Is nitrogen fertiliser an economic option in tussock hill country?

D.R. STEVENS[1], B.R. THOMPSON[1], W.D. CATTO[2], and K.D. TRAINOR[3]
[1]*AgResearch Invermay, Private Bag 50034, Mosgiel*
[2]*Ballance Agrinutrients Ltd, Tauranga*
[3]*SouthTech Ltd, Alexandra*
david.stevens@agresearch.co.nz

Abstract
Tussock hill and high country is a finite resource. Farmers are developing these areas to increase production but often at the expense of tussock which provides shelter for stock, increases biodiversity and captures moisture in dry environments. An experiment at a single hill country site near Roxburgh, Otago was established on oversown tussock with soil of low pH (5.1) and high soluble aluminium (15 ppm) to compare the use of capital lime (0–5 t/ha), annual and capital superphosphate (0–1000 kg/ha) and annual nitrogen (N) fertiliser inputs (0–150 kg/ha) over 4 years to investigate the potential of different fertiliser strategies to increase economic returns. Annual yield of the Control without fertiliser was approximately 3200 kg DM/ha/annum, which may support an estimated stocking rate of 6 ewes/ha during the growing season. Using lime did not increase the pasture production or stocking rate, though even small amounts increased pasture quality. Use of phosphate and sulphur increased the stocking rate to approximately 9 ewes/ha, while adding N fertiliser increased potential stocking rate to approximately 12 ewes/ha. These increases were a combination of increased pasture production and increased pasture quality. A combination of phosphate, sulphur, lime and nitrogen provided a potential net increase in gross margin of $200/ha. This cost benefit analysis suggests that regular use of N fertiliser along with other known fertiliser requirements may be a very cost effective way of increasing hill country production without resorting to full scale tussock development.

Keywords: gross margin, hill country, fertiliser, quality, sheep stocking rate, yield.

Introduction
Tussock hill and high country is a finite resource. Farmers are looking to develop these areas to increase production to make the most of their resources. This is often at the expense of tussock which provides shelter for stock, increases biodiversity and captures moisture in dry environments. Developing dry hills can be an expensive and uncertain business. Double spraying and over-sowing are expensive and often seed sown may not germinate or survive in the highly variable rainfall and temperature regimes. The improvements, if achieved, may be relatively transient as pastures revert to the original pasture species (Thompson & Stevens 2011).

One of the major limiting nutrients in many hill soils is nitrogen (N) (Lambert *et al.* 2003). Experience in the Wise Use of Nitrogen in Hill Country Sustainable Farming Fund programme (www.wisenuse.co.nz) indicates that significant changes in pasture production can be made using high rates of N in moist hill country (Lambert *et al.* 2003). This indicates a potential for N fertiliser to be used as a development tool rather than a tactical feed supplement.

The use of N fertiliser also provides the opportunity to retain, and possibly enhance, native vegetation such as tussock while gaining the benefit of improved forage production and feed quality.

However, while much research has focused on using N in developed hill country (Ball *et al.* 1982; Gillingham *et al.* 2003), relatively little is known about the cost-effectiveness of this approach in tussock hill county that often has low soil pH (Boswell & Floate 1992). Questions remain about the cost effectiveness of N compared to other options such as superphosphate and lime, and how it may change seasonal production and pasture quality.

This experiment aimed to compare the impacts of N fertiliser in oversown tussock hill country with superphosphate and lime, and determine the cost effectiveness of development using the two fertiliser options.

Materials and Methods
Fertiliser strategies were compared at a previously oversown tussock grassland site located east of Roxburgh, Otago (45.525°S, 169.475°E) at 695 m a.s.l., on a moderate slope of 10° facing south-east, starting in October 2009. Measurements continued for four growing seasons. The site has a long-term average rainfall of between 550 and 600 mm p.a. The soil type was a Pinelheugh silt loam classified as a Brown soil, moderate (50–75 mm available soil water) soil moisture holding capacity, pH of 5.1, Olsen P value of 15 and high soluble aluminium concentration (17.5 ppm). Previous fertiliser history has included the application

of phosphate and sulphur as sulphur superphosphate (0:8.5:0:14.7) at approximately 165 kg/ha every 2 years. Molybdenum was applied at approximately 4-year intervals.

The pastures were predominantly browntop (*Agrostis tenuis*), Yorkshire fog (*Holcus lanatus*), dogstail (*Cynocurus cristatus*) and sweet vernal (*Anthoxanthum odoratum*) with a white clover (*Trifolium repens*) companion. The tussock was predominantly red tussock (*Chionocloa rubra*) with some remnant snow tussock (*Chionocloa rigida*).

