Potential profit gains from improving pasture productivity on New Zealand South Island high-country farms

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Abstract
Soil acidity combined with low levels of key nutrients on New Zealand hill-country farms are limiting factors for legume establishment/growth. However, legumes are a critical component of these farms as they provide nitrogen and high-quality feed. A farm-systems model was developed to estimate the impact of targeted fertiliser and lime application, combined with sowing clover, on whole-farm productivity and profitability. A base model was developed that incorporated 17 years' worth of Beef + Lamb NZ survey data for Class 1: South Island Farms. This base model was then used investigate two lime-application/oversowing models where part of the modelled high-country farm was targeted for improvement: (1) Conservative, i.e. 0.6% farm area; and (2) Aggressive, i.e. 2.8% farm area. Three scenarios to utilise the additional pasture grown were then investigated for each model by: (a) increasing ewe numbers; (b) increasing ewe performance (lambing percentage); and (c) increasing liveweight gain of stock. Scenario 2a, generated the highest profitability level (Earnings before Interest Tax and Rent, EBITR $58,870) above the base model but became less financially attractive when the two years required to build the maternal ewe flock were factored in. Scenarios 2c and 1b generated increases in profitability (EBITR) between $33,310 and $41,290 above the base model. Variation in product prices, production levels and time to develop the final farm-management system would also influence the productivity and profitability of the scenarios. Environmental aspects, infrastructure and staff availability would affect the suitability of the development for individual farming businesses.

Keywords: high country, lime, farm profit, Farmax, farm systems

Introduction
Legumes are a critical component of high country and other farming systems as they provide nitrogen via N-fixation (Haynes & Williams 1993) and also high-quality feed to drive animal performance (Hoffman et al. 2007). However, soil acidity combined with low levels of plant-available phosphorus and sulphur are key limiting factors for legume establishment and growth. This is a large-scale issue as approximately 500,000 ha of farmed New Zealand South Island high-country soils have low pH and possibly high aluminium concentrations (Moir & Moot 2010). Consequently, high-country farms may struggle to be sustainable businesses in the long term without increasing soil pH by topdressing with fertiliser and lime in order to improve legume productivity (Moir & Moot 2014).

Topdressing with lime and fertiliser is carried out infrequently in the high country due to the high cost of application (Moir & Moot 2010). Farms can be located some distance from lime quarries increasing transportation costs, and steeper parts of the farms require more expensive aerial application of fertiliser and lime. One approach could be to focus on improving the productivity of lower and mid-elevation areas of the farms (Maxwell et al. 2010) via a development programme with lime, fertiliser and over sowing.

Maximum returns from land development may not be achieved unless fine tuning of the existing farm management and economic factors are considered first (Frengley & Anderson 1989). A key consideration with any farmland development, assuming the productivity capacity is increased, is how the farming system can be adjusted to utilise any additional pasture growth. Often with large-scale development there is an increase in the stocking rate and or a change in the stock policy, for example including more finishing in the system (Gaukrodger 2015).

A farm-systems model was developed using Farmax software (Farmax n.d.) to estimate the impact of targeted land development on whole-farm productivity and profitability. The model developed was used to investigate two lime-application/oversowing models where part of a simulated high-country farm was targeted for improvement: (1) Conservative, i.e. 0.6% farm area; and (2) Aggressive, i.e. 2.8% farm area. The profitability of these models was compared using EBITR, as the measure is independent of business ownership and funding (Shadbolt & Gardner 2005). Three scenarios to utilise the additional pasture grown were then investigated by: (a) increasing ewe numbers; (b) increasing ewe performance (lambing percentage); and (c) increasing liveweight gain of stock. This paper reports the effects of applying these models and scenarios on whole-farm productivity and profitability.

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Materials and Methods

A farm model was constructed from Beef + Lamb NZ survey data for Class 1: South Island High Country farms (Beef + Lamb New Zealand 2019). Mean survey data for the seventeen years (2000-01 to 2016-17) were ranked by EBITR per stock unit. Data from quartile two was selected to provide the physical and financial data for the model. This quartile was selected as there was the potential to improve EBITR and farms in this quartile applied less lime and fertiliser per hectare, on average than farms in the other quartiles.

