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Abstract:

Soil acidification is one of the major forms of soil degradation in higher rainfall areas of the tablelands of NSW. A grazing experiment was conducted near Sutton, NSW, to assess the effect of various rates of superphosphate, lime, sewage ash and stocking rates on wool production and sustainability between 1999 and 2008. The results from the discounted cash flow analysis show that the net present value of the treatment without lime, the lower rate of superphosphate and the lowest stocking rate returned the highest net present value of $266.30/ha. Raising the application of superphosphate from 125kg/ha every two to three years to 250kg/ha every year on un-limed and limed soil reduced the net present value by $278.70/ha and $249.30/ha, respectively. The addition of lime at the rate of 4t/ha on un-limed soil at the low superphosphate level reduced the net present value by about $234.60/ha. The net present value fell by $205.24/ha when the level of superphosphate rate increased to 250kg/ha every year. The net present value decreased as the level of stocking rate increased. We conclude that wool producers will be unlikely to use lime to ameliorate acid soil, even though production will not be sustainable, unless there are more favourable input and commodity prices in the market and government intervention.

Key words: economic, acid soil, lime, superphosphate, sewage ash, stocking rate, policy

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1. Introduction

Soil acidification is one of the major soil degradation problems in the high rainfall zone of south eastern Australia (Li, *et al.* 2001 and Scott, *et al.* 2000). Soils in this region are becoming increasingly acidic (Conyers, 1986 and Helyar, *et al.* 1990) and soil acidity is estimated to have affected approximately 13.7 million hectares in NSW (Fenton, *et al.* 1996). The processes of soil acidification, its effects and ways of reversing it have been discussed by Scott, *et al.* 2000, Mullen, *et al.* 2006 and White, *et al*. 2000. Moreover, according to Reeve (2000) primary producers in the high rainfall temperate zone of south eastern Australia identified soil acidity as a research issue, farm management focus and cause for pasture and crop decline.

Applying and incorporating lime and changing farming practices are considered the most practical ways of managing soil acidity (Li, *et al.* 2003). A number of previous experiments under cereal cropping and pasture in southern NSW have demonstrated yield increase following lime application (Scott, 1992 and Scott, *et al.* 1997). In addition, Mullen (2006) reported that liming increased crop production in acid tolerant wheat, barely and canola and these benefits persisted for more than six years. However, these results were focussed mainly on the effects of lime incorporated into the soil profile at the depth of 0-10 cm where land is easily cultivated. Yet, there are large areas of semi or non-arable soils on the tablelands of NSW and in north eastern Victoria where soils are infertile and often acidic to depth. The only option available to ameliorate these acid soils is to apply lime directly to the soil surface. There has been little research to study the effect of surface-applied lime on the profitability and sustainability of wool production.

In addition, the higher rainfall pastures in NSW have a long history of phosphorus use (Scott, 1997) because increasing the levels of soil phosphorus where deficient increases total herbage thereby allowing greater stocking rates (Lodge, 1979). There is however, a lack of information on appropriate P levels for production on both un-limed and limed soils. Without this information, there is the possibility of wool producers either under- or over-fertilising pastures, with consequent negative effects on economic viability and/or ecological stability of their pastures.

To address these knowledge deficiencies a grazing experiment comprising 18 experimental treatments assessed the combined effects of various rates of superphosphate, lime, sewage ash and stocking on the profitability and sustainability of wool production on the southern tablelands of NSW. A fine wool production enterprise was targeted from sheep initially selected for uniform fleece weight and fibre diameter to determine the effects of the above treatment combinations on financial returns.

2. Materials and methods

The grazing experiment with merino wethers covering over 20 hectares was conducted near Sutton, approx. 30 km north of Canberra on the Southern Tablelands of NSW. The climate of the area is temperate, with average annual rainfall of 660mm, evenly spread throughout the year. The soils at the experiment site were strongly acidic ranging from pH($CaCl_2$) 4.1 to 4.7.

The multi-factorial trial assessing the effect of different levels of lime, superphosphate, sewage ash and stocking rate was commenced in 1998. The 3 levels of lime were: nil lime (L0); lime to raise pH in the 0-10 cm profile to 5.0 (L1) and lime to raise pH to 5.5 (L2).