The experimental design included the following treatments in four replicates with individual plot size of 10 × 10 m.

Capital lime
1. 0 lime, 250 kg superphosphate p.a.
2. 2.5 t lime once, 250 kg superphosphate p.a.
3. 5.0 t lime once, 250 kg superphosphate p.a.
4. 0.5 t fine lime once, 250 kg superphosphate p.a.

Capital superphosphate (+ Mo)
5. 0 superphosphate, 2.5 t lime once
6. 1000 kg superphosphate once, 2.5 t lime once

Nitrogen as urea
7. 100 kg N per annum each autumn, 250 kg superphosphate p.a. plus 2.5 t lime once
8. 50 kg Nitrogen per annum each spring, 250 kg superphosphate p.a. plus 2.5 t lime once
9. 50 kg N spring and 100 kg N in autumn.
10. Control (0 kg lime, 0 kg super, 0 kg N)

The plots were fenced with a single electrified wire to allow access to sheep and calves, while excluding adult cattle. The plots were grazed occasionally when livestock were in the paddock, between late October and May each year. Pasture growth and botanical composition was measured from two caged sites of 0.1 m^2 per plot approximately four times per annum, depending on pasture growth. Each cage was repositioned after each measurement, to a site of known pasture mass, similar to the grazing residual of the plot. Pasture growth was determined by difference using a pasture plate meter, and botanical composition was determined by sub-sample dissection and drying. Metabolisable energy and crude protein concentration of the pasture was measured using NIRS (Corson *et al*. 1999) during summer in years 1 and 2.

Soil samples were taken at the beginning of the experiment and annually. Each plot had 10 cores 7.5 cm deep removed and air dried before analysis. Molybdenum as molybdate prills (10% Mo) was applied at 20 g/ha at the beginning of the experiment. Maintenance superphosphate fertiliser was applied each October and nitrogen fertiliser was applied either then and/or as soon as possible after autumn rains, though often in April, each year.

The main effects of lime, superphosphate and nitrogen fertiliser were analysed using contrasts. To determine the economic impacts of different fertiliser regimens the relative potential stocking rates of main treatments were compared. It was assumed that this land type would be used for store lamb production. The intake of 65 kg ewes lambing at 140% with a lamb weaning weight of 32 kg at 100 days of age was calculated. This intake was then split into three periods, spring (1 October–25 November; 31 MJME/ewe/day), late spring (26 November–18 January; 22 MJME/ewe/day) until weaning, and summer/autumn (18 January–20 April; 12 MJME/ewe/day), when ewes were removed for

Table 1 Cost and income assumptions

Parameter	Assumption			
Maximum pasture utilisation	85%			
Ewe variable costs	$12/ewe			
Death Rate	4%			
Weaning Rate	140%			
Ewe liveweight	65 kg			
Lamb weaning wt	32 kg			
Lamb sale price	$2.50/kg			
Ewe replacement rate	28%			
	Superphosphate	**Lime**	**Urea**	**Superphosphate+ Lime**
Rate (t)	0.25	0.5	0.22	0.25/0.5
Fertiliser ($/t)	325	28	610	
Transport ($/t)	16	43.70	16	
Application ($/t)	21	34	23	55

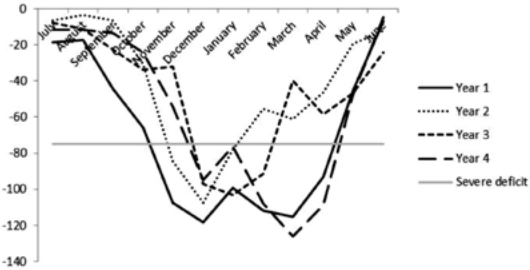

Figure 1 Calculated soil moisture deficit for the experimental site over the four years of the trial. The deficit where soil moisture availability in the top 50 cm reaches wilting point is noted as "severe deficit".