The farm simulation was developed using farm-systems modelling software (Farmax Sheep, Beef & Deer (7.2.2.04)) (Farmax n.d.). Data on farm location, topography, pasture type and growth rate, liveweights, mating and calving/lambing dates were not available from the survey. Assumptions were made for these factors based on the environmental conditions farms near Omarama, Mackenzie Basin, South Canterbury, would experience with an annual rainfall of 500 mm. The base farm model was 12,500 ha, and consisted of developed (2%), underdeveloped (9%), medium slope hill (24%) and steep slope hill (65%) country. Overall, the simulated farm produced 6 tDM/ha of utilised pasture. The maternal merino flock (4167 head) was mated to a merino ram with a lambing percentage of 89%. All hoggets (1177 head) were kept on farm, with a replacement rate of 20% mixed age ewes. Shorn wool sold was 4.90 kg per ewe and 2.74 kg per hogget. The beef enterprise consisted of Hereford cattle with a calving percentage of 81%. The base model had a stocking rate of 0.5 stock units (SU)/ha and a ratio of sheep to beef of 75:25.

Land improvement model and scenario development

The base model was adapted to generate: (1) a Conservative; and (2) an Aggressive lime-application/oversowing model. With the Conservative model, $21,000 was allocated to capital lime, application and reseeding costs to develop 70 ha, or 0.6% of the modelled farm. With the Aggressive model, 345 ha, or 2.8% of the farm was improved (Table 1).

An increase of 0.2 units of soil pH per tonne of lime applied was predicted and over-sowing with *Trifolium subterraneum* (subterranean clover; which could not previously persist and grow without liming; Moir et al. 2016) was used to estimate the additional feed grown. Both lime-application/oversowing models were then used to test three scenarios to utilise the additional feed grown: (a) increasing ewe numbers; (b) increasing ewe performance (lambing percentage); and (c) increasing liveweight gain of stock (Figure 1). These scenarios were analysed in both models 1 and 2 to find the most productive and profitable development option.

Scenario (a) was achieved by scaling the ewe flock, and the associated reconciliation, to consume the additional feed grown. For the Conservative model (1), sheep numbers were scaled up by 4% and for the Aggressive model (2), sheep numbers were scaled up by 14%. The initial increase in ewe lambs retained to build the maternal ewe flock was modelled over a two-year time period using the short-term mode in Farmax (Farmax n.d.).

Increasing sheep and cattle performance was achieved though improving either lambing percentage by 9% (Scenario b) or liveweight gain of sheep and cattle (Scenario c) post land development. Increasing lambing percentage (Scenario b) was not accompanied by an increase in ewe liveweight. The amount of daily dry matter consumed was as closely aligned as biologically feasible across the scenarios generated.

Financial analysis

Product prices were from the default South Island high-country values already included in the Farmax model system (Farmax n.d.). Livestock prices were based on the 2019 South Island sheep and beef schedules. The farm working expenses, wages, weed and pest, animal health, repairs and maintenance, administration, cartage rates, depreciation and electricity (see Appendix) were based on the Beef + Lamb NZ survey data for Class 1: South Island High Country farms (Beef + Lamb NZ 2019). The remaining expenses were based on the default South Island high-country values already included in the Farmax model system (Farmax n.d.).

Scenarios (b) and (c) were modelled in the final farm system with the sheep numbers at the desired level using the long-term mode in Farmax (Farmax n.d.). In Scenario (a), it took two years to build the maternal ewe flock to the desired level. The financial results presented for this Scenario were from the third year, which is a future value that needs to be discounted back two years to a present value in order to be comparable with the financial results from the other scenarios, which took one year to achieve. A discount rate of 7% (based on a 5% bank mortgage rate and a 2% personal factor) was used to calculate the present value for this analysis. Expenses were calculated primarily on a 'per stock unit' basis, where a stock unit was considered to be 550 kg DM eaten.

Results

Animal intake was closely aligned across all scenarios to ensure they were comparable. The biological feasibility of each scenario was also assessed. Simulation of Scenario 2b (Aggressive + increased lambing percentage) generated a lambing percentage that was considered too high for the farming conditions and biologically infeasible. Thus, the results for this Scenario were not considered in the remainder of the study.

Table 1 Development costs for the Conservative and Aggressive lime-application/oversowing models.

