The value of legumes to a Whanganui hill country farm

J.M. RENDEL[1], A.D. MACKAY[2] and P.N. SMALE[1]
[1]*AgResearch, Private Bag 50034, Mosgiel, New Zealand*
[2]*AgResearch, Private Bag 11008, Palmerston North 4422, New Zealand*
john.rendel@agresearch.co.nz

Abstract
There is interest in the sheep and beef sector in lifting the legume content of hill pastures. This interest is tempered by the uncertainty of the benefits and how much farmers can afford to spend to achieve them. The objective of this study was to quantify the value to a hill country farm of differing proportions of legumes in a mixed species pasture using AgInform® (Integrated Farm Optimisation and Resource Allocation Model). AgInform® is a multi-year farm systems model, adapted so that the legume proportion of pasture as it influences pasture growth and animal performance through its influence on diet could be included as variables in the model. Three levels of legume (Low, Base and High) in a mixed pasture were modelled. The model predicts that increasing the legume proportion increases farm profitability although not in a linear manner with increasing legume proportion. This analysis provides an indication of the investment that hill country farmers can afford to increase the legume proportion in mixed pastures.

Keywords: farm systems, legume, variability, AgInform®, multi-year

Introduction
There is interest among the sheep and beef sector in lifting the legume proportion of sheep and beef hill pastures (Nelson *et al.* 2017). This is in an attempt to lift pasture quality for improving livestock performance and biological nitrogen (N) fixation to increase pasture growth. Little nitrogenous fertiliser is used on New Zealand hill pastures and therefore they are heavily dependent on legumes for the N required to sustain production (Ball *et al.* 1979). The value of legumes in the diet of ruminants comes from two sources: that of a higher energy content of legumes (12 MJ ME/kg DM; Holmes *et al.* (2002)) compared to other pasture species in the diet and from increased efficiency of ME for growth (see equation 38, Freer *et al.* (2012)). This influences the dry matter intake (DMI) of animals. With N still the macro-nutrient most limiting pasture growth on sheep and beef farms, lifting the growth and vigour of the legume proportion of pasture is a cost-effective way of lifting the quality and quantity of feed available to the animal (Lambert *et al.* 2003). The incentive to increase the proportion of animals finished to slaughter weights in hill county and the greater focus on per head performance, requires lifting the legume proportion of existing hill pastures. Uncertainty exists around what the economic return might be and so how much farmers can afford to spend to lift on-farm performance.

AgInform® (Integrated Farm Optimisation and Resource Allocation Model), is a multi-year farm systems model that advances the use of Linear Programming in whole-farm-systems modelling and decision making by integrating independently obtained biological data for specific land management units (LMU) within a farm system (Rendel *et al.* 2016). This model has the capacity to predict the expected returns for the whole farm business from investments targeted at specific LMUs. As part of this development, AgInform® has been modified so that the legume percentage in the pasture as it influences the energy and dry matter requirements of the animal can vary with the season of the year and from year to year. Before the current version (6.8.2.5) legume proportion was assumed to be 20% of the diet for the purpose of calculating the ME and DM requirements of animals. The user provides input data about the resources available (land area, pasture and livestock performance including crops and nitrogen responses), costs (per hectare, per animal and enterprise) and prices (meat schedules); AgInform® identifies the entry stock policy at the beginning of the planning horizon and the exit strategy at the end. Capital stock can be purchased or sold over the planning horizon, with the purchase price being set at 150% of stock valuation and sale price 50% of valuation, in an effort to represent scarcity of stock when purchased and over supply at sale time. The Net Present Value (NPV) is maximised over the planning horizon. The objective of this study was to model, using AgInform®, the value to a hill country farm of differing proportions of legumes in a mixed species pasture.

Methods
The pasture energy details provided to the model assumed that legumes contained 12 MJ ME/kg DM (Holmes *et al.* 2002). Further, the amount of N fixed by legumes impacts directly on the amount of forage grown. Nitrogen fixed is assumed to be 6.1% of the legume grown (kg N fixed/kg DM/ha legume produced) (Ledgard *et al.* 2001).