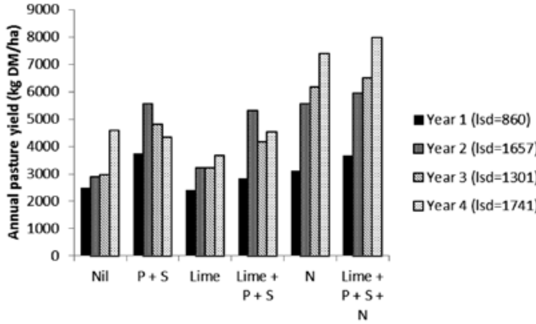

Figure 2 Annual pasture yield for each fertiliser regimen over four years.

winter. The stocking rate for each period was calculated after multiplying the average daily pasture production (kg DM/day) by the average feed energy concentration reported, to provide a comparative estimate of the fit of each fertiliser option to the farming system. The early spring stocking rate was chosen as the limiting stocking rate and applied for the whole period for each treatment. Autumn feed deficit due to low pasture growth was assumed to be filled by surplus late spring pasture growth. The value and costs of the systems were calculated using the assumptions in Table 1. Average prices for input and output variables were determined from local sources to match actual requirements for the 2014 season. The output of lambs for sale at weaning was calculated using ewe death and replacement rate. No ewe sales were calculated for this comparison. Data were analysed by REML to perform a repeated measures in time analysis (Genstat 15th edition, VSN International Ltd). The results were analysed for main effects on pasture production, botanical composition and pasture quality to understand the impacts of the different fertiliser regimens. Then the main effects of lime, superphosphate, N, lime plus superphosphate, and lime plus superphosphate plus N were used to evaluate the economic effects.

Results

Estimated annual rainfall at the site was 490, 690, 500 and 575 mm in years 1 to 4 respectively (NIWA 2014). Calculated water deficit at the site (Figure 1) indicated that Year 1 had the greatest deficit (6 months) while the other years were relatively similar with 2 or 3 months of deficit at or below wilting point. The total pasture production in each year was relatively well correlated to the rainfall in spring.

Soil pH had increased to approximately 6.0 and soluble aluminium concentrations had declined to 0.6 ppm by year 4 when lime was applied at 5 t/ha (results not shown). Annual pasture production was unaffected by the use of lime at any rate. A capital superphosphate application produced an interaction with time ($P=0.001$), with the capital fertiliser application providing a significantly higher yield in year 2, while returning to yields similar to the maintenance application in year 3. Use of superphosphate provided no advantage over the control in year 4. The use of N fertiliser at 50 kg/ha in spring provided significantly higher pasture production than other N treatments in years 1 and 2. Use of 100 and 150 kg N/ha provided higher pasture production in years 3 and 4, while the use of 50 kg N/ha was intermediate and the control lowest ($P<0.001$). From these results the following treatments were used for the economic comparisons.

No fertiliser (Control)
500 kg/ha lime
250 kg/ha superphosphate
250 kg/ha superphosphate and 2.5 t/ha lime
150 kg/ha N
250 kg/ha superphosphate and 2.5 t/ha lime plus 100 kg/ha N

The pasture production measured in the treatments was lowest in year 1 with no significant differences between the treatments (Figure 2). The annual yield from the control and lime treatment was similar and varied little between years, averaging 3200 kg DM/ha/yr. From year 2 onwards, the addition of superphosphate, and superphosphate plus lime provided the same significant increase in pasture yield. Addition of N fertiliser, with or without lime and superphosphate produced the highest annual yields (Figure 2). When averaged over the four years seasonal pasture yields (Figure 3) reflected the same trends as the annual yields, with the control and lime treatments growing the least in all seasons, with N treatments being greatest and superphosphate treatments being intermediate.

Pasture energy concentration, measured during years 1 and 2, (Table 2) was significantly improved by application of lime (at any rate) and superphosphate. Nitrogen fertiliser application did not significantly improve feed quality. Pasture protein concentration was low in the control and N only treatments and highest in treatments receiving superphosphate (Table 2).

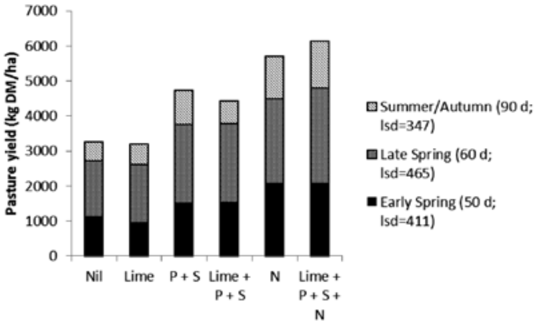

Figure 3 Average (4 years) pasture yields in early spring, late spring and summer autumn for each of the fertiliser treatments.