	Model		
	Unit cost ($/ha)	**1. Conservative ($ for 70 ha)**	**2. Aggressive ($ for 345 ha)**
Spraying cost	40.00	2,800	13,800
Seed (subterranean clover 10 kg/ha)	80.00	5,600	27,600
Lime (2.5 t/ha)	75.00	5,250	25,875
Superphosphate (250 kg/ha)	86.00	6,020	29,670
Spreading	19.00	1,330	6,555
Total ($)		**21,000**	**103,500**

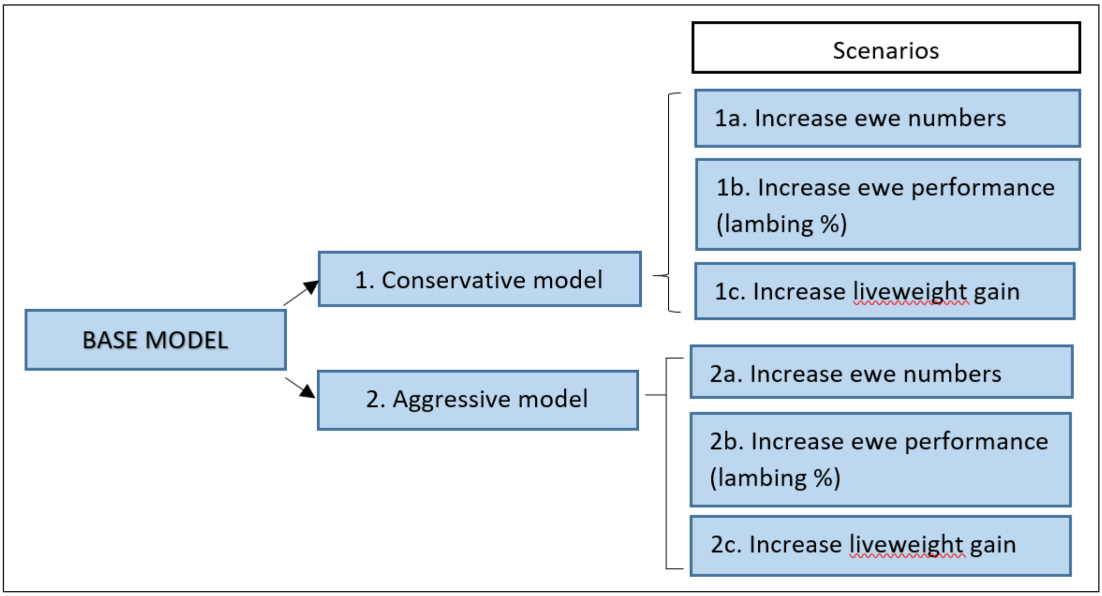

Figure 1 Flow diagram showing the lime-application/oversowing models used and the utilisation of the additional pasture grown scenarios tested.

Pasture consumption and stocking rate

Application of either Scenario 2a or 2c resulted in a slight increase in stocking rate (0.6 SU/ha) compared with the base farm model (0.5 SU/ha) or the other Scenarios tested (Table 2). Implementation of all scenarios led to an increase in pasture eaten compared with the base model (Table 2). The ratio of sheep to beef remained constant at 75:25 for Scenarios 1a–c and 2a but Scenario 2c resulted in more sheep, with a ratio of 77:23.

Livestock sales

Scenarios 1a and 2a both led to increased stock sales in Year 3 compared to the base farm model, although weights at which stock were sold were similar across all models (Table 3). Ewe sales to the works were 4% and 14% higher for Scenario 1a and 2a respectively compared to the base system. Ewe hogget sales were 4% and 13% higher and mixed hoggets 4% and 14% higher for Scenario 1a and 2a respectively compared to the base system.

Scenario 1b led to 16% more mixed hoggets sold with similar livestock sale weights than in the base farm model.

Scenario 1c resulted in the sale of mixed hoggets that were 12% heavier than the base model. In Scenario 2c, just over half (55%) the mixed hoggets were sold as finished, the only scenario to do so. In addition, the hoggets sold store from the aggressive model were 8% heavier than those sold store from the base model. The number of ewes and ewe hoggets sold from the base, conservative and aggressive models were the same, however ewe hoggets sold from the conservative and aggressive models were 16 and 35%, respectively heavier than those sold from the base model.

Table 2 Comparison of total pasture eaten, stocking rate and feed conversion efficiency for various lime-application/oversowing models and pasture utilisation scenarios.

Model + Scenario	Stocking rate (SU/ha)	Total pasture eaten (kgDM/ha)	Feed conversion efficiency (kgDM/kg product)
Base model	0.5	290	35.4
1. Conservative model			
1a. Increase ewe numbers	0.5	299	35.4
1b. Increase ewe performance	0.5	298	34.4
1c Increase liveweight gain	0.5	299	34.0
2. Aggressive model			
2a. Increase ewe numbers	0.6	321	35.3
2c. Increase liveweight gain	0.6	320	32.8

Table 3 Comparison of the number and weight of sheep sold for various lime-application/oversowing models and pasture utilisation scenarios.