ISSN 2463-2872 (Print) ISSN 2463-2880 (Online)

Farm description

The Whanganui hill country sheep and beef farm has been used for a number of case studies (Rendel *et al.* 2013, 2015, 2016). The farm consists of 508 ha split into 4 LMUs (210, 179, 90 and 31 ha) producing on average 12.5, 7.9, 5.2 and 10.2 t DM/ha/year, respectively. The costs associated with running the property were split into animal (ewes, cattle, replacements and finishing stock and include labour, animal health, etc.), land (consisting of fertiliser, R&M, rates, etc.) and enterprise costs (that do not fit entirely with animals or land, which included legal, accountancy, and communication). If farm accounts are available, these costs can be obtained from the Farm Working Expenses. The animal costs were converted to a per head basis using stock numbers from the stock reconciliation statement in the accounts. The land costs were converted to a hectare basis. If the farm accounts are not available then monitoring reports for the farm location and type (e.g. MPI or Beef + Lamb New Zealand) can be used. The costs and prices remained constant over the planning horizon. The farm details have been described in Rendel *et al.* (2016).

Farm systems modelling

For the Whanganui farm the legume proportion of the pasture and the diet of the grazing animals was based on data collected in Gisborne at 314 m a.s.l. (Gray *et al.* 1987). On average, the legume proportion was 13% of the DM grown, with a minimum of 3% in mid-July through to a peak of 23% in late December and early January. This was selected as the base (‘Base’). The low (‘Low’) legume proportion option used an annual average legume proportion of 2% on all the LMUs throughout the year, whilst still maintaining the seasonal variation. Pasture growth rates and ME were decreased to account for the low legume proportion. The high (‘High’) legume proportion was evaluated by doubling the legume proportion of the base sward on each of the 4 LMU’s whilst maintaining the seasonal variation. Fortnightly pasture growth rates and ME were both adjusted to reflect the extra legume. The farm was modelled for each of the three legume proportions (Base, Low and High) and the systems compared for both physical and economic performance. The cost of increasing the legume proportion was not included, as the break-even investment was being estimated. The next step compared the value of additional legume on different areas of the farm. The higher pasture growth LMUs (1 & 4) and lower growth LMUs (2 & 3) were allocated different legume levels (Table 1) so that the contribution of additional legume on different areas of the farm could be valued.

Due to the model having complete knowledge over the 10 years and to better represent actual decision making on farm, capital stock (ewes and beef cows) numbers were required to be the same at 1 July each year and 17 June in the final year (as this is the last complete fortnightly period in the planning horizon). The model retained the option to purchase or sell capital stock between those dates, if it positively contributed to the NPV.

Pasture covers for each LMU were required to be on average between 1500 and 2500 kg DM/ha. Further, opening pasture covers for 1 July 1996 were set at 1500 kg DM/ha to best represent the covers at that time of year. If the model was allowed to choose the starting pasture cover it will invariably pick the upper level, 2500 kg DM/ha in this case. This does not represent the farm situation at that time of year.

The first model runs were set up to quantify the effect of increasing legume proportion over the whole farm. The second set of runs were to quantify the impact and value to the whole farm of changing legume proportion on just parts of the farm. To do this the highest pasture producing LMUs were grouped together (LMU 1 & 4) as were the two lower producing LMUs (2 & 4). It was assumed that the legume proportion of the poorer producing group would never be greater than the better group. Table 1 provides a description of the alternatives modelled.

Farm systems analysis

AgInform® identified optimal farm systems that maximised the NPV of the annual Earnings Before Interest, Tax, Depreciation and Amortisation (EBITDAs), including the initial capital spent on livestock and their liquidated at the end of the 10 year planning horizon. EBITDA was used as a measure of annual profit as it does not include items associated with farm structure (tax rates, depreciation) nor debt (interest and amortisation). The annual EBITDA were discounted as if they occurred at the end of the year. The NPVs were converted to an annuity (equal payments per year that would be received from interest and capital such that no capital remained at the end of the planning horizon) using the same discount rate as used for the NPV (5%/year in this case). The discount rate should reflect the future risk-free rate, as inflation was not included in this analysis. The annuity makes it easier to visualise the returns from different investment options. This type of investment analysis was required due to differing numbers of animals at the beginning and end of the planning horizon. The NPVs (and annuities) can be compared to the base system (usually current system optimised) to identify and quantify the best investment. The next step after the investment analysis, would be a funding analysis – how could the farm fund this investment? This would include the existing debt levels, capital structure and tax. It is possible that an investment has a favourable NPV yet the farm is not able to fund that investment and that option is not taken up. A funding analysis was not undertaken.

Table 1 Combinations of legume proportions on LMUs analysed within each farm system.