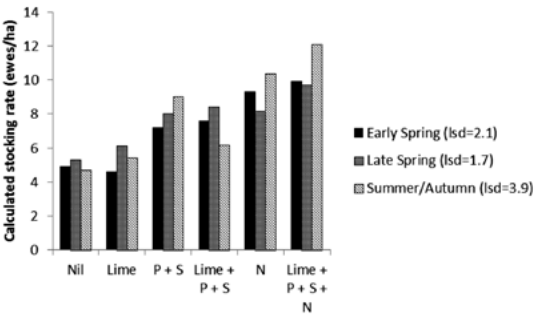

Figure 4 Calculated stocking rate for each period using the intake required to support a 65 kg ewe weaning 140% lambs at 32 kg liveweight at the end of the late spring period (mid-January) and grazing on through summer to late April.

Average potential stocking rates were calculated for early spring, late spring and summer using the feed requirements for a store lamb sheep system (Figure 4). The N treatments had the greatest potential stocking rates in early spring and summer/autumn, while the superphosphate treatments were intermediate, with the lime only and control having the lowest stocking rates. The superphosphate treatments had similar stocking rates to the N treatments during late spring, but lower stocking rates in early spring and summer.

The lowest calculated stocking rate was chosen for an analysis of the economic value of each fertiliser treatment. The calculated number of lambs weaned reflected in this stocking rate, along with the ewe costs and lamb returns are summarised in Table 2. Final net returns were greater from the N treatments, while the superphosphate regimens were intermediate. Pasture utilisation was lowest when lime or superphosphate alone was used and high in all other fertiliser treatments.

Discussion

Three elements are the key to driving productivity in these environments. The first is pasture production. Usually higher production is considered better. The second is the seasonal spread of that production. Seasonal supply of pasture has to meet the feed requirements of the farm system. The third is the quality of the pasture produced. Higher quality is better. A fourth factor in these extensive hill country systems is the fit of the block of land within the wider farming operation. These blocks are limited to being three-season blocks by winter snowfalls and so rely on other parts of the farm to provide winter grazing. This makes a significant difference to the feed profile required from this mid-altitude country.

The purpose of this experiment was to compare the merit of different fertiliser strategies, rather than repeating previous studies on the influence of nutrient addition on pasture production (Boswell & Floate 1992; Gillingham *et al.* 2003). Further, we aimed to evaluate different nutrient combinations to determine if adjustments to existing fertiliser strategies could increase production, at a lower costs than that associated

Table 2 The comparative returns from the use of differing fertiliser regimens in tussock hill country valued using a sheep policy of selling store lambs.

	Nil	Lime	P + S	Lime + P + S	N	Lime + P + S + N	lsd
Pasture energy concentration (MJME/kg DM)	8.46	9.38	9.17	9.58	8.63	9.17	0.58
Pasture protein concentration (g CP/100 g DM)	12.5	14.7	15.4	17.5	13.0	15.9	2.8
Stocking rate (ewes/ha)	4.9	4.6	7.2	7.6	8.1	9.7	2.1
Pasture utilisation (% of annual yield)	84	72	78	83	88	82	13
Lambs weaned/ha	6.6	6.2	9.7	10.2	10.9	13.1	5.6
Lambs sold/ha	5.2	4.9	7.7	8.1	8.3	10.3	4.4
Lamb return	$420	$394	$617	$651	$671	$827	$348
Costs per ewe	$59	$55	$86	$91	$112	$119	$50
Fertiliser Costs	$0	$53	$91	$143	$43	$286	
Net return/ha	$361	$286	$440	$416	$417	$422	$166

with full redevelopment, including the removal of tussocks.

The pasture production in these hill country tussock grasslands is very dependent on fertiliser inputs (Boswell & Floate 1992). In the first instance this is to grow legumes, often white clover, to fix N that then grows grass. In these inland situations the most deficient element is often sulphur, with phosphate and minor elements such as molybdenum also being required. This was the case at this site, with the basal Olsen P concentrations of approximately 15 being adequate to grow much more pasture than was measured indicating that sulphur was the more limiting element.

The present study provides new insights into the possible fertiliser strategies available for use in low pH tussock hill country. The lack of pasture growth response to liming, up to 5 t/ha, even when applied with superphosphate, and despite an increase in soil pH from 4.9 to 6.0 over the four seasons, is a significant finding. Importantly the field site did receive a basal dressing of Mo. Lime however did improve feed quality, when any liming rate (from 500 kg/ha) was used, confirming an earlier finding (Boswell & Floate 1992) and providing farmers with a relatively cheap option to improve feed quality. Pasture feed quality is an important element of gaining benefit from developing hill country. The use of lime and superphosphate both improved feed quality, while N fertiliser alone did not. Much of this response was related to changes in legume and dead material content as previously reported (e.g. Lambert *et al.* 2003; Ball *et al.* 1982). Combinations of lime, superphosphate and N did improve the feed quality, but less than lime and superphosphate alone, reflecting the influence of added N on legume growth.