Because soil acidity varied across the experimental site separate measurements of pH were taken for each plot and subsequently calculated lime rates were applied. On average, about 4.0 t/ha lime was applied at L1 and about 7.0 t/ha at L2.

Two levels of single superphosphate fertiliser (8.8% P; 11% S) were applied: 125 kg/ha every two to three years (P1) and 250 kg/ha every year (P2). Sewage ash (SA) at 5 t/ha was applied as a separate treatment and studied at three levels of stocking. Merino wethers were allocated to plots at three stocking rates (low, medium and high) set by determining the medium stocking rates for each treatment and then setting the lower rate at 20% less and the higher rate at 20% higher. These led to the establishment of the18 treatments listed in Table 1.

Table 1: Trial structure showing number of replicates of each combination of P × Stocking Rate × Lime or Sewage Ash.

P and SA rates	Average Stocking rates	Lime rates			SA
		L 0	L1 (~ 4.0 t/ha)	L2 (~ 7.0 t/ha)	
P1 (125 kg/ha)	3.8	2	2	X[1]	X
	4.6	1	1	X	X
	5.3	1	1	X	X
P2 (250 kg/ha)	4.7	2	2	2	X
	5.7	1	1	1	X
	6.8	2	2	2	X
SA 5t/ha	4.7	X	X	X	1
	5.7	X	X	X	1
	6.8	X	X	X	2

[1] Treatments with these combinations of rates were not included

Live weight and condition score of the sheep were assessed regularly and wool yield and fibre diameter were measured annually at shearing. In autumn 1998 a mix of introduced pasture including subterranean clover, cocksfoot, phalaris and ryegrass was sown at the combined rate of 15 kg/ha after an initial spray with herbicide. Normal sheep management procedures were followed during the experiment and supplementary feeding occurred when there was below average rainfall and pasture supply.

2.1. Costs and benefits

The economic information collected from the trial included the quality and quantity of wool per head, stocking rates for each treatment over the 10 years, applied rates of lime, P and sewage ash, amount of supplementary feed and additional variable costs. Information collected from external sources included average prices of inputs and outputs. The project benefits were derived from the sale of wool clips (18-21µ) and surplus sheep over the period of the project. The project costs were the expenses incurred to purchase sheep and other inputs specified above.

2.2. Analytical Framework.

Economists have used response analysis, partial budgeting and dynamic models for the analysis of response to fertiliser. A standard economic tool to analyse farm production decisions relating to fertiliser responses has been response surface analysis integrating the principle of profit maximisation (Dillion, 1997). For example, Hall (1983), specified response functions for the economic evaluation of crop response to lime and fitted these functions for lucerne, corn and soybeans. However, the most commonly used farm management tool for fertiliser decision making still appears to be the use of partial budgeting techniques (Godden and Helyar, 1980) which have been widely applied for economic analysis of fertiliser response, enterprise choice and comparison of production strategies (Scott, *et al*. 2000a).

A major drawback of partial budgeting methodology is that it may underestimate the benefits of soil ameliorants and fertiliser applications because it has limited capacity to incorporate the off-site effects. Soil acidity is likely to have substantial negative off-site effects which have spatial and temporal dimensions affecting environmental resources and ecosystem services outside the point source (Mullen, *et al.* 1999 and Scott, *et al*. 2000).

The dynamic programming approach takes into account the currently applied and residual effect of fertiliser across spatial and temporal decision horizons (Kennedy, 1990). However, Godden and Helyar (1980) noted that the dynamic approach has two shortcomings: (1) it ignores the cost of maintaining fertiliser stock in the ecosystem and (2) it assumes the final period beyond the stock of fertiliser residue is irrelevant.

The process of assessing the economic impacts of applying P and lime involves identifying and valuing the benefits and costs of each treatment from which the net benefit is derived. In this analysis the conventional discounted cash flow method specified in equation 1 was used.

$$\text{NPV} = \sum_{t=1}^{T} \frac{B_t - C_t}{(1+r)^t} \qquad (1)$$

Where NPV is the Net Present Value, which is the sum of the discounted benefits minus costs. B and C are the dollar values of the total benefits and the costs (respectively) in a particular year, t, r is the discount rate and T is the number of years beginning at the base year 1999.