Scenarios	LMU 1&4	LMU 2&3
Low-Low	Low	Low
Base-Base	Base	Base
High-High	Double	Double
Base-Low	Base	Low
High-Low	Double	Low
High-Base	Double	Base

Results

Comparison of different proportions of legume across the whole farm

The optimal farm systems for Low, Base and High legume proportions (Tables 2, 3 and 4, respectively)

Table 2 Summary of farm system and financial analysis with Low (average of 2% of DM across the year) legume proportion.

	Stock Value ($)	Ewes[1]	Lambs Sold		Cattle Sold		EBITDA ($)
			Head	Date[2]	Head	Date[2]	
1996	-748885						
1996/1997		4153	4692	13 April	31	29 Jan.	315806
1997/1998		4153	4671	16 May			
433109							
1998/1999		4153	4686	22 April			381041
1999/2000		4153	4688	19 April			377816
2000/2001		4153	4688	18 April			331811
2001/2002		4153	4673	13 May	130	18 April	437499
2002/2003		4153	4731	11 Feb.			223534
2003/2004		4153	4670	17 May			442718
2004/2005		4153	4689	20 April	75	18 Jan.	360742
2005/2006		4153	5715	19 April	169	27 May	551219
2006	625631						
NPV							2584700
Annuity							334730

[1] Ewes present at start of lambing [2] Average sale date

Table 3 Summary of farm system and financial analysis with Base (average of 13% of DM across the year) legume proportion.

	Stock Value ($)	Ewes[1]	Lambs Sold		Cattle Sold		EBITDA ($)
			Head	Date[2]	Head	Date[2]	
1996	-907257						
1996/1997		4718	5254	11 April	102	29 Jan.	349277
1997/1998		5031	5662	11 May	27	4 June	532560
1998/1999		5031	5679	19 April			479647
1999/2000		5031	5685	11 April			466585
2000/2001		5031	5684	13 April			422407
2001/2002		5393	6166	3 May	66	4 June	532379
2002/2003		5031	5730	13 Feb.			300690
2003/2004		5031	5662	11 May	20	4 June	524142
2004/2005		5031	5685	14 April	134	28 Jan.	447465
2005/2006		5031	6929	14 April	215	4 June	679933
2006	757937						
NPV							3174490
Annuity							411111

[1] Ewes present at start of lambing [2] Average sale date

varied in several ways including the amount of capital invested and liquidated in livestock, the number of ewes present at the start of lambing which was reflected in the number of lambs sold, the timing of lamb sales, the number of cattle purchased to finish and their sale dates. Annual EBITDA, NPV and annuity also varied. All farm systems exhibited variation in EBITDA across years and most systems kept ewe numbers at lambing constant. In the Base and High systems ewes were sold as culls at scanning in the 1996/1997 year. This perhaps indicates that the constraint requiring ewe numbers to be equal each year as at 1 July could be relaxed for the first year. All farm systems purchased supplementary feed and fed it out in July 1996. Furthermore, they also applied nitrogen at the beginning of July 1996 to maintain pasture covers above the LMU minimum (1500 kg DM/ha). All farm systems also sold all ewe lambs as prime in the final year, rather than keeping some as replacements and being valued as capital stock at the end of the planning horizon.

Table 4 Summary of farm system and financial analysis with High (average of 27% of DM across the year) legume proportion.

	Stock Value ($)	Ewes[1]	Lambs Sold		Cattle Sold		EBITDA ($)
			Head	Date[2]	Head	Date[2]	
1996	-1134290						
1996/1997		5436	5936	5 April	196	2 Feb.	325487
1997/1998		6290	7094	25 April	63	12 Feb.	632350
1998/1999		6290	7108	11 April			606924
1999/2000		6290	7118	1 April			580506
2000/2001		6290	7113	6 April			539482
2001/2002		6290	7100	19 April	225	14 May	646832
2002/2003		6290	7164	13 Feb.			385538
2003/2004		6290	7100	19 April	75	14 May	619766
2004/2005		6290	7115	7 April	198	29 Jan	560561
2005/2006		6290	8662	14 April	270	23 Apr	841827
2006	947603						
NPV							3809870
Annuity							493396

[1] Ewes present at start of lambing [2] Average sale date

Table 5 Summary of farm system and financial analysis with Base legume on LMUs 1 & 4 and Low legume on LMUs 2 & 3.

