

The profitability of wool production after surface application of lime and superphosphate on acid soils

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Abstract Soil acidity is one of the major farm management problems on the Southern Tablelands of NSW. Soil acidity occurs naturally and yet some agricultural practices exacerbate the process through nitrification, leaching, removal of produce and accumulation of organic matter in the soil. A grazing experiment was conducted between 1999 and 2008 near Sutton, NSW, to assess the impact of various combinations of lime and superphosphate application, and stocking rates, on the profitability and sustainability of wool production on the Southern Tablelands. The profitability of 15 alternative experimental treatments was assessed using the discounted cash flow analysis method for a Merino wether enterprise. The results revealed that the highest net present value was generated by a low input system involving un-limed soil, the lower superphosphate rate and the lowest stocking rate. We conclude that with current input and commodity prices, wool producers with a Merino wether enterprise will be unlikely to use lime to ameliorate acid soils, implying that soil resources will be exploited unless there are favourable inputs and commodity prices or policy intervention.

Keywords: Lime, superphosphate, profitability, stocking rate.

Introduction

Soil acidification is one of the major soil degradation and farm management problems on the Southern Tablelands of NSW where the average annual rainfall is greater than 650 mm (Li et al. 2001; Scott et al. 2000). Soil acidity is an important farm management problem for two reasons. Firstly, high levels of soil acidity reduce farm profitability by increasing costs of production and reducing yields of crops and pastures (Scott et al. 2000a). Secondly, soil acidy affects nutrient balance in the soil by immobilising phosphorus and increasing aluminium and manganese toxicity, consequently facilitating soil degradation and reducing plant production (Trapnell and Malcolm 2004; Upjohn et al. 2005).

The soils of the Southern Tablelands are predominantly loams and clays, mainly Chromosols and Lithosols (Isbell 1996), which are increasingly becoming acidic (Conyers 1986; Helyar et al. 1990) because of leaching, nitrification, removal of soil nutrients in produce and accumulation of organic matter (Trapnell and Malcolm 2004; Upjohn et al. 2005). Consequently, it is estimated that soil acidity has affected about 13.7 million hectares in NSW (Fenton et al. 1996) and the rate of acid addition to the soil profile is estimated at 10–20 kmoles H^+/ha/year (Helyar et al. 1990).

Reeve et al. (2000) noted that soil acidification is one of the major farming systems research issues in south-eastern Australia. One of the practical ways of ameliorating soil acidity is applying and incorporating lime (Helyar and Porter 1989 Li et al. 2003). A number of experiments conducted on the application of lime on acid soils under cropping and pasture rotations demonstrated that crop yield and the persistence of pastures increased following lime application (Scott and Cullis 1992; Scott et al. 1997; Scott et al. 2000a). According to Mullen et al. (2006) and Brennan and Li (2006) yields of acid tolerant wheat, barely and canola improved following liming of acid soils. Brennan and Li (2006) found that the profitability of a number of crops and perennial pastures grown on acid soils increased by an average of $554 and $25/ha, respectively, over 12 years following lime application.

However, these results were based mainly on the effects of lime incorporated into the soil profile at a depth of 0–10 cm. In addition, they were derived mainly from agricultural areas where land is easily cultivated. However, large areas of the Southern Tablelands of NSW are characterised by semi or non-arable soils on which the only option is to apply lime directly to the soil surface and incorporation is not practical.

To date little research has been conducted to assess the combined effects of surface-applied lime and superphosphate on the profitability of wool production. The purpose of adding superphosphate is to increase total herbage mass and enable greater stocking rates (Lodge and Roberts 1979). The objective of this study is to analyse the impacts of alternative combinations of surface-applied lime and superphosphate application rates on the profitability of fine wool production in the Southern Tablelands of NSW, based on data from a grazing experiment.

Materials and methods

This grazing experiment was conducted approximately 30 km north of Canberra, near Sutton, between 1999 and 2008.

The experimental area covered more than 20 hectares and is characterised by a temperate climate, with average annual rainfall of 660 mm evenly distributed throughout the year. Soils are predominantly shallow and stony. Profiles display texture contrast with brown loam topsoils overlying reddish to reddish brown light clays and clay loams. They are broadly described as Red Chromosols and Lithosols by Isbell (1996) and are becoming increasingly acidic with surface acidity (pH_{CaCl2}) ranging from 4.1 to 4.7 (Helyar et al. 1990).