Model + Scenario	Ewes	Ewe hoggets	Mixed Hoggets	
	Works	Store	Store	Works
Base model				
-Number	613	332	2324	
- Weight (kg)	18.2	30.0	33.1	
1. Conservative model				
1a. Increase ewe numbers (Yr3)				
- Number	638	346	2416	
- Weight (kg)	18.3	30.0	33.1	
1b. Increase ewe performance				
- Number	613	332	2705	
- Weight (kg)	18.2	30.5	33.0	
1c. Increase liveweight gain				
- Number	613	332	2323	
- Weight (kg)	18.2	34.8	37.2	
2. Aggressive model				
2a. Increase ewe numbers (Yr3)				
- Number	699	377	2650	
- Weight (kg)	18.3	30.0	33.1	
2c. Increase liveweight gain				
- Number	613	332	1031	1293
- Weight (kg)	18.9	40.5	35.8	18.6

Sources of income

Sources of revenue for the various scenarios were net sheep sales, wool and beef sales (Table 4). For net sheep sales, Scenario 1a (year 3) and Scenarios 1b and 1c all had higher sales ($375,510, $408,090 and $401,910 respectively) compared to the base model of $361,300. However, increasing ewe numbers took three years to reach the lower level of net sheep income than the other two scenarios. The trend was similar in the aggressive model, with Scenarios 2a (year 3) and 2c reaching similar levels of net sheep sales of $412,050 and $410,040 respectively. However, as with Scenario 1a, Scenario 2a took three years to reach that level of stock sales.

Revenue from wool increased for both Scenarios 1a and 2a compared to the base model, as the number of

Table 4 Comparison of sources of income for various lime-application/oversowing models and pasture utilisation scenarios.

	Sheep		**Wool**	**Beef**
	Net sales ($)	**Capital livestock value change ($)**	**($)**	**($)**
Base model	361,300	0	209,900	131,000
1. Conservative model				
1a. Increase ewe numbers				
- Year 1	367,890	-23,090	209,760	115,370
- Year 2	271,530	54,820	213,150	126,990
- Year 3	375,510		218,400	130,940
1b. Increase ewe performance	408,090	0	209,330	130,990
1c. Increase liveweight gain	401,910	0	209,100	130,990
2. Aggressive model				
2a. Increase ewe numbers				
- Year 1	363,860	-11,590	209,760	115,370
- Year 2	265,910	66,880	217,970	127,940
- Year 3	412,050	0	239,220	130,940
2c. Increase liveweight gain	410,040	0	206,950	136,950

sheep increased in years 2 and 3 (Table 3). Income from wool was driven by sheep shorn and was similar across the remaining scenarios.

Beef income was lower that the base model for years 1 and 2 for both Scenarios 1a and 2a (Table 3), as feed was directed to building ewe numbers. Scenario 2c was the only instance where there was sufficient total daily dry-matter intake to increase both sheep and cattle liveweight gain. Thus the beef income was higher (5%) than the base model.

Financial results

Scenario 2a produced the highest level of profitably with an EBITR 24% higher than the base model (Table 5). However, it took two years to build the maternal ewe flock to the desired size and this financial result is from year 3. Once the EBITR is adjusted to a present value that can be compared to the other scenarios, this option is less attractive in the short term.

Scenario 1b achieved an EBITR of $41,290, which was 17% higher than the base model compared with an EBITR of $34,600 for Scenario 1c, which was 14% higher than the base model. Both Scenarios 1c and 2c produced similar levels of profitability with EBITRs of $284,690 and $283,400 respectively but Scenario 1c resulted in a lower revenue ($741,950) (but also proportionally lower total farm expenses) to generate a similar EBITR to Scenario 2c. The expenses were calculated primarily on a ‘per stock unit’ basis, where a stock unit was considered to be 550 kg DM eaten. Thus subtle changes in costs due to additional production were captured.

Discussion

Modelling across an entire simulated farm demonstrated that improvements in productivity and profitability were possible though land improvement by lime-application/ oversowing to varying extents. Increasing ewe numbers across 2.8% of the farm (Scenario 2a) resulted in the highest level of profitability of all the scenarios tested and was the most attractive financial option over the long term for the final farm system. However, the cost of building capital stock can be expensive in terms of both time and money, requiring two years of reduced income and profit to reach the final farm system. Therefore, other scenarios became financially more attractive in the short term when the cost of building capital stock was included, and increasing ewe numbers over 2.8% of the farm was discounted back to a present value for comparison.

Gains were modest given that they arose from developing small areas of the farm and then measuring changes in productivity and profitability at the whole-farm scale.