The evaluation method estimated the flow of net incomes and discounted them to arrive at the NPV's for each treatment. The decision rule used stated that if the NPV of a treatment is positive, then the investment on that particular treatment is desirable and the treatment with the highest NPV is considered the best. The assumptions used in the analysis are given in Table 2.

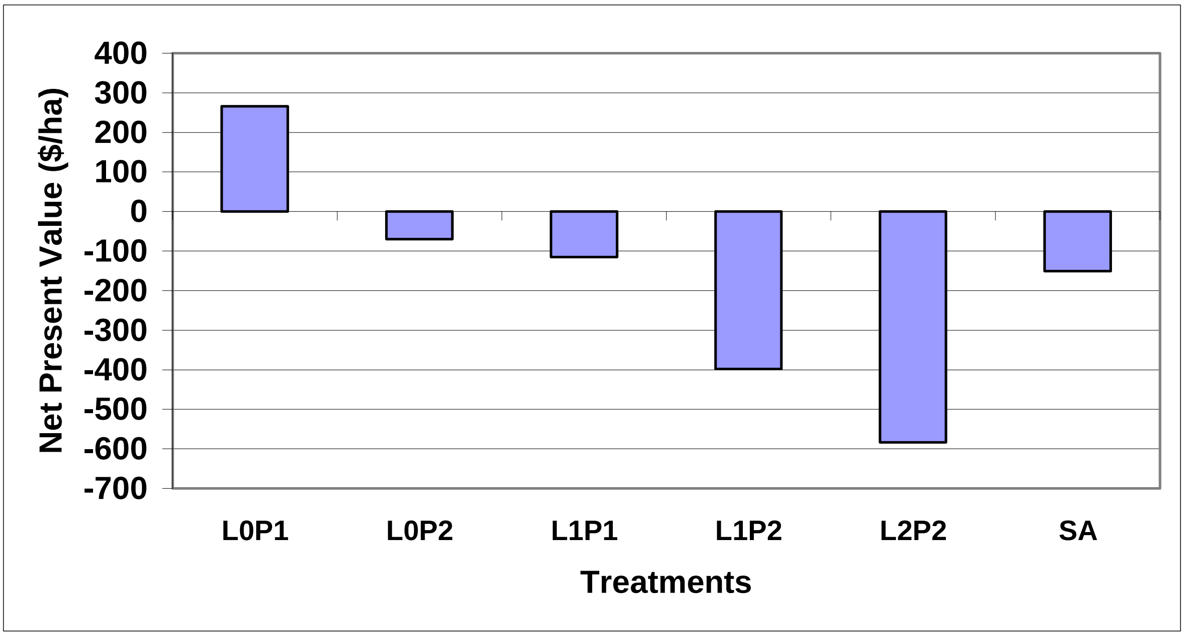
Table 2: Assumptions used in the analysis

Descriptions	Units	Value used
Price of wool (greasy)	$/kg	7.0
Wool cut per head	kg/hd	varies
Wool micron	micron	19
Stocking rate	DSE/ha	varies
Price (Super)	$/t	420
Price (lime)	$/t	57
Sewage ash applied	$/t	92
Application cost (Super)	$/t	40
Application cost (Lime)	$/t	15
Price of sheep sold	$/hd	50
Variable cost	$/hd	15
Price of sheep purchased	$/hd	30
Land size	ha	1
Discount rate	%	4

3. Results

The NPVs of the superphosphate, lime and sewage ash treatments, averaged across stocking rates, are shown in Figure 1. The treatment without lime (L0) and lower rate of P (P1) were the best because it has the highest NPV of $266/ha whereas all other treatments returned negative NPV's.

Figure 1. The net present values of the superphosphate, lime and sewage ash treatments averaged across stocking rates



The full set of net present values for all treatment combinations tested with differences and averages are given in Table 3

Table 3: The net present values of combinations of superphosphate, stocking rate, lime and sewage ash.