	Stock Value ($)	Ewes[1]	Lambs Sold		Cattle Sold		EBITDA ($)
			Head	Date[2]	Head	Date[2]	
1996	-846909						
1996/1997		4697	5310	7 April	30	29 Jan.	355595
1997/1998		4697	5282	16 May			492997
1998/1999		4697	5301	20 April			439453
1999/2000		4697	5305	14 April			429366
2000/2001		4697	5305	15 April			385648
2001/2002		4697	5289	6 May	130	15 May	498306
2002/2003		4697	5350	12 Feb.			263829
2003/2004		4697	5282	16 May			493723
2004/2005		4697	5306	16 April	98	26 Jan.	417182
2005/2006		4697	6466	16 April	181	4 June	629769
2006	707521						
NPV							2957350
Annuity							382990

[1] Ewes present at start of lambing [2] Average sale date

To estimate the value of additional legume to the farm system it was necessary to account for the different capital investments and liquidation at the end of the planning horizon and the variable annual EBITDAs. Comparing NPVs for the options modelled provides this. The increase in NPV/ha from increasing legume from Base to High ($1251) is slightly more than would be achieved in moving from Low to Base ($1161). This can be interpreted as spending $1161 to move legume proportion from Low to Base would be a break-even investment, based on a 5%/year discount rate.

Comparison of different proportions of legume across individual LMUs

The legume proportion was altered in each group of LMUs to provide the farm system details to enable comparisons between levels of legumes. The farm systems summaries (Tables 5, 6 and 7) for the remaining 3 combinations identified in Table 1 (Base-Low, High-Low and High-Base) showed similarities with

Table 6 Summary of farm system and financial analysis with High legume on LMUs 1 & 4 and Low legume on LMUs 2 & 3.

	Stock Value ($)	Ewes[1]	Lambs Sold		Cattle Sold		EBITDA ($)
			Head	Date[2]	Head	Date[2]	
1996	-948392						
1996/1997		4897	5443	11 April	106	29 Jan.	365679
1997/1998		5259	5920	10 May	41	20 March	556558
1998/1999		5259	5936	20 April			509663
1999/2000		5259	5945	09 April			491635
2000/2001		5259	5941	14 April			452300
2001/2002		5642	6451	02 May	77	04 June	560159
2002/2003		5259	5990	13 Feb.			321728
2003/2004		5259	5922	07 May	37	04 June	542206
2004/2005		5259	5944	14 April	158	29 Jan.	470177
2005/2006		5259	7244	13 April	226	04 June	715248
2006	792302						
NPV							3346030
Annuity							433326

[1] Ewes present at start of lambing [2] Average sale date

Table 7 Summary of farm system and financial analysis with High legume on LMUs 1 & 4 and Base legume on LMUs 2 & 3.

	Stock Value ($)	Ewes[1]	Lambs Sold		Cattle Sold		EBITDA ($)
			Head	Date[2]	Head	Date[2]	
1996	-1048090						
1996/1997		5023	5484	7 April	187	25 Feb.	348575
1997/1998		5812	6549	3 May	42	12 Feb.	599446
1998/1999		5812	6565	15 April			561815
1999/2000		5812	6574	5 April			545965
2000/2001		5812	6570	9 April			496979
2001/2002		6059	6896	24 April	148	4 June	610481
2002/2003		5812	6619	14 Feb.			357074
2003/2004		5812	6556	25 April	57	4 June	581880
2004/2005		5812	6571	10 April	177	29 Jan.	527297
2005/2006		5812	8004	14 April	244	12 May	785810
2006	875590						
NPV							3614490
Annuity							468093

