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Sensitivity analysis of weaner lamb production in New Zealand

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ABSTRACT

Many factors contribute to the profitability of sheep farms. A sensitivity analysis, using a simulation model, was conducted to investigate the impact of changes in pasture growth, ewe live weight, conception rate, ewe prolificacy (EP), lamb survival, lamb growth rate and lamb price on farm gross margin (FGM).

The model simulated herbage growth and flock energy requirement on a daily basis over a one-year period starting on the 1st January and calculated gross margins for a 500 ha farm, using average Manawatu herbage growth rates. Ewe energy requirements were calculated as a function of live weight, lambing percentage, week of pregnancy or lactation and milk production and lamb energy requirements as a function of live weight, growth rate and body composition. The pre-weaning survival rate and lamb daily growth rate were adjusted for litter size. For each simulation, stocking rates were adjusted so that the pasture cover at the beginning and the end of the year was 1200 kgDM/ha. Simulations were conducted for different farm productivity levels ('Low', 'Medium' and 'High').

Results of the simulations show that, over all farm productivity levels, lamb price and growth rate had the largest impact on FGM followed by ewe liveweight, EP, conception rate and herbage growth. However, the ranking and the effect of these parameters on FGM varied across farm types. For example in "Low productivity farms" a 1 % increase in lamb growth rate has the same impact on FGM as a 1 % increase in EP (+$5.4 / ha vs +$5.9 / ha) and in "High productivity farms" a 1 % increase in lamb growth rate is equivalent to a 3 % increase in EP (+$11.2 / ha vs +$11.1 / ha). This illustrates that for each specific farm production level there are different management strategies to optimize FGM. It was also found that the relationship between EP and FGM was not linear. Across the liveweight ranges a one percent increase in EP between 140% and 160% increases FGM by $3.95 /ha, between 160% and 180% by $2.51 /ha, between 180% and 200 % by $1.33 /ha, between 200% and 220% by $2.83/ha, and between 220% and 240% by $2.33/ha.

Simulation models can be useful tools when considering farm management decisions as they help identify optimal management systems and identify areas that may require further research.

Keywords: Ewe live weight, ewe productivity, lamb growth rate, gross margin.

INTRODUCTION

Many factors contribute to the profitability of New Zealand sheep farms. Determining the impact of any single factor on profitability is difficult as each factor may interact with another. For example it has been shown that heavier ewes at breeding are associated with higher ovulation rates (Rattray *et al.,* 1983; Rutherford *et al.,* 2003) and scanning percentage (Kenyon *et al*., 2004), and therefore possibly improvement in farm profitability. However, heavier ewes producing more lambs require more feed for maintenance and production (Geenty & Rattray 1987) which may result in a decrease in stocking rate. In addition, higher lambing percentages are associated with an increase in the percentage of twin- and triplet-born lambs (Amer *et al*., 1999), which display higher mortality rates than single-born lambs (Morris & Kenyon, 2004; Thompson *et al*., 2004). Therefore estimating the impact of a single factor such as ewe liveweight on farm profitability is not an easy task. Fortunately, computer models, simulating production systems allow for the examination of a single factor and it's interaction with others on profitability. Such an approach allows for the identification of optimal management strategies, which may not be universal across farm types, and may identify areas requiring further research. Our group has recently conducted a sensitivity analysis for lamb finishing farms (Morel *et al.,* 2005a and 2005b) using a simulation model. A simulation model (Morel *et al.,* 2004) for weaner lamb production was used in this paper to investigate the impact of changes in ewe live weight, conception rate, ewe prolificacy, lamb survival, lamb growth rate, herbage growth and price schedule on farm gross margin (FGM) at three farm productivity levels.

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METHOD

Model description

The simulation model used in this study was adapted from the model previously described by Morel *et al.,* (2004) and Morel *et al.,* (2005c). The model simulates herbage growth and flock energy requirements on a daily basis over a one-year period starting on the 1st January and calculates gross margins on a 500 ha farm basis. The model is briefly described below.

The daily herbage dry matter (DM) growth rates are based on the Manawatu 10 year, monthly average and the metabolisable energy (ME) content of the herbage was set at a constant 11 MJME/kg DM. The pasture cover (kg DM/ha) at the start was set to 1200kg DM/ha. Pasture cover was re-calculated daily using the pasture cover at the end of the previous day plus the daily herbage dry matter growth less the herbage dry matter utilised by the flock (this was determined as the daily ME requirement divided by a utilization factor of 0.8).

The reproductive performance of the flock in the model was simulated by the following parameters. Ewes were bred over a two-cycle period and the conception rate (CR) per breeding cycle was a variable in the simulation. All ewes which conceived lambed. Ewe prolificacy (EP) is defined as the number of lambs born per ewe lambing expressed as a percent. The number of single-, twin- and triplet-born lambs for a given EP were calculated according to the method described by Amer *et al*. (1999). The pre-weaning survival rate used was dependant on the number of single-, twin- and triplet-born lambs and was based on the data published by Amer *et al*. (1999) for survival in different environments in New Zealand.