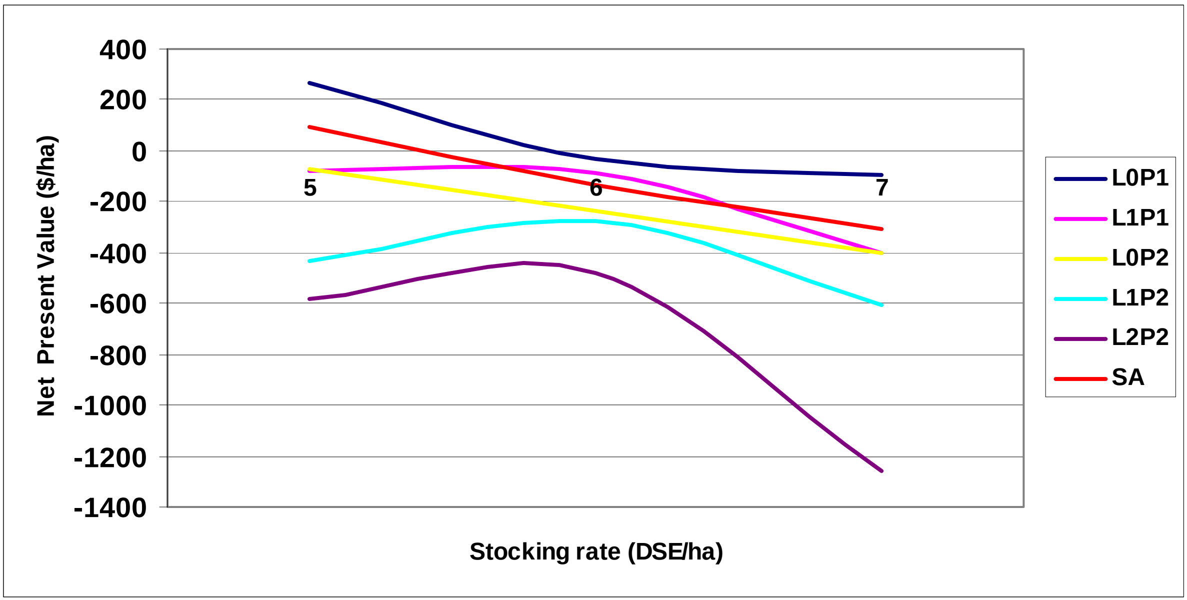
P and SA rates	Stocking rates	Lime and SA rates				
		L 0	L1	L2	SA	**L1 - L0**
P1	3.8	266.32	-79.00	X[1]	X	**-345.32**
	4.6	-35.84	-89.29	X	X	**-53.45**
	5.3	-95.45	-400.45	X	X	**-305.00**
	Average	**45.01**	**-189.58**	X	X	**-234.59**
P2	4.7	-69.74	-434.21	-583.55	X	**-364.48**
	5.7	-233.01	-277.41	-476.51	X	**-44.40**
	6.8	-398.35	-605.18	-1257.74	X	**-206.84**
SA	4.7	X	X	X	92.48	
	5.7	X	X	X	-135.87	
	6.8	X	X	X	-310.77	
	Average	**-233.70**	**-438.93**	**-772.60**	**-118.05**	**-205.24**
	P2 - P1	**-278.71**	**-249.35**			**29.35**

[1] as explained in Table 1

On average the application of lime to un-limed soil with 125 kg/ha P (P1) every two or three years reduced the NPV from $45.0/ha to -$189.60/ha which is a decline of about $234.60/ha. The application of lime to un-limed soil with 250kg/ha P (P2) every year reduced the NPV from -$233.70/ha to -$438.90/ha which is a reduction of about $205.20/ha Similarly, increasing the application of superphosphate from P1 to P2 on un-limed soil (L0) reduced the NPV from $45.00/ha to -$233.70/ha, a reduction of about $278.70/ha whereas increasing the rate of P at L1 reduced NPV from -$189.60/ha to -$438.90/ha, a reduction of about $249.90/ha.

The effect of changes in stocking rate on the NPV of treatments is depicted in Figure 2. Generally, NPVs declined with increasing stocking rates for all treatments except L1P1, L1P2 and L2P2 where NPV slightly increased at medium stocking rates.

