NITROGEN USE ON HILL COUNTRY: LESSONS FROM THE NATIONAL WISE USE OF NITROGEN FOCUS FARM PROJECT

M. G. Lambert[1], **A. H. C. Roberts**[2], **J. D. Morton**[3]

[1]*90 Godley Street, Halcombe, RD 9, Feilding 4779*
[2]*Ravensdown Fertiliser Co-op P O Box 608, Pukekohe, 2677*
[3]*Ballance Agri-Nutrients, PO Box 28, Feilding 4740*
Email: greg.lambert@clear.net.nz

Abstract
The focus farm component of the Wise Use of Nitrogen programme ran for 3 years, during which time local community groups designed, implemented, monitored and reported on 31 demonstrations on 16 commercial sheep & beef farms throughout New Zealand. The demonstrations were mainly paddock scale and mainly ran from pre-lambing to weaning. Nitrogen application treatments (range 19 to 260, average 90 kg/ha/yr) were compared with zero-N controls, and production, economic and environmental measurements were made. Results for production and economic measurements are reported in this paper.

Pasture production responses ranged from 7 to 55, and averaged 22 kg DM/kg N; ryegrass content was increased and clover content decreased by N application. Animal production was greater for N treatments, mostly through a higher base ewe stocking rate, and more grazing for finishing cattle; lambing % and ewe and lamb liveweights were generally not affected. Estimated net economic benefit of N use ranged from -$322 to +$221/ha, and averaged +$35/ha; lower rates of N application were generally most profitable. Factors influencing profitability were: the cost of the extra feed generated (including response efficiency and costs of fertiliser and application); the timing of that feed; the % of the extra feed harvested; and the efficiency of conversion of that feed into product.

A comprehensive review concluded any potential direct effects of N-boosted pasture on animal health would be small and insignificant compared to the advantages of increased animal nutrition.

N fertiliser application can be used to reduce risk, through tactical application to generate feed to fill in seasonal feed deficits. However, where N is used strategically to increase whole-farm stocking rate (as is the case on many dairy farms), production risk is increased and careful feed planning and management are required. The key to effective use of fertiliser N on hill country sheep & beef farms is feed budgeting to identify where feed deficits are likely to occur and to assist in identifying ways of mitigating these. The most likely future use of fertiliser N on such farms will involve tactical applications at low rates on parts of the farm, to generate feed to increase feeding levels of responsive stock and fill identified seasonal feed gaps. The likelihood of profitable N fertiliser use on hill country is high when its use is well planned, the plan is well implemented and monitored, and the plan is flexible.

Introduction
New Zealand pastures are chronically nitrogen (N) deficient and production responses to increased N fertiliser application generally occur whenever other severe growth limitations, particularly low soil moisture or temperature, are not present.

Biological fixation has historically been the major source of N input to pastures. However commencing in 1989, pastoral industry use of fertiliser N increased rapidly, to such an extent it has become in the largest N input on some dairy farms. This is certainly not the case on sheep & beef farms, however there has been a parallel trend for increased use e.g. average annual fertiliser N inputs to hill country increased from 0.7 to 5.7 kg N/ha during 1996 to 2002 (PCE 2004). Whilst these are very low inputs per hectare relative to those used in dairying, the area involved is large, hill country representing the major portion of the sheep & beef industry, and so the total amount of N applied is very significant. The increases in N use occurred during a time of pastoral industry intensification and increased production, underpinned by increased feed consumption by animals and associated greater nutrient and greenhouse gas emissions.

The Wise Use of Nitrogen (WUN) programme was initiated to demonstrate the rational use of fertiliser nitrogen under commercial conditions in a range of hill farming situations, in order to encourage practices that enhanced long-term farming profitability whilst minimising potential detrimental environmental effects.

The programme had several components including grazing trials at the Ballantrae and Invermay research stations, and a national focus farm network involving commercial farms spread through New Zealand.

In this paper we summarise practical messages arising from the focus farm experiences and supporting technical material presented at programme conferences in Palmerston North in February 2005, March 2006 and May 2007. This information can currently be accessed at http://www.wisenuse.co.nz and the material stored on the site has also been archived by AgResearch.