The metabolisable energy requirements for ewes and their lambs were calculated as described by Morel *et al.* (2004). Ewe liveweight was a variable in the simulation. The basal lamb birth weight was set at 4 kg for singles, and the energy requirement for lamb growth was set at 5.17 MJME / kg body weight gain. All lambs were weaned 118 days after the birth of the first lamb. Lamb daily growth rates were adjusted for litter size effects using correction factors derived from those for weaning weight ((Clark & Rae, 1976) single = +0, twin reared as twin (2:2) = -42 g/d , twin reared as a single (2:1) = -20 g/d, triplets reared as triplets (3:3) = -68 g/d and triplets reared as twins (3:2) = -54 g/d). The number of single, 2:2, 2:1, 3:3, and 3:2 sets of lambs were calculated based on the number of single-, twin- and triplet-born lambs and their respective survival rates.

The following financial parameters were used. Herbage was valued at 8 cents/kg DM and a fixed cost per ewe of $7.5/ewe was used. Lambs were valued at $2 kg/live weight at weaning and culled ewes valued at $40. All ewes were assumed to produce 5 kg of greasy fleece weight per year at a value of $2.5 per kg. Replacement ewes were selected from within the flock, and the replacement rate (which is equal to the culling rate) was set at 20 %. In the model farm gross margin (FGM) is calculated as the return of lambs, wool and culled ewes sold less the herbage cost and fixed costs per ewe.

Model Simulations

For each simulation, number of ewes per ha was adjusted so that the pasture cover at the beginning and the end of the year was maintained at 1200 kg DM/ha. The first simulation study investigated the impacts of ewe liveweight (50, 55, 60, 65, 70 and 75 kg) and EP (140, 160, 180, 200, 220 and 240) on farm gross margin. In these simulations the conception rate per breeding cycle was set to 80 %, single lamb growth rate to 200 g/d, and lamb survival rates for an intensive farm (Amer *et al*., 1999) were used.

A sensitivity analysis for herbage growth, lamb price, ewe liveweight, conception rate, ewe prolificacy, survival rate and lamb growth rate was calculated for three levels of farm production ('Low', 'Medium', 'High'). In each sensitivity analysis, only one factor was changed (by + or – 10%) at a time while the other factors were kept constant at their default values. The survival rate value for easy hill country (Amer *et al*.1999) was chosen as the default value for mortality and changed to either intensive or hard hill country for the sensitivity analysis. The default values used for each farm production level are presented in Table 1.

TABLE 1: Default values used for the sensitivity analysis.

Farm Productivity	'Low'	'Medium'	'High'
Herbage Growth (kg DM/ha/year)	10,984	10,984	10,984
Lamb price ($/kg liveweight)	2.00	2.00	2.00
Ewe liveweight (kg)	55	60	65
Conception rate per cycle (%)	75	80	85
Ewe prolificacy (%)	120	160	200
Mortality (%)	15	15	22
Single lamb growth rate (g/d)	200	250	300

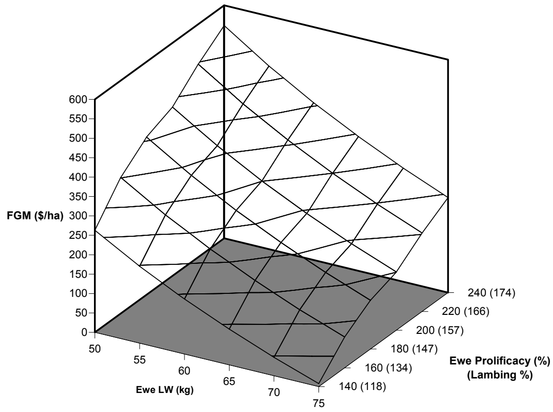
The changes in $FGM/ha/year per percent changes in each parameters (Table 3) were calculated as well as the change in each parameter required to increase or decrease the profitability by $10/ha/year (Table 4).