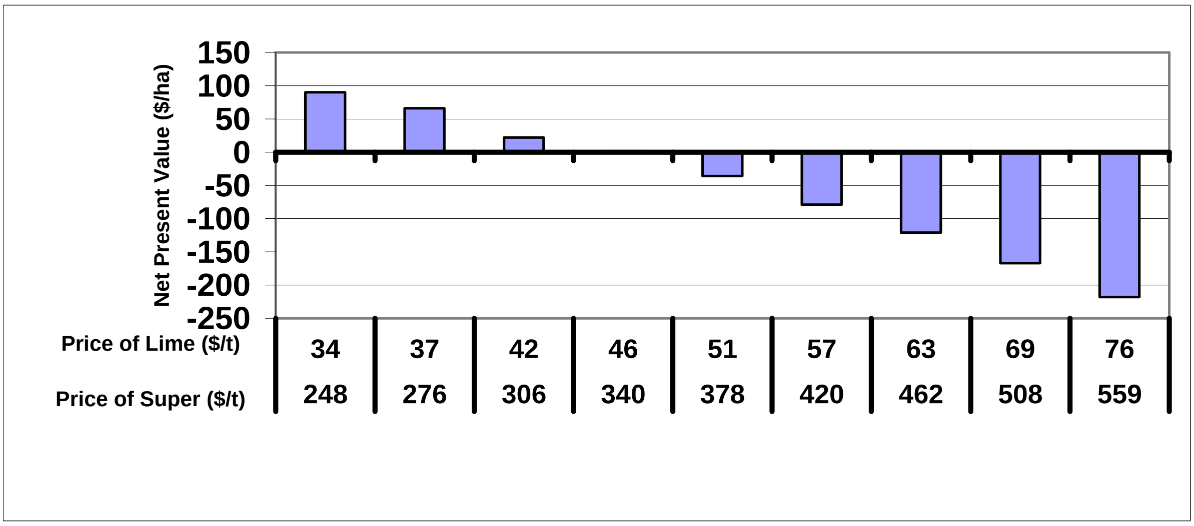
Figure 2: The effects of stocking rates on the NPV's of the treatments.



3.1. Sensitivity of the Net Present Value for L1P1 to changes in input and commodity prices

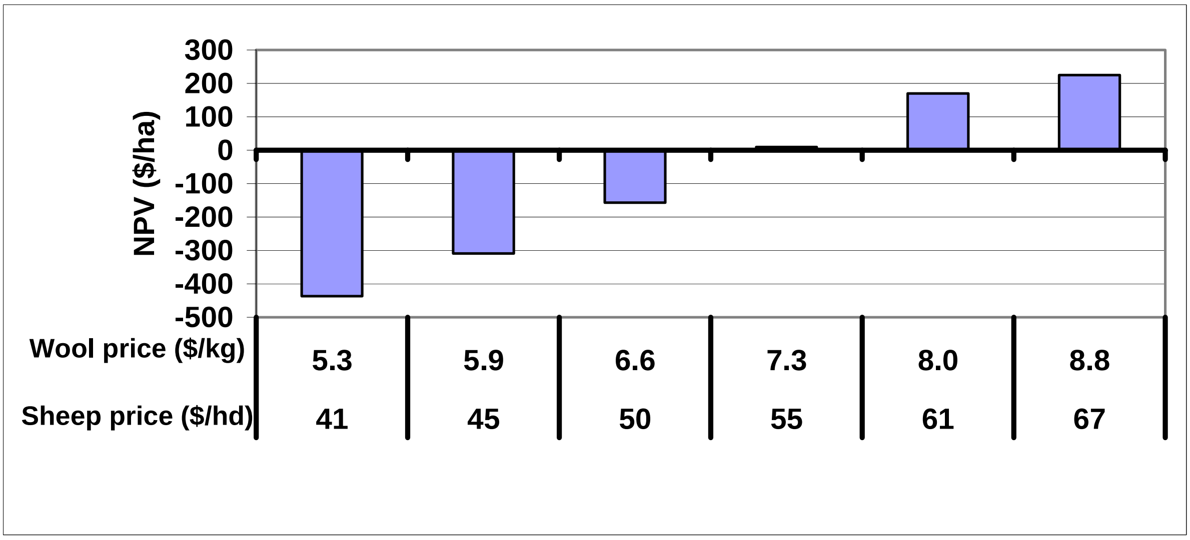
The ability to use lime to increase pasture production and yield depends on commodity prices and the cost of inputs (Vere, 1986). The prices of inputs and outputs have been discretely varied by 10% to determine the combination of input and commodity prices that would make the net present value of L1P1 positive. The break-even price for combinations of lime and superphosphate and the price of wool and sheep are plotted in Figures 3 and 4.