In autumn 1998, a mix of pasture species including subterranean clover, cocksfoot, phalaris and ryegrass was sown after an initial spray with herbicide and insecticide at a total cost of $293/ha. The multi-factorial trial assessing the effect of three levels of lime, two levels of superphosphate and six levels of stocking rate commenced in 1999 (see Table 1). The overall experimental design led to the establishment of 15 independent treatments as indicated in Table 1.

The two levels of superphosphate fertiliser (8.8% P; 11% S) applied were 125 kg/ha every two to three years (P_1) and 250 kg/ha every year (P_2). The three levels of surface-applied lime were: nil lime (L_0); lime to raise pH (0–10 cm) to 5.0 (L_1) and lime to raise pH (0–10 cm) to 5.5 (L_2). Because soil acidity varied across the experimental site, soil pH was measured for each plot prior to the application of treatments and the amount of lime subsequently applied to raise pH to the desired level differed accordingly. On average, about 4.0 t/ha lime was applied at L_1 and about 7.0 t/ha at L_2.

Merino wethers were purchased and allocated to the plots at three stocking rates (low, medium and high), which were 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. Subsequently, live weight and condition score of the sheep were assessed every six weeks and wool yield and fibre diameter were measured annually. Normal sheep management practices such as shearing, crutching, selling, marking, drenching, jetting and vaccination were followed during the experiment and supplementary feeding was provided when there was a less than average pasture supply.

Costs and benefits

The economic data used in this analysis were obtained from both primary and secondary sources. The primary source of data was the experimental results, which included the quality and quantity of wool cut per head, stocking rates, the quantity of lime and superphosphate applied, costs of supplementary feeding per head and other variable costs associated with livestock husbandry practices and services. The information obtained from the secondary source (Department of Finance 1991) included the costs of inputs, prices of wool and sheep, discount and inflation rates.

The project income was derived mainly from the sale of wool and sheep. The project costs were the expenses incurred to establish and maintain the pasture, purchase replacement sheep, agricultural inputs and other variable costs. Preliminary economic statistics obtained from the experiment are given in Table 2.

Wool cut per head varied between 4.6 and 6.2 kg. Average gross margin was negative because generally the variable costs were higher than total income. Incomes from the sales of wool and sheep constituted about 63.6% and 34.4% of the total sales, respectively. About 19.3% of the costs were associated with pasture establishment and the proportion of the total cost associated with lime and superphosphate were about 8.9 and 15.2%, respectively. The cost of supplementary feeding averaged about 14% of the total cost.

Analytical framework

The economic frameworks commonly used for the analysis of response to fertiliser include partial budgeting, response surface analysis, and dynamic programming. The partial budgeting technique appears to be the most commonly used farm management tool for making decisions on fertiliser applications (Godden and Helyar 1980). This is because the technique is relatively straightforward and enables choices and comparisons between enterprises and farm management strategies (Scott et al. 2000a). However, one of the limitations of the partial budgeting technique is that it may underestimate the long-term carry over benefits of fertiliser and the positive externalities associated with correcting soil acidity (Mullen et al. 1999; Scott 2000).

Determining the appropriate analytical technique requires a choice among the possible investment criteria that may be used to compare future streams of net benefits resulting from alternative decisions on fertiliser application. These criteria include net present value (NPV), benefit-cost ratio and internal rate of return (Sinden and Thampapillai 1995).

The net present value is the sum of the discounted net benefits of an investment over time. Under the NPV criterion the investment with the highest NPV is the most desirable. The benefit-cost ratio is the ratio of the sum of the present value of benefits to the sum of the present value of costs. Based on this criterion the alternative with the highest ratio is the most desirable. The internal rate of return is the discount rate at which the NPV equals zero. With this criterion the alternatives with an internal rate of return greater than the social discount rate are acceptable, the highest being the most preferred.