RESULTS AND DISCUSSION

The effects of ewe liveweight and EP on FGM/ha are shown in Figure 1. Overall, FGM increases with an increase in EP and decreases with an increase in ewe liveweight. However, the relationship between EP and FGM is not linear. Across the liveweight ranges a one percent increase in EP between 140% and 160% increases FGM by $3.95 /ha, between 160% and 180% by $2.51 /ha, between 180% and 200 % by $1.33 /ha, between 200% and 220% by $2.83/ha, and between 220% and 240% by $2.33/ha. The low value observed between 180 and 200 % can be explained by the fact that at those EP levels single-born lambs are replaced by triplet-born lambs and this results in proportionally greater lamb mortality and lower lamb growth rates. A similar pattern was observed by Amer *et al.,* (1999), when investigating the impact of EP levels on the economic value for EP. Kenyon *et al.*, (2004) reported that when the condition score at mating of mixed age Romney ewes increased from 1.5 to 2.0 and liveweight at mating from 50 to 55 kg the scanning percentage increased from 130 % to 160 %, and according to the present simulations the FGM's would have increased from $75.9/ha to $114.7/ha. However, a further increase in LW of 10 kg, from 55 kg to 65 kg resulted in a smaller proportional increase in scanning percentage (160 to 172%) (Kenyon *et al.*, 2004). The present model indicated a FGM of $77.0/ha. This is less economical than having 55 kg ewes scanning 160%, due to a reduction in ewe numbers to maintain a constant feed demand and herbage cover. The yearly maintenance energy requirements increase from 4089 MJME/year for a 55 kg ewe to 4634 MJME/year for a 65 kg ewe (Geenty & Rattray, 1987), which is equivalent to an extra 50 kgDM/year. Given the non-linear relationship between ewe liveweight and scanning percentage the previous results may indicate that it is unprofitable for New Zealand farmers to further increase ewe liveweight as a means of increasing lambing percentage.

The results of the sensitivity analysis are presented in Table 2. The FGM ranged from $0.0/ha for a 'Low' productivity farm with 10 % decrease in lamb price to $691/ha for a 'High' productivity farm with a 10 % increase in lamb price.

FIGURE 1: Effect of Ewe Liveweight (LW) and Ewe Prolificacy (EP, with equivalent lambing % (LP) given in brackets), on farm gross margin (FGM $/ha).



As expected, the FGM increases as the productivity level increases, $70/ha for 'Low', $354/ha for 'Medium' and $574/ha for 'High' farm types. The lambing percentage (LP) observed for 'Low', 'Medium' and 'High' farm types were 76%, 100% and 136%, respectively. The Sheep and Beef Farm Survey 2001-2002 (Meat and Wool Innovation) indicated that average LP ranges from 86.5% for South Island High Country farms to 130.9% for South Island Intensive Finishing farms, thus our simulations are representative of the normal ranges.

A 1 % change in lamb price across all farm types had the largest impact on FGM/ha/year ($9.90 on average), followed by lamb growth rate ($8.40), ewe liveweight ($7.30), EP ($5.20), herbage growth rate ($3.30), conception rate ($2.20) and mortality ($1.80) (Table 3). As the lamb price ($/kg carcass) is dependant on the world market, farmers should focus on the other parameters to improve profitability.

It should be noted that the previously mentioned values are averages across the farm types and that the absolute values do differ between farm types. For example, a 1% increases in EP is worth $5.90/ha for 'Low' and $3.70/ha for 'High' farm types, while a 1 % increase in lamb growth rate is worth $5.40/ha for 'Low' and $11.20/ha for 'High' farm types. The lower additional benefit of a 1% increase in EP in 'High' compared to 'Low' farm types is due to the fact that the 'high' farm types already display relatively high EP and a further increase in EP increase the proportion of twin- and triplet-born lambs which as previously mentioned display lower survival rates and growth rates to weaning. Conversely, a greater response to a 1% increase in lamb growth was observed in 'High' compared to 'Low' farm types. This greater response in 'High' farm types would most likely be due to the greater numbers of lambs present per ha on these farms resulting in a greater effects of the total weight of lambs weaned per ha. These results indicate that for each specific farm type there are differing management strategies to optimize FGM.

TABLE 2: Number of ewes and lambs, lamb liveweight (LW), farm income, expenses and gross margin (FGM) for the default values and 10 % changes (-) (+) in parameters for farms with 'Low', 'Medium' and 'High' productivity levels.