The focus farm network

The WUN focus farm project formally ran for 3 years during 2004 to 2007, although activities on the individual farms involved ran for between 1 and 4 years. The project was funded by the MAF Sustainable Farming Fund, Ravensdown Fertiliser Cooperative, Ballance Agri-Nutrients and Meat & Wool NZ (now Beef + Lamb NZ). Each focus farm was a commercial property (in one case 3 separate properties) with a community group consisting of other farmers and agri-business, consultancy and research representatives plus other interested stakeholders e.g. regional councils. In many cases the community groups were existing Meat & Wool NZ monitor farm community groups. Each group was facilitated by a farm consultant and had an aligned scientist who provided technical advice to a greater or lesser extent.

Across the life of the project 14 community groups and 16 individual farms were involved. Farms were located in Northland, King Country (2), Bay of Plenty, Hawke's Bay (4), Taranaki, Manawatu, Wairarapa (2), Nelson, Marlborough, Canterbury and Southland. They covered a range of altitudes and climates, representing summer dry to summer wet country, average annual rainfall ranging from 650 to 2200 mm.

The demonstrations

Each focus farm farmer and community group designed, implemented and monitored a practical demonstration of fertiliser N use on part (or in a few cases all) of the focus farm. The part-farm demonstrations were paddock scale, paddock size ranging from 4 to 30 ha. Results were reported by the community groups at 3 annual WUN national conferences.

Annual fertiliser N (in almost all cases applied as urea) application rates on the demonstrations ranged from 19 to 260 with an average of 90 kg N/ha and in most demonstrations treatments were compared with a zero N control. In most instances the annual N applied to each treatment was split into 2 or 3 smaller dressings; and in many cases more than one N application treatment was compared with the control. Fertiliser N was applied most commonly in late winter-early spring (August/September) although some demonstrations included autumn (April) applications, and a few involved June, July or October applications. Treatments were replicated 2 or 3 times in some cases. Over the life of the project, 31 focus farm demonstrations were run.

All demonstrations were stocked with lambing ewes and most spanned the period of pre-lambing to weaning (5 to 6 months). In most demonstrations ewe stocking rate was increased in the N treatments compared to the control, the size of the increase being related to the N application rate. In addition cattle “grazers” were moved in and out of control and treatment blocks to ensure high pasture utilisation.

The aim of the programme was to consider both production/economic and environmental implications of fertiliser N use on hill country. Because of funding and methodological constraints most of the measurements made in the focus farm project were aimed at the production/economic aspects although in all cases significant effort was devoted to considering the environmental implications of N use. In most cases Overseer analyses were completed, in some water measurements were made, and in a couple of instances comprehensive environmental measurements were made.

In this paper only the production/economic measures and their implications are considered.

Measurements most commonly made included direct or indirect estimates of pasture growth and in some cases estimates of botanical composition. Animal measurements included animal numbers and liveweights and lambing performance. Analytical and data interpretation approaches were wide ranging, were applied at a range of levels from small paddock/seasonal through to whole farm/whole year using the Farmax Pro decision-support model. In some cases decision-support tools were also used as an aid to demonstration design. Financial and logistical constraints meant replicated farm systems comparisons were not feasible. Allowing the consultant-led community groups to design and analyse their own demonstrations led to innovative and insightful design, data analysis and interpretation within a practical real-life context. It also generated a high level of commitment and learning for the participants.

The lessons

1. Pasture response efficiencies

There was no apparent influence of N application rate on response to applied N i.e. kg extra pasture dry matter produced per kg N applied (kg DM/kg N). Although responses to N applications are generally regarded as being curvilinear i.e. response efficiencies decrease as application rate increases (Roberts & Morton, 2007), and some of the annual application rates used in the demonstrations were >100 kg N/ha, the use of split-applications meant individual applications were generally at rates <60 kg N/ha where response to increasing N rate is fairly linear.

Estimated response efficiencies ranged from 7 to 55 and averaged 22 kg DM/kg N applied, with 75% of the values falling between 10 and 30 kg DM/kg N. Published results for hill country fertiliser N trials were reviewed (Hoogendoorn, 2006): the review of Ball et al (1982) suggested responses were commonly in the range 7 to 33 kg DM/kg N and in 5 subsequent grazing trials responses of 8 to 43 kg DM/kg N applied were reported. The responses estimated in the WUN focus farm demonstrations align well with the results from these much more structured experiments.

Increases in the proportion of ryegrass and decreases in the proportion of clover in the pasture in N treatments as compared to the control treatment were noted in several demonstrations, and this is in line with published research results.

2. Farm practice influencing fertiliser N responses

There