Sinden and Thampapillai (1995) noted the net present value approach is widely applied in investment analysis because of the nature of capital flow in competitive market situations. The benefit-cost ratio criterion is used when economic efficiency is the objective and capital is limited.

On the other hand, the economic analysis of response to fertiliser also involves the use of response surface analysis and dynamic programming methods. Response surface analysis integrating the principle of profit maximisation is the standard economic tool for the analysis of farm production decisions in response to fertiliser (Dillion 1997). Hall (1983), for example, specified response functions for the economic evaluation of crop response to lime and fitted these functions for lucerne, corn and soybeans. However, these techniques are rather complex and their application is not straightforward (Godden and Helyar 1980).

The dynamic programming method proposed by Kennedy (1988) addresses the problems associated with partial budgeting and fertiliser response functions. Kennedy (1988) proposed that the level of fertiliser currently available in the soil is the total of fertiliser applied and fertiliser carried over from previous years. The dynamic programming technique was applied to analyse the effects of nitrogen fertiliser on the response of sorghum crops at the Ord River (Kennedy et al. 1973). However, Godden and Helyar (1980) noted that the dynamic approach proposed by Kennedy (1988) has two shortcomings: (1) it ignores the cost of maintaining fertiliser stock in the ecosystem; and (2) it assumes a final period beyond which the stock of fertiliser residues in the system is irrelevant.

In this study we used the net present value approach to compare the profitability of alternative treatments described in Table 1. For each treatment the analysis involved identifying and valuing the costs and benefits between 1999 and 2008. Consequently, the Net Present Value (NPV) for each treatment was calculated using the conventional benefit cost formula described in equation 1

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

where B_t and C_t are the dollar values of the benefit and cost respectively in year t, r is the discount rate and T is the number of years starting from 1999 to 2008. The decision rules were that if the NPV is greater than zero, then the investment in that particular treatment is desirable; and the treatment with the highest NPV will be the most desirable.

Assumptions used in the analysis

The calculation of net present values depended on assumptions about the prices of inputs and outputs. These assumptions are given in Table 3.

The price for 19-micron wool used in the analysis is \$6.80/kg. Wool prices have not changed significantly since 1991. Khairo et al. (2008) noted that the annual increase in wool price since this time has been only about 0.03%.

The price for superphosphate used is \$280/tonne. In fact, the prices for agricultural inputs, particularly fertilisers and chemicals fluctuate significantly depending on season, availability and demand, the historical peak for superphosphate being about \$560/tonne in 2008 (P Graham, per. com. 2009). The figure used here is considered an average price. The discount rate and interest on loans used are 7% and 8%, respectively.

Results

The NPVs of lime and superphosphate treatments, averaged across stocking rates, are shown in Figure 1. The treatment without lime (L_0) and with the lower rate of P (P_1) is the most desirable because it had the highest NPV of \$185/ha. The NPVs of all other treatments are negative, implying that they are not economically desirable. The NPVs decreased as lime and superphosphate application rates increased.

The full set of NPVs is given in Table 4.

At the low superphosphate rate the application of lime (L_1), on average, reduced NPV by about $241/ha (from -$31/ha to -$272/ha) compared with un-limed soil. The use of lime (L_1), at high P application (P_2) reduced NPV by about $206/ha (from -$188/ha to -$394/ha) compared with un-limed soil, and heavier lime application (L_2) resulted in an even greater reduction in NPV. Increasing the application rate of superphosphate from P_1 to P_2 on un-limed soil (L_0) reduced the NPV by about $157/ha (from -$31/ha to -$188/ha), while the corresponding reduction at L_1 was about $122/ha (from -$272/ha to -$394/ha).

The effect of changes in stocking rate on the NPV of alternative treatments is depicted in Figure 2. NPVs declined with increasing stocking rate for all treatments except L_2P_2 and L_1P_2 for which the NPV slightly increased at medium stocking rates.

Vere and Muir (1986) noted that the ability to use superphosphate and lime to increase pasture production and yield depends on commodity prices and the cost of inputs. The prices of lime, superphosphate, wool and sheep have been discretely varied to determine the combination of inputs and commodity prices that would make the NPV for the most commonly used application, L_1P_1, positive. The break-even prices for combinations of lime and superphosphate (given the current sheep and wool prices) and the prices of wool and sheep (given the current super and lime prices) are plotted in Figures 3 and 4.