Figure 3: The sensitivity of the NPV for L1P1 to changes in the prices of lime and superphosphate.



Given the current prices of inputs and outputs provided in Table 1, the price of superphosphate and lime should be equal or less than $340/t and $46/t respectively, to justify the use of the lime at the L1 application rate. Similarly, the prices of greasy wool and sheep should be above $7.00/kg and $53/hd, respectively to justify the use of lime.

Figure 4: The sensitivity of NPV for L1P1 to changes in the price of wool and sheep



Discussion

Soil in ecosystems is only managed sustainability for agricultural production if the fertility is maintained or improved over time. This means that the addition of inputs to the soil needs to be equal to or greater than the fertility lost through production and soil degradation. Soil acidification limits plant growth and reduces yield (Scott, *et al.* 1992; Mullen *et al.* 2006 and Coventry *et al.* 1997). In addition, soil acidity has a negative impact on the persistence and production of perennial pasture species (Li, *et al*. 2003). Therefore, the application of lime and phosphate has been considered as the basis to increase the longevity of many perennial pastures.

Lime is an agricultural input (Hall, 1983) which needs to be managed by graziers in the way that maximises their net benefit (Scott, *et al*. 2000a and Islam, 1999) while economically sustaining production. However, the financial return to the use of lime on livestock enterprises vary significantly and according to Scott (2000a) the economic return for the use of lime on improved pastures grazed by merino wethers was less profitable than for merino ewes, breeding cows, and steer fattening enterprises. This occurs for a number of reasons:

1. Wether systems have a very low capacity to pay for the lime and superphosphate required to maintain production. Consequently the incremental value of production is relatively lower than the cost of the changes and so economic justification for the change will always be difficult to demonstrate (Scott, *et al*. 2000);
2. The perennial pasture species, such as phalaris, cocksfoot and perennial ryegrass, often do not persist long enough to guarantee graziers a reasonable return on the cost of establishment and maintenance (Virgona and Bowcher, 2000);
3. The changes in pasture management largely depends on movements in output prices and input costs (Vere and Muir, 1986) and
4. These improvements are associated with substantial pasture establishment costs.

However, if soil acidity is not treated, soil resources will be exploited beyond a level desired for the national good. Mullen (1999) notes that there is a divergence between private and public interest and so suggests that there is a ground for some sort of public policy intervention, collective action and change in land management.

Conclusion

In this economic analysis we found that the capacity of wool grazing enterprises to ameliorate soil acidity by liming will be limited because of the inability of liming to generate extra income. The experimental treatment without lime and lower superphosphate (P1) returned the highest net present value whereas the net present values of all other treatments were negative. The use of lime, at least at a lower rate (L1) can only be justifiable if income is maintained by lowering input costs and increasing commodity prices. However, because soil acidification involves substantial negative off-site effects it can be argued that government intervention is justified to assist the required change in land management.

References

Conyers, M. (1986), The relationship between average annual rainfall and exchangeable aluminium in soils of south-eastern New South Wales, *Australian Journal of Experimental Agriculture* 26: 587-590.

Coventry, D.R., Slattery, W.J., Burnett, V.F. and Ganning, G.W. (1997), Longevity of wheat yield response to lime in south-eastern Australia, *Australian Journal of Experimental Agriculture* 37: 571-575

Dillion, J. L. (1977), *The Analysis of Response in Crop and Livestock Production*, Pergamon, Oxford, Second edition.

Fenton G, Helyar K, Abbott T, Orchard P (1996), Soil acidity and liming, Agfact AC 19, 2nd Ed. (NSW Agriculture: Orange, NSW).

Godden, D.P and Helyar, K.R. (1980), An Alternative Method for Deriving Optimal Fertiliser Rates, *Review of Marketing and Agricultural Economics*, 48, 83-97.

Hall, H. H. (1983), Economic evaluation of Crop Response to Lime, *American Journal Agricultural Economics*, 65, 811-817

Helyar, K.R., Cregan, P.D. and Godyn, D.L. (1990), Soil acidity in New South Wales - Current pH values and estimates of acidification rates, *Australian Journal of Soil Research* 28: 523-537.