Increasing ewe performance over 0.6% of the farm area would take several years to achieve the desired gains in productivity (Stevens & Young 2013) so, as with increasing ewe numbers over the same area, this is not a short-term option. Increasing liveweight gain requires no increase in maternal ewe flock size

Table 5 Comparison of financial results for various lime-application/oversowing models and pasture utilisation scenarios.

	Revenue ($)	Total farm expenses ($)	EBITR ($)	Increase over base model	% change
Base model	702,150	452,060	250,090		
1. Conservative model					
1a. Increase ewe numbers					
-At year 3	725,000	458,080	266,920	16,830	7
-Comparable present value	633,240	400,100	233,140	-16,950	-7
1b. Increase ewe performance	748,360	456,980	291,380	41,290	17
1c. Increase liveweight gain	741,950	457,260	284,690	34,600	14
2. Aggressive model					
2a. Increase ewe numbers					
-At year 3	782,210	473,250	308,960	58,870	24
- Comparable present value	683,210	413,350	269,860	19,770	8
2c. Increase liveweight gain	753,940	470,540	283,400	33,310	13

or lambing percentage but it would still take time to achieve the budgeted gains in liveweight.

New Zealand high country is known for extremes in climate (Morris 2009). Bad weather during the initial stages of any development could adversely affect the survival and growth of the new pastures. There is also a high level of uncertainty around what level of productivity is possible and within what time frame. Increasing ewe numbers is the most explicit of the changes required and so easier to include in the model than other factors. Although all modelled scenarios require time to develop, obtaining estimates from the whole-farm simulation is a first step to investigating the potential returns and practicality and sustainability of a land-development programme.

Other key aspects of farm development are infrastructure and labour. The suitability of infrastructure, yards, woolshed and, in particular, fencing would have a large influence on whether any development is practical and realistic for a high-country property. Farms with spare capacity in their woolshed and yards, could increase ewe numbers or performance scenarios, whereas those without additional capacity maybe restricted to the increase liveweight gain scenario. Fencing, which is critical for subdivision and so pasture utilisation (Chapman & Macfarlane 1985), can be expensive. Non-electric conventional fencing cost $24.88 per metre on steep country, $17.88 on rolling country and $16.36 on flat terrain (Agribusiness Group 2016). Staff and labour costs were included in the model on a 'per stock unit' basis allowing for gradual changes in expenditure in line with changes in livestock numbers. As with the infrastructure costs, changes in the farm system may generate a threshold above which another staff member needs to be hired, the costs of which may not be adequately covered in the labour costs per stock unit. In short, this development maybe attractive to farmers with spare capacity in their existing infrastructure and staff/labour, and unattractive to those who do not.

The livestock or product prices represent a financial risk. The prices for products in 2019 were high (StatsNZ 2019), and future research could run selected models and scenarios with a wider range of product prices, to undertake a sensitivity analysis.

The environmental impact of intensification involving capital lime applications to develop targeted areas of the high country is another key consideration for future research. This could be investigated by analysing the scenarios with different software.

This study has taken the first step into quantifying potential production and profitability benefits of high-country farm development via lime, superphosphate and clover application at a whole-farm scale. The results from this study suggest that there is potential for varying gains in productivity and modest profitability gains between 14 and 17% if ewe numbers are not altered in the short term from the targeted land-improvement strategies. However, these findings are based heavily on a base model under ideal conditions.

Conclusions/Practical implications/Relevance

There is potential for modest gains in productivity and profitably by improving land with lime, superphosphate and clover. The key risks to the production and economic impacts are climatic, the productive capacity of the land and the existing amount and suitability of existing farm infrastructure.

These results indicate modelling capital inputs of lime and legumes for interested high country farming businesses may be worthwhile. Discussions and experience could then focus on how the development policy will perform in that environment, e.g. rainfall, with a range of financial conditions e.g. product prices and the farming infrastructure and system used by that business.

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APPENDIX

Farm expenses for the base lime-application/oversowing model

	Farm Expenses for the Base model ($/SU)
Wages	7.6
Management wage	0.3
Animal health	3.3
Shearing	2.9
Feed conservation	11.0
Purchased feeds	3.7
Fertiliser (excl. N & lime)	7.0
Lime	0.6
Weed and pest	2.4
Vehicle expenses	6.6
Fuel	5.1
Repairs and maintenance	3.4
Freight and cartage	1.5
Electricity	0.6
Administration expenses	1.8
Insurance	3.1
ACC levies	1.2
Rates	2.0
Depreciation	4.3