Given the current prices of wool and sheep provided in Table 3, the price of lime and superphosphate should be equal to or less than $29/t and $118/t respectively at the same time to justify the use of lime at L_1P_1. Similarly, assuming the current prices of lime and superphosphate in Table 3 prevail, the prices of greasy wool and sheep should be equal to or greater than $7.50/kg and $58/hd, respectively, before considering the use of lime and superphosphate on acid soils (see Figure 4).

The analysis presented above takes no account of the effect of the different lime and superphosphate applications on the longer-term productive potential of the soil resource to which they were applied. However, a full appreciation of the effects of the trial necessitates an awareness of the environmental implications of the different regimes of lime and superphosphate applications. Furthermore, it is appropriate that the costs associated with ameliorating any degradation of the soil resource associated with a treatment be presented. This information is essential for a balanced assessment of the economic impact of the trial. To achieve this the model, 'Lime It' was used to estimate the amount of acid addition to the soils of the different treatments (Liu et al. 2003). In the treatments without lime addition in 1998 (L_0P_1, L_0P_2), the values of 'acid added less lime applied' showed substantial amounts of acidity (3.02 and 2.65 t lime equivalent/ha respectively) added to these soils between 1998 and 2008 (Table 5). Three treatments in the trial added lime in 1998 (L_1P_1, L_1P_2, L_2P_2) and in 2008 these still showed a residual effect of the 1998 applications. This was because there was still lime present from the 1998 applications that had not been neutralised by the acid additions during the period 1998–2008. Using the cost of lime of $57/t (Table 3), it could be argued that L_0P_1 and L_0P_2 incurred costs of $172.14 (3.02*57) and $151.05 (2.65*57) respectively, currently unaccounted for, required to ameliorate the acid addition to the soil brought about by these two treatments.

Discussion and conclusion

A number of previous studies assessing the profitability of liming acid soils found that the net return varied significantly depending on the type of farming system. Scott et al. (2000a) and Brennan and Li (2006) found that the net benefits from liming acid soils under pastures grazed by Merino wethers were significantly less than the net benefits from enterprises under crop and pasture rotations, Merino ewes, breeding cows and fattening enterprises.

The application of lime on perennial pasture systems stocked with Merino wethers is less profitable than the other systems for several reasons: (1) the Merino wethers in this trial were grazed on land classes of such low potential productivity that the perennial pasture species, phalaris, cocksfoot and perennial ryegrass, could not persist long enough to guarantee graziers a reasonable return on the cost of establishment and maintenance (Virgona and Bowcher 2000) and a more favourable result may have occurred had a more productive land class been studied; (2) wether enterprises have lower productive capacity to pay for the lime required to maintain soil fertility and production. Consequently, the incremental value of production is relatively lower than the costs associated with the changes (Slattery and Coventry 1993; Scott et al. 2000; Trapnell and Malcolm 2004); and (3) the profitability of pastoral enterprises depends largely on changes in output prices and input costs (Vere and Muir 1986) and both have been unfavourable to wool producers in recent years.

Under such circumstances the use of lime and superphosphate to ameliorate acid soils and improve soil fertility will be difficult to justify in financial terms. In other words, the ability of wool producers who rely on a Merino wether enterprise to use lime and superphosphate will be restricted because the enterprise will not generate enough extra income to cover the costs associated with pasture establishment and maintenance. The lower than average rainfall conditions experienced during this project required substantial supplementary feeding and this increased costs further. In addition, the possibility that these drought conditions have influenced the results of the trial should not be ignored.

In this study we found that the experimental treatment with a positive NPV was the un-limed soil, with the lower rate of superphosphate and the lowest stocking rate. However, it is important to note that the costs of pasture establishment and maintenance, and supplementary feed, accounted for about 33% of the total cost associated with each treatment. Therefore, results are expected to differ in cases where lime and superphosphate are applied to existing pastures and the costs of supplementary feeding are lower.