While the plots were open to grazing, this often did not occur until early November as sheep were introduced to the site from other areas of the farm. This may have influenced the total pasture production, and certainly influenced the pasture composition from year to year, and the feed quality recorded. However, influences of the fertiliser treatments were still observed, indicating how robust the impacts were.

Early spring pasture supply is the limiting variable in developing this type of tussock hill country, as it sets the stocking rate for these systems, which are often part of a larger farm that has wintering and finishing country at lower altitudes. An imbalance of feed supply and demand (Figure 4), between early and late spring dictates the overall utilisation of pasture. The overall pasture utilisation (Table 2) suggest that the N and superphosphate plus lime regimens provide the greatest utilisation of feed, hence also providing a more consistent feed quality result as less dead matter is likely to build up. Using lime alone or superphosphate alone reduced the utilisation of the annual pasture produced and therefore are likely to be less effective in increasing overall productivity and profitability.

Overall, the N-based fertiliser strategies provided greater returns for the farmer, a conclusion also reached in long-term farmlet studies in dry hill country (Gillingham *et al.* 2004). Research on large single dressings of N has focussed on short-term responses where marginal response rate (kg DM/kg N applied) declines significantly with rate (e.g. Sherlock & O'Connor 1974) and as such has discounted long-term changes. However, the variability of the results indicates how challenging it can be to set appropriate stocking rates. The use of cattle in these systems is one buffer that allows spring surpluses to be utilised. The regular use of autumn N provided significant year on year improvements in pasture growth, which led to potential increases in profitability. The near doubling of stocking rate on this country has significant implications on other parts of the farm as the provision of winter feed and greater areas for summer lamb finishing would need to be considered. This type of development potential would require a redesign of the farm system to enable the farmer to fully utilise the benefits of hill country development. The underlying principle of using N fertiliser to aid development while retaining tussock appears to be achievable, resulting in increases in both profitability and productivity.

Cheaper options of using fertilisers with lower phosphate and greater sulphur contents would help improve the economics. The concept of applying N plus S may be important in this environment. Using products that provide both elements may be a more cost-effective method of achieving a comparable result to that when all fertilisers were used.

In this analysis lime has been applied at 500 kg/ha as a standard annual dressing. The results showed that the feed quality benefits from liming were recorded in both the year of application and the following year. This suggests that a small dressing of 500 kg/ha may be used in alternate years to maintain feed quality while minimising cost. When reanalysing the figures with these changes then the annual cost of achieving the all fertiliser application declines to \$178/ha/yr, increasing the calculated return from \$422/ha to \$530/ha.

ACKNOWLEDGEMENTS

The authors thank Ballance Agrinutrients Ltd and Sustainable Farming Fund for funding, and John Pannett, Lime Hills, for the land, grazing and access.

REFERENCES

Ball, P.R.; Luscombe, P.C.; Grant, D.C. 1982. Nitrogen in hill country. Pp 133-148. *In*: Nitrogen fertilisers in New Zealand agriculture. Ed. P.B. Lynch. New Zealand Institute of Agricultural Science.

Boswell, C.; Floate, M. 1992. Fertilisers and lime for pasture establishment and maintenance. Pp. 61-69. *In*: Guide to tussock grassland farming. Ed. M Floate. New Zealand Pastoral Agricultural Research Institute Ltd, Mosgiel.

Corson, D.C.; Waghorn, G.C.; Ulyatt, M.J.; Lee, J. 1999. NIRS: Forage analysis and livestock feeding. *Proceedings of the New Zealand Grassland Association 61*: 127-132.

Gillingham, A.G.; Gray, M.H.; Morton, J.D. 2004. Animal production, economic results and lessons from nitrogen fertiliser use on dry hill country. *Proceedings of the New Zealand Grassland Association 66*: 35-40.

Gillingham, A.G.; Morton, J.D.; Gray, M.H. 2003. The role of differential fertiliser application in sustainable management of hill pastures. *Proceedings of the New Zealand Grassland Association 65*: 253-257.

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

NIWA Virtual Climate Network. 2014. http://cliflo.niwa.co.nz/, Station 14660

Sherlock, R.R.; O'Connor, M.B. 1974. The use of nitrogen on hill country. *Proceedings of the New Zealand Grassland Association 35*: 52-62.

Thompson, B.R.; Stevens, D.R. 2011. Pasture and tussock responses to a single application of nitrogen of a full development process for drier hill country over two years. *Proceedings of the New Zealand Grassland Association 73*: 27-30.