Islam, Q., Mullen, J.D, Brennan, J.P., Helyar, K.R. and Li, G. (1999), 'Farming options for ameliorating acidifying soils in south-eastern Australia: an economic assessment', 43rd Australian Agricultural and Resource Economics Society Conference, Christchurch, New Zealand.

Kennedy, J.S, (1988), Principles of dynamic optimisation in resource management, *Agricultural Economics*, 21, 57-72.

Kennedy, J.S., Whan, I. F., Jackson, R. and Dillion, J.L. (1973), Optimal fertiliser carryover and crop recycling policies for a tropical grain crop, *Australian Journal of Agricultural Economics*, 17 (2), 104-113.

Li, G.D., Helyar, K.R., Evans, C.M., Wilson, M.C., Castleman, L.J.C., Fisher, R.P., Cullis, B.R. and Conyers, M.K. (2003), Effects of lime on the botanical composition of pasture over nine years in a field experiment on the south-western slopes of New South Wales, *Australian Journal of Experimental Agriculture* 43: 61-69.

Li, G.D., Helyar, K.R., Conyers, M.K., Cullis, B.R., Cregan, P.D., Fisher, R.P., Castleman, L.J.C., Poile, G.J., Evans, C.M. and Braysher, B. (2001), Crop responses to lime in long-term pasture-crop rotations in a high rainfall area in south-eastern Australia, *Australian Journal of Agricultural Research,* 52: 329-341.

Lodge, G.M. and Roberts, E.A. (1979), The effects of phosphorus, sulphur and stocking rate on the yield, chemical and botanical composition of natural pastures, North-West Slopes, New South Wales, *Australian Journal of Experimental Agriculture* 19: 698-705.

Mullen, C. L., Scott, B. J., Evans, C. M. and Conyers, M. K. (2006), Effects of soil acidity and liming on lucerne and following crops in central-Western New South Wales, *Australian Journal of Experimental Agriculture*,46, 1291-1300

Mullen, J. D., Helyar, K.R. and Pagan, P (1999), Economic and Biological Perspective on Off-site Effects Associated with Soil Acidification, *Contributed Paper presented at the 44th annual Conference of the Australian Agricultural and Resource Economics Society*, University of Sydney, January 23=25, 1999.

Reeve, I.J., Kaine, G., Lees, J.W. and Barclay, E. (2000), Producer perceptions of pasture decline and grazing management, *Australian Journal of Experimental Agriculture* 40: 331-341.

Scott, J.F., Lodge, G.M. and McCormick, L.H. (2000a), Economics of increasing the persistence of sown pastures: costs, stocking rate and cash flow, *Australian Journal of Experimental Agriculture* 40: 313-323.

Scott, B. J., Ridley, A. M. and Conyers, M. K. (2000), Management of soil acidity in long-term pastures of south-eastern Australia: A review, *Australian Journal of Experimental Agriculture*, 40, 117-1198

Fenton, Greg, Helyar, Keith and Orchard, Peter (1993), Soil acidity and liming, Agfact AC. 19, Agricultural Research Institute, Wagga Wagga.

Scott, B.J., Conyers, M.K., Poile, G.J. and Cullis, B.R. (1997), Subsurface acidity and liming affect yield of cereals, *Australian Journal of Agricultural Research* 48: 843-854.

Scott, B.J. and Cullis, B.R. (1992), Subterranean clover pasture responses to lime application on the acid soils of southern New South Wales, *Australian Journal of Experimental Agriculture* 32: 1051-1059.

Vere D.T., and Muir, A.M. (1986), Pasture Improvement Adoption in South-Eastern New South Wales, *Review of marketing and Agricultural Economics*, 54, 19-31.

Virgona, J.M. and Bowcher, A. (2000), Effects of grazing interval on basal cover of four perennial grasses in a summer-dry environment, *Australian Journal of Experimental Agriculture* 40: 299-311.

White, R.E., Helyar, K.R., Ridley, A.M., Chen, D., Heng, L.K., Evans, J., Fisher, R., Hirth, J.R., Mele, P.M., Morrison, G.R., Cresswell, H.P., Paydar, Z., Dunin, F.X., Dove, H. and Simpson, R.J. (2000), Soil factors affecting the sustainability and productivity of perennial and annual pastures in the high rainfall zone of south-eastern Australia, *Australian Journal of Experimental Agriculture* 40: 267-283.