewes sold June	0	≤	0																														
Twin ram lambs from ewes sold	0	≤	0																														
Twin ram lambs from ewes sold November	0	≤	0																														
Twin ram lambs from ewes sold December	0	≤	0																														
Twin ram lambs from ewes sold January	0	≤	0																														
Twin ram lambs from ewes sold February	0	≤	0																														
Twin ram lambs from ewes sold March	0	≤	0																														
Twin ram lambs from ewes sold April	0	≤	0																														
Twin ram lambs from ewes sold May	0	≤	0																														
Twin ram lambs from ewes sold June	0	≤	0																														
Triplet ram lambs from ewes sold	0	≤	0																														
Triplet ram lambs from ewes sold November	0	≤	0																														
Triplet ram lambs from ewes sold December	0	≤	0																														
Triplet ram lambs from ewes sold January	0	≤	0																														
Triplet ram lambs from ewes sold February	0	≤	0																														
Triplet ram lambs from ewes sold March	0	≤	0																														
Triplet ram lambs from ewes sold April	0	≤	0																														

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	July	August	September	October	November	December	January	February	March	April	May	Total	Stock units	Wool sales dry hogget	Wool sales wet hogget	Wool sales 2th	Wool sales 4th	Wool sales 6th	Wool sales 4yr	Wool sales 5yr	Wool sales 6 yr	Wool sales Rams	Wool sales ewe lambs (singles)	Wool sales ewe lambs (twins)	Wool sales ewe lambs (triplets	Wool sales ewe lambs (quadruplets)	Wool sales wether lambs (singles)	Wool sales wether lambs (twins)	Wool sales wether lambs (triplets	Wool sales wether lambs (quadruplets)	
Triplet ram lambs from ewes sold May	0	≤	0																															
Triplet ram lambs from ewes sold June	0	≤	0																															
Quadruplet ram lambs from ewes sold	0	≤	0																															
Quadruplet ram lambs from ewes sold November	0	≤	0																															
Quadruplet ram lambs from ewes sold December	0	≤	0																															
Quadruplet ram lambs from ewes sold January	0	≤	0																															
Quadruplet ram lambs from ewes sold February	0	≤	0																															
Quadruplet ram lambs from ewes sold March	0	≤	0																															
Quadruplet ram lambs from ewes sold April	0	≤	0																															
Quadruplet ram lambs from ewes sold May	0	≤	0																															
Quadruplet ram lambs from ewes sold June	0	≤	0																															
Single cryptorchid lambs from ewes sold	0	≤	0																															
Single cryptorchid lambs from ewes sold November	0	≤	0																															
Single cryptorchid lambs from ewes sold December	0	≤	0																															
Single cryptorchid lambs from ewes sold January	0	≤	0																															
Single cryptorchid lambs from ewes sold February	0	≤	0																															
Single cryptorchid lambs from ewes sold March	0	≤	0																															
Single cryptorchid lambs from ewes sold April	0	≤	0																															
Single cryptorchid lambs from ewes sold May	0	≤	0																															
Single cryptorchid lambs from ewes sold June	0	≤	0																															
Twin cryptorchid lambs from ewes sold	0	≤	0																															
Twin cryptorchid lambs from ewes sold November	0	≤	0																															
Twin cryptorchid lambs from ewes sold December	0	≤	0																															
Twin cryptorchid lambs from ewes sold January	0	≤	0																															
Twin cryptorchid lambs from ewes sold February	0	≤	0																															
Twin cryptorchid lambs from ewes sold March	0	≤	0																															
Twin cryptorchid lambs from ewes sold April	0	≤	0																															
Twin cryptorchid lambs from ewes sold May	0	≤	0																															
Twin cryptorchid lambs from ewes sold June	0	≤	0																															
Triplet cryptorchid lambs from ewes sold	0	≤	0																															
Triplet cryptorchid lambs from ewes sold November	0	≤	0																															
Triplet cryptorchid lambs from ewes sold December	0	≤	0																															
Triplet cryptorchid lambs from ewes sold January	0	≤	0																															
Triplet cryptorchid lambs from ewes sold February	0	≤	0																															
Triplet cryptorchid lambs from ewes sold March	0	≤	0																															
Triplet cryptorchid lambs from ewes sold April	0	≤	0																															
Triplet cryptorchid lambs from ewes sold May	0	≤	0																															
Triplet cryptorchid lambs from ewes sold June	0	≤	0																															
Quadruplet cryptorchid lambs from ewes sold	0	≤	0																															
Quadruplet cryptorchid lambs from ewes sold November	0	≤	0																															
Quadruplet cryptorchid lambs from ewes sold December	0	≤	0																															
Quadruplet cryptorchid lambs from ewes sold January	0	≤	0																															
Quadruplet cryptorchid lambs from ewes sold February	0	≤	0																															
Quadruplet cryptorchid lambs from ewes sold March	0	≤	0																															
Quadruplet cryptorchid lambs from ewes sold April	0	≤	0																															
Quadruplet cryptorchid lambs from ewes sold May	0	≤	0																															
Quadruplet cryptorchid lambs from ewes sold June	0	≤	0																															
Single ewe lambs from hoggets sold	0	≤	0																															
Single ewe lambs from hoggets sold November	0	≤	0																															
Single ewe lambs from hoggets sold December	0	≤	0																															