Therefore, the use of lime and higher rates of superphosphate in a Merino wether enterprise will only be justified if the input prices are lower, commodity prices are higher and/or resources are used more efficiently (Scott et al. 2000a; Islam et al. 1999). Changing the livestock enterprise from wethers to Merino ewes or breeding cows, which have a higher capacity to pay, may offer a partial solution, although there will be extra capital costs for livestock purchase and other adjustments.

If soil acidification is untreated, agricultural production and farm profitability will fall as soil resources are degraded and yields of crops and pastures fall (Scott and Cullis 1992; Mullen et al. 2006; Coventry et al. 1997). Consequently, soil resources will be exploited beyond the level desired by the public unless there is government intervention because soil acidification represents a market failure, which is a divergence between private and public interests.

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Appendix

Table 1. Trial structure showing number of treatments and replicates of each combination of P × Stocking Rate × Lime

Superphosphate rate	Average Stocking rates	Lime rates		
		L_0 (0t/ha)	L_1 (4.0 t/ha)	L_2 (7.0 t/ha)
P_1	3.8	2	2	X[1]
(125 kg/ha)	4.6	1	1	X[1]
	5.3	1	1	X[1]
P_2	4.7	2	2	2
(250 kg/ha)	5.7	1	1	1
	6.8	2	2	2

[1]Treatments with these combinations were not established as they are highly unlikely. The numbers in the table indicate the number of replicates for each treatment.

Table 2. Preliminary economic information obtained from the experiment

Description	**Unit**	**Mean**	**St. Dev**	**Min**	**Max**
Wool cut per head	Kg/hd	5.3	0.45	4.6	6.2
Average income/ha	$	218	127	0	363
Average cost/ha	$	250	44	181	373
Average gross margin/ha	$	-32	15	-23	37
Proportional income/ha					
Wool	%	63.6	-	13	100
Sheep	%	34.4	-	0	87
Proportional cost/ha	%				
Pasture establishment		19.3	3.1	12.6	25.9
Sheep purchase		18.5	2.1	15.2	22.0
Lime		8.9	7.2	0.0	19.4
Superphosphate		15.2	7.0	4.9	24.8
Supplementary feed		14.0	8.9	4.2	28.5
Sheep husbandry		24.1	3.0	20.2	31.7

Table 3. Assumptions used in the analysis

Items	Units	Values used
Price of wool (greasy)	$/kg	6.8
Price (Superphosphate)	$/t	280
Price (Lime)	$/t	57
Application cost (Super)	$/t	40
Application cost (Lime)	$/t	15
Sheep price (sold)	$/hd	60
Sheep price (purchase)	$/hd	30
Other variable cost	$/head	15
Land area	ha	1
Discount rate	%	7
Interest on loan	%	8

Table 4. NPVs for all experimental treatments

P rates	Stocking rates (SR)	Lime rates			Impacts
		L_0	L_1	L_2	L_1-L_0
	3.9	185	-181	X	-367
P_1	4.7	-110	-181	X	-71
	5.4	-168	-454	X	-286
	Average	-31	-272		-241
	4.7	-47	-403	-538	-356
P_2	5.7	-187	-246	-440	-59
	6.8	-330	-533	-393	-203
	Average	-188	-394	-456	-206
	P2-P1	-157	-122		35

Table 5: The effects of a trial comprising three rates of lime and two of superphosphate at a site with soils varying in lime requirement showing, the amount of lime applied per treatment in 1998/99, the amount of acid added to the 0–40 cm profile during 1998–2008, the amount of acid added less lime applied to the 0–40 cm soil profile during this period, and the amount of lime still needed in 2008 to raise the entire 0–40 cm profile to pH 5.5.

Treatment	Lime added 1998/99 (t/ha)	Acid added (t lime equivalents/ha)	Acid added less lime applied (t lime eq. /ha)	Amount of lime needed for pH 5.5 (t/ha)
L0P1	0	3.023	3.02[a]	14.4
L0P2	0	3.170	2.65[a]	15.3
L1P1	4.1	2.653	-0.93[b]	10.6
L1P2	4.0	2.784	-1.24[b]	8.8
L2P2	7.3	3.519	-3.78[b]	9.0

[a]amount of lime needed to raise pH in 2008 to 1998 levels.