	Ewe	Lamb	LW (kg)	Income ($/ha)	Expenses ($/ha)	FGM ($/ha)
'Low'						
Default	9480	7169	24.5	1091	1021	70
EP (-)	9595	6339	25.3	1035	1023	13
(+)	9363	7976	24.0	1149	1019	130
Ewe LW (-)	10130	7661	24.5	1166	1031	135
(+)	8920	6746	24.5	1027	1012	14
Herbage (-)	8533	6453	24.5	982	919	63
(+)	10428	7886	24.5	1200	1123	77
Mortality +(-) (11)	9430	7556	24.5	1127	1020	107
(+) (22)	9562	6478	24.7	1033	1022	11
Growth rate (-)	9550	7222	22.4	1037	1022	16
(+)	9413	7118	26.6	1144	1020	124
Conception rate (-)	9730	6930	24.3	1074	1025	49
(+)	9300	7335	24.7	1105	1018	87
$ / kg lamb (-)	9480	7169	24.5	1021	1021	0
(+)	9480	7169	24.5	1161	1021	140
'Medium'						
Default	8363	9246	27.5	1358	1004	354
EP (-)	8475	8263	28.8	1301	1006	295
(+)	8250	10068	26.9	1420	1003	417
Ewe LW (-)	8905	9845	27.5	1446	1012	434
(+)	7895	8729	27.5	1282	997	285
Pasture (-)	7525	8320	27.5	1222	904	319
(+)	9200	10172	27.5	1494	1105	390
Mortality (-) (13)	8335	9471	27.5	1382	1004	378
(+) (26)	8495	7957	28.4	1254	1006	247
Growth rate (-)	8455	9348	24.8	1273	1006	268
(+)	8275	9149	30.1	1442	1003	439
Conception rate (-)	8569	9026	27.3	1336	1007	328
(+)	8225	9380	27.7	1376	1002	374
$ / kg lamb (-)	8363	9246	27.5	1257	1004	253
(+)	8363	9246	27.5	1460	1004	456
'High'						
Default	7523	10261	30.6	1565	991	574
EP (-)	7608	9605	31.7	1531	993	539
(+)	7445	10579	30.6	1601	990	611
Ewe LW (-)	7993	10902	30.6	1663	999	665
(+)	7115	9705	30.6	1481	985	495
Pasture (-)	6770	9234	30.6	1409	892	517
(+)	8275	11287	30.6	1722	1091	631
Mortality (-) (18)	7500	10523	30.4	1589	991	598
(+) (34)	7700	8395	32.6	1410	994	415
Growth rate (-)	7628	10404	27.4	1453	993	460
(+)	7425	10128	33.9	1676	990	686
Conception rate (-)	7688	10083	30.4	1540	994	546
(+)	7425	10345	30.9	1584	990	594
$ / kg lamb (-)	7523	10261	30.6	1440	1000	440
(+)	7523	10261	30.6	1691	1000	691

TABLE 3: Change in farm gross margin ($/ha/year) for a one percent change (-) (+) in performances

Farm Productivity	'Low'		'Medium'		'High'	
	-	+	-	+	-	+
Ewe Prolificacy	-5.7	5.9	-5.9	6.3	-3.5	3.7
Ewe LW	6.5	-5.6	8.0	-6.9	9.1	-7.9
Herbage growth	-0.7	0.7	-3.5	3.5	-5.7	5.7
Mortality	1.4	-1.3	1.8	-1.5	2.4	-2.3
Lamb growth rate	-5.5	5.4	-8.7	8.5	-11.4	11.2
Conception rate	-2.1	1.6	-2.6	1.9	-2.8	2.0
$ kg lamb	-7.0	7.0	-10.2	10.2	-11.7	11.7

The absolute changes in performance required to increase FGM by $10/ha/year are presented in Table 4. It is apparent that for 'Low' farm types a 3.7 g/d increase in lamb growth rate has the same impact on FGM as a 1.0 kg decrease in ewe liveweight. This information can be used by farmers to identify which factors are optimal to change to maximize any potential benefit. For example to improve herbage production it can be calculated that a 'Low' type farm can afford to spend up to 0.6 cents/kgDM for it to be economical, while a 'High' type farm can spend up to 5.2 cents/kgDM.

TABLE 4: Change in performance required for a $10/ha decrease (-) or increase (+) in farm gross margin.

Farm Productivity	'Low'		'Medium'		'High'	
	-	+	-	+	-	+
Ewe Prolificacy (%)	-2.1	2.0	-2.7	2.5	-5.6	5.4
Ewe LW (kg)	0.8	-1.0	0.7	-0.9	0.7	-0.8
Herbage (kg DM/ha/year)	-1566.8	1566.8	-309.6	309.6	-191.3	191.3
Mortality (%)	1.1	-1.2	0.8	-1.0	0.8	-0.9
LambGrowth rate (g/d)	-3.7	3.7	-2.9	2.9	-2.6	2.7
Conception rate %	-3.6	4.6	-3.1	4.1	-3.1	4.3
$ kg lamb	-0.028	0.028	-0.020	0.020	-0.017	0.017

To our knowledge no sensitivity analysis for weaner lamb production on pasture have recently been published. However similar modeling studies have been conducted when deriving Economic Value for selection programs, and can be used to compare with our results. The non-linear relationship between EP and FGM has also been reported by Amer et al. (1999) for New Zealand sheep farms and by Conigton et al. (2003) for hill sheep farms in the United Kingdom.

Sensitivity analyses are useful to identify factors with a major impact on profitability, but they don't provide any information on how the required improvement can be made, or how difficult it would be for the farmer to achieve this goal. In conclusion, simulation models are useful tools when undertaking farm management decisions. However, dependent on individual farm circumstance there are differing options available to improve FGM. These models can also be used to identify areas which require further research.

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