[1] Ewes present at start of lambing [2] Average sale date

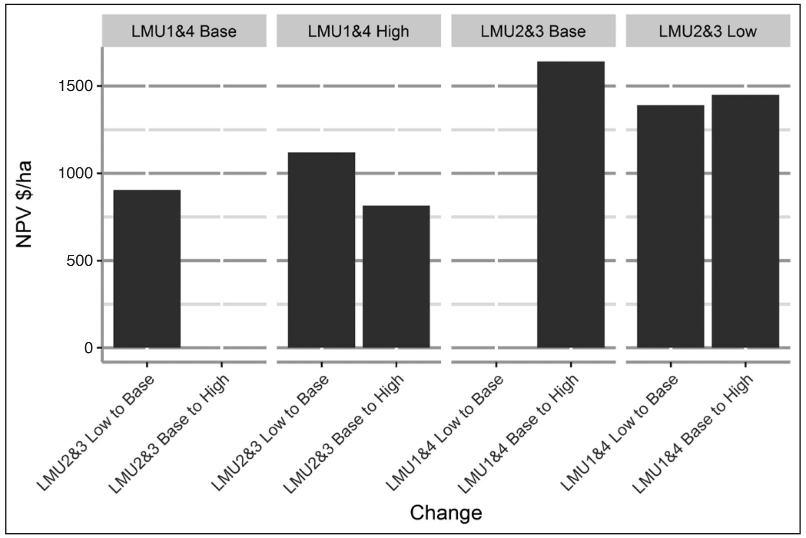

Figure 1 Change in NPV ($/ha) due to changes in legume proportion on different areas of the farm (LMU1 & 4 total 268 ha and 1 & 3 total 240 ha).

the previous 3 combinations (Low, Base and High), namely different levels of investment (and liquidation) in capital livestock, cattle being purchased to finish in some years, and lamb sales dates and EBITDA varying across years in all systems. Also, no replacement ewe lambs were retained in the final (2005/2006) year, rather they were sold prime.

The value of altering the legume proportion of the pasture on different LMUs was estimated by comparing the NPV's of the options modelled (Figure 1). The blank options in Figure 1 were not evaluated as that would have resulted in the lower producing LMUs (2 & 3) having a greater legume proportion than the higher producing LMUs (3 & 4), which would be unlikely due to the physical characteristics of the LMUs (slope, aspect, etc.). In all cases increasing the legume proportion led to higher NPV. The increase in NPV/ha was always greater when the legume proportion was increased on the higher performing LMUs (1 & 4) than lower performing areas of the farm. This would be expected as they have greater pasture production. The greatest contribution to increasing legume proportion in the lower producing LMUs (2 & 3) came from increasing legume proportion from Low to Base when the legume proportion in the good LMUs were at High levels. Whereas in the better LMUs (1 & 4) the greatest returns came from increasing legumes from Base to High with Base legume proportion in the poorer LMUs. This indicates that the responses were not linear.

Discussion

There is clearly a value to the farm of increasing legume proportion in the sward (Lambert *et al.* 1986; Fraser & Rowarth 1996; Chapman & Caradus 1997), allowing for the change in capital invested in livestock. This has been also shown by Khaembah *et al.* (2012) in modelling a pasture-based Waikato dairy farm, although cow numbers were held constant and the analysis modelled the farm as three independent years. This analysis identifies that between $800 and $1600/ha is returned from increased levels of legumes, depending upon the current level of legume and the pasture production of the blocks. Note that the cost of capital stock has been included in the analysis. However, the question that needs to be answered is how much can be spent on the capital investment to make a worthwhile return, allowing for such factors as establishment risk, market risk, owners risk profile and the businesses current financial position.

The analysis undertaken provides an estimate, from a strategic perspective, of the maximum that could be spent to be economically profitable. This would give direction to those wanting to invest in extra pasture legume as well as researchers looking at new ways to introduce and manage extra legumes. This approach could also be used in legume breeding programmes to estimate the economic weights used in a selection index for pastoral grazing farm systems.

Extension of this analysis to other locations or mix of landscapes should be done cautiously as clearly, the proportions of different land classes that make up the farm will define the value of additional legume.

There are a number of shortfalls in the analysis, that whilst they may change the absolute values would be unlikely to change the result. In estimating the grass growth in the Low level of legumes it was assumed that there would not be change in grass species from that present in the Base. It is more likely that lower fertility grasses would increase, resulting in a change in the shape of the pasture growth curve. This is likely to mean that the farm systems involving Low legume proportion have EBITDA's and NPV's that are over-estimated. Therefore, the size of the difference may be larger than indicated in Figure 1.

It has also been assumed that the extra growth from having High legume will be sustained over time. It is likely that the extra legume would result in fluctuations

of pasture growth between periods. The extra nitrogen fixed would result in increased competition for the legume and hence increase grass production followed by the opposite as legume regains a foothold. The other assumption made with the High legume option is that the increased pasture growth rates are actually achievable with the climate, altitude, aspect, slope and soil type that exists on the LMU.

The options modelled will be overestimates of what may happen in reality. The model has perfect and complete information about the whole planning horizon. A farm manager only has information available up to the day a decision is being made. However, the differences among the options should be comparable on a relative basis and be sufficient to inform better decision making.