[b]amount of lime applied in 1998/99 which still has not been neutralised by acid additions up to 2008 (ie. the pH is still above the 1998 pH by an amount equivalent to this amount of lime).

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

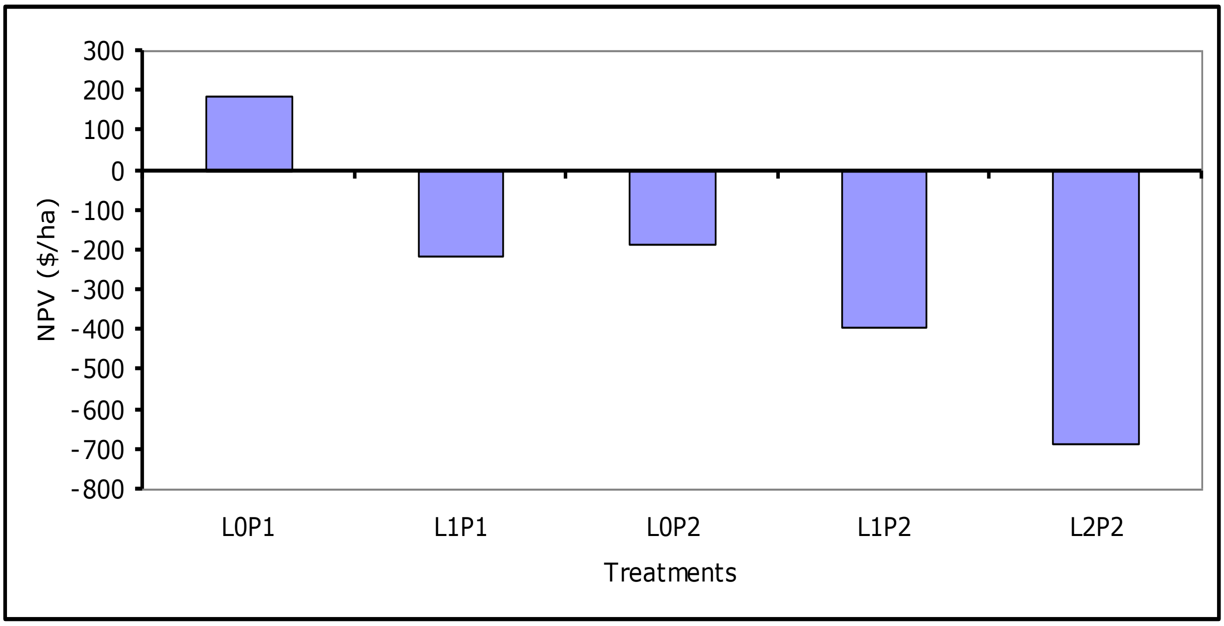