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	July	August	September	October	November	December	January	February	March	April	May	Total	Stock units	Wool sales dry hogget	Wool sales wet hogget	Wool sales 2th	Wool sales 4th	Wool sales 6th	Wool sales 4yr	Wool sales 5yr	Wool sales 6 yr	Wool sales Rams	Wool sales ewe lambs (singles)	Wool sales ewe lambs (twins)	Wool sales ewe lambs (triplets	Wool sales ewe lambs (quadruplets)	Wool sales wether lambs (singles)	Wool sales wether lambs (twins)	Wool sales wether lambs (triplets	Wool sales wether lambs (quadruplets)
Single ewe lambs from hoggets sold January	0	≤	0																														
Single ewe lambs from hoggets sold February	0	≤	0																														
Single ewe lambs from hoggets sold March	0	≤	0																														
Single ewe lambs from hoggets sold April	0	≤	0																														
Single ewe lambs from hoggets sold May	0	≤	0																														
Single ewe lambs from hoggets sold June	0	≤	0																														
Single wether lambs from hoggets sold	0	≤	0																														
Single wether lambs from hoggets sold November	0	≤	0																														
Single wether lambs from hoggets sold December	0	≤	0																														
Single wether lambs from hoggets sold January	0	≤	0																														
Single wether lambs from hoggets sold February	0	≤	0																														
Single wether lambs from hoggets sold March	0	≤	0																														
Single wether lambs from hoggets sold April	0	≤	0																														
Single wether lambs from hoggets sold May	0	≤	0																														
Single wether lambs from hoggets sold June	0	≤	0																														
Twin ewe lambs from hoggets sold	0	≤	0																														
Twin ewe lambs from hoggets sold November	0	≤	0																														
Twin ewe lambs from hoggets sold December	0	≤	0																														
Twin ewe lambs from hoggets sold January	0	≤	0																														
Twin ewe lambs from hoggets sold February	0	≤	0																														
Twin ewe lambs from hoggets sold March	0	≤	0																														
Twin ewe lambs from hoggets sold April	0	≤	0																														
Twin ewe lambs from hoggets sold May	0	≤	0																														
Twin ewe lambs from hoggets sold June	0	≤	0																														
Twin wether lambs from hoggets sold	0	≤	0																														
Twin wether lambs from hoggets sold November	0	≤	0																														
Twin wether lambs from hoggets sold December	0	≤	0																														
Twin wether lambs from hoggets sold January	0	≤	0																														
Twin wether lambs from hoggets sold February	0	≤	0																														
Twin wether lambs from hoggets sold March	0	≤	0																														
Twin wether lambs from hoggets sold April	0	≤	0																														
Twin wether lambs from hoggets sold May	0	≤	0																														
Twin wether lambs from hoggets sold June	0	≤	0																														
	0	≤	0																														
	0	≤	0																														
	0	≤	0																														
Dry Hgt Tie	0	≤	0																														
Hgt/2th Tie	0	≤	0																														
2th/4th tie	0	≤	0																														
4th/6th tie	0	≤	0																														
6th/4yr tie	0	≤	0																														
4yr/5yr tie	0	≤	0																														
5 yr/ sale tie	0	≤	0																														
6yr/sale tie	0	≤	0																														
Age cull	0	≤	0																														
Dry hogget cull	0	≤	0																														
Wet hogget cull	0	≤	0																														
Wool from dry hogget	0	≤	0														1																
Wool from wet hogget	0	≤	0															1															
Wool from 2th	0	≤	0																1														
Wool from 4th	0	≤	0																	1													
Wool from 6th	0	≤	0																		1												
Wool from 4yr	0	≤	0																			1											
Wool from 5yr	0	≤	0																				1										
Wool from 6yr	0	≤	0																					1									
Wool from Rams	0	≤	0																						1								
	0	≤	0																														
Wool from Ewe lambs (singles)	0	≤	0																							1							
Wool from Ewe lambs (twins)	0	≤	0																								1						
Wool from Ewe lambs (triplets)	0	≤	0																									1					
Wool from Ewe lambs (quadruplets)	0	≤	0																										1				

Appendix D: Linear Program Spreadsheet Under the 'Base' Scenario

	Constraint	Reltnshp	Demand	July	August	September	October	November	December	January	February	March	April	May	Total	Stock units
Wool from wether lambs (singles)	0	≤	0													
Wool from wether lambs (twins)	0	≤	0													
Wool from wether lambs (triplets)	0	≤	0													
Wool from wether lambs (quadruplets)	0	≤	0													
Cattle	0	≤	0													
Stock units total	6006000	≤	3441													
Switch	0		0													
Variable costs	-1000000		47767												-267	
Number of stock	0		0	5779192	5979944	4511074	4967207	5760353	5087317	4069635	2512768	1270946	74054	1108558	378	0

	Wool sales dry hogget	Wool sales wet hogget	Wool sales 2th	Wool sales 4th	Wool sales 6th	Wool sales 4yr	Wool sales 5yr	Wool sales 6 yr	Wool sales Rams	Wool sales ewe lambs (singles)	Wool sales ewe lambs (twins)	Wool sales ewe lambs (triplets	Wool sales ewe lambs (quadruplets)	Wool sales wether lambs (singles)	Wool sales wether lambs (twins)	Wool sales wether lambs (triplets	Wool sales wether lambs (quadruplets)
Wool from wether lambs (singles)														1			
Wool from wether lambs (twins)															1		
Wool from wether lambs (triplets)																1	
Wool from wether lambs (quadruplets)																	1
Cattle																	
Stock units total																	
Switch																	
Variable costs	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50
Number of stock	1172	0	1286	1247	1210	1173	1138	1104	107	657	703	0	0	0	0	0	0