Conclusion

As expected increasing the amount of legume in the pasture and therefore in the diet of farm animals leads to both a change in the farm system and a change in farm profitability. The change in capital stock numbers in the farm system, necessitated that an investment analysis be undertaken. This identified that the Whanganui hill country case-study farm could benefit between $800 and $1600/ha from additional legumes, depending upon the areas of the farm that were identified for improvement. This does not include the cost of increasing the legume content. The areas with the greatest potential return were those in the areas of the farm that had the greatest pasture production. Furthermore, the benefit varied with the base level of legume in the pasture.

ACKNOWLEDGEMENTS

Dougal and Di McIntosh for allowing us to use their farm for this case study. The P21 consortia (Beef+Lamb New Zealand, MBIE, DairyNZ, Fonterra, DCANZ and AgResearch) for funding. Gerald Cosgrove, Andrew Wall and the two anonymous referees that added to the clarity of the manuscript.

REFERENCES

Ball, R.; Brougham, R.W.; Brock, J.L.; Crush, J.R.; Hoglund, J.H.; Carran, R.A. 1979. Nitrogen fixation in pasture. 1. Introduction and general methods. *New Zealand Journal of Experimental Agriculture 7*: 1-5.

Chapman, D.F.; Caradus, J.R. 1997. Effects of improved, adapted white clover (*Trifolium repens* L.) germplasm on the productive properties of a hill pasture. *New Zealand Journal of Agricultural Research 40*: 207-221.

Fraser, T.J.; Rowarth, J.S. 1996. Legumes, herbs or grass for lamb performance? *Proceedings of the New Zealand Grassland Association 58*: 49-52.

Freer, M.; Moore, A.D.; Donnelly, J.J. 2012. The GRAZPLAN animal biology model for sheep and cattle and the GrazFeed decision tool. CSIRO Plant Industry Technical Paper Dec 2012.

Gray, M.H.; Korte, C.J.; Christieson, W.M. 1987. Seasonal distribution of pasture production in New Zealand XX. Waerengaokuri (Gisborne). *New Zealand Journal of Experimental Agriculture 15*: 397-404.

Holmes, C.W.; Brookes, I.M.; Garrick, D.J.; MacKenzie, D.D.S.; Parkinson, T.J.; Wilson, G.E. 2002. Milk Production from pasture: principles and practices. Massey University, Palmerston North, New Zealand. 602 pp.

Khaembah, E.N.; Gregorini, P.; Beukes, P.; Cosgrove, G.P. 2012. Modelling the effect of increasing dietary proportion of white clover on cow milk production and nitrogen excretion, and profitability of a Waikato dairy farm. Proceedings of the 5th Australasian Dairy Science Symposium: 146-149.

Lambert, M.G.; Clark, D.A.; Grant, D.A.; Costall, D.A. 1986. Influence of fertiliser and grazing management on North Island moist hill country 2. Pasture botanical composition. *New Zealand Journal of Agricultural Research 29*: 1-10.

Lambert, M.G.; Mackay, A.D.; Devantier, B.P.; McDougall, D.B.; Barker, D.J.; Park-Ng, Z.A. 2003. Redefining the production potential of hill pastures using fertiliser nitrogen. *Proceedings of the New Zealand Grassland Association. 65*: 35-40.

Ledgard, S.F.; Sprosen, M.S.; Penno, J.W.; Rajendram, G.S. 2001. Nitrogen fixation by white clover in pastures grazed by dairy cows: Temporal variation and effects of nitrogen fertilization. *Plant and Soil 229*: 177-187.

Nelson, T.A.; Zydenbos, S.M.; Stevens, D.R. 2017. Information required from research programmes when introducing legume forage systems into challenging environments. *Journal of New Zealand Grasslands 79*: 135-138.

Rendel, J.M.; Mackay, A.D.; Manderson, A.; O'Neill, K. 2013. Optimising farm resource allocation to maximise profit using a new generation integrated whole farm planning model. *Proceedings of the New Zealand Grassland Association 75*: 85-90.

Rendel, J.M.; Mackay, A.D.; Smale, P.N. 2015. Valuing on-farm investments. *Journal of New Zealand Grasslands 77*: 83-88.

Rendel, J.M.; Mackay, A.D.; Smale, P.N.; Vogeler, I. 2016. Moving from exploring on-farm opportunities with a single to a multi-year focus: Implications for decision making. *Journal of New Zealand Grasslands 78*: 57-66.