Figure 2. The effect of stocking rate on NPV

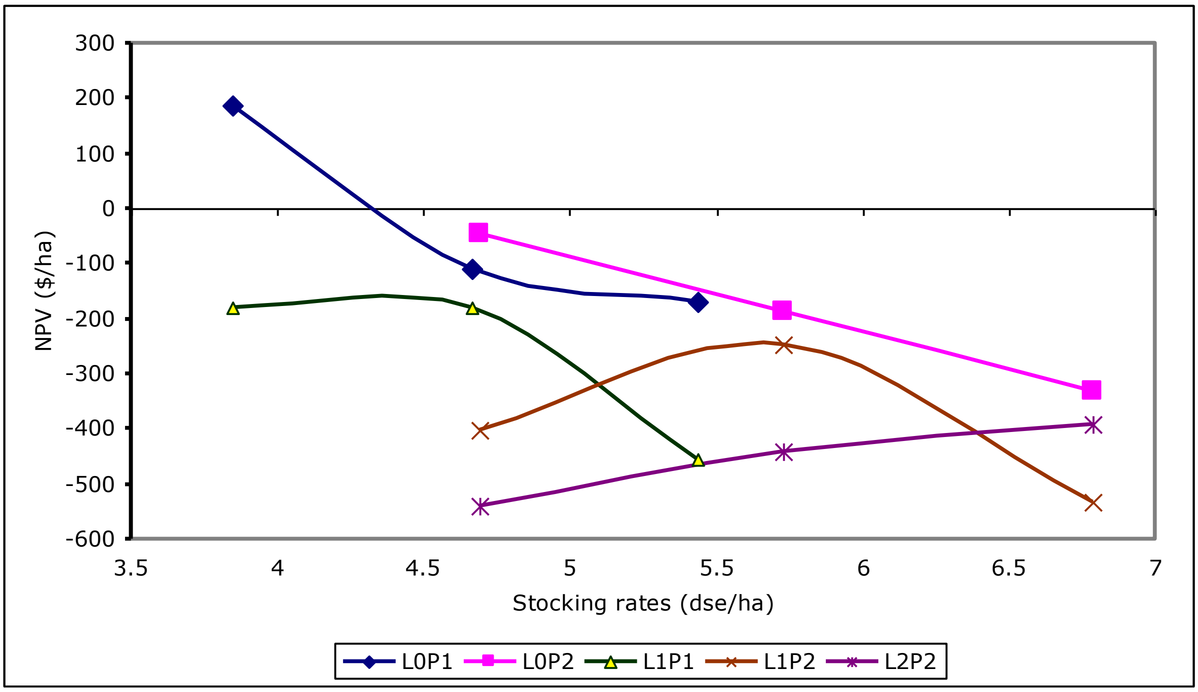

Figure 3. The sensitivity of NPV for L_1P_1 to changes in the price of lime and super

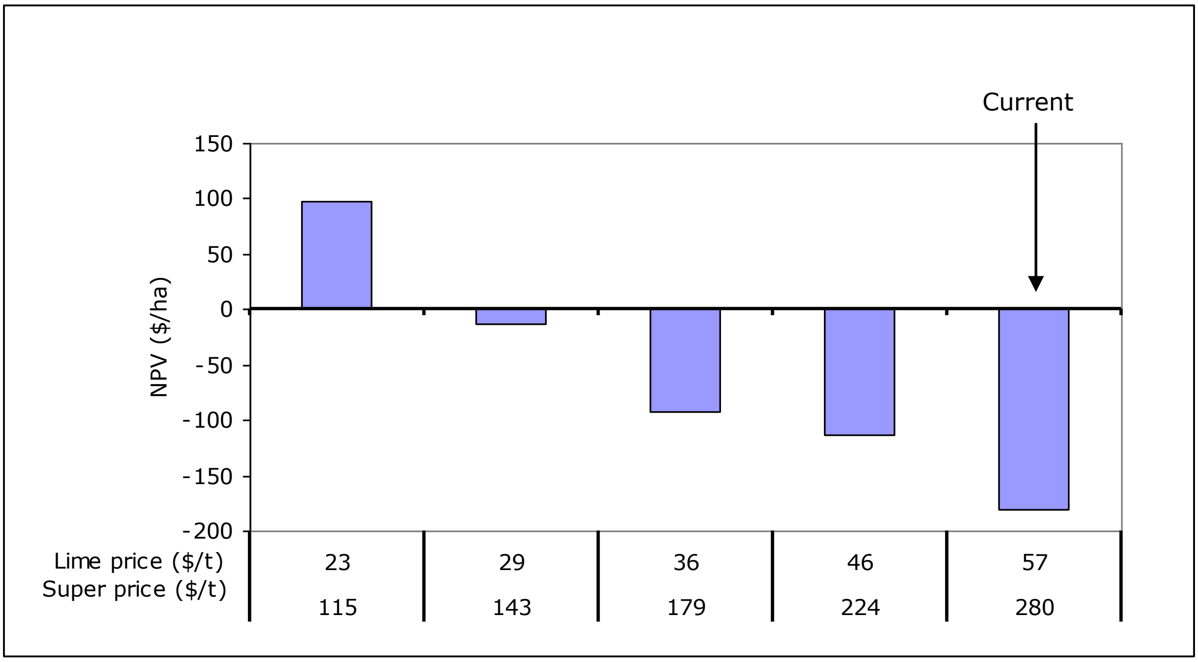

Figure 4. The sensitivity of NPV for L_1P_1 to changes in the price of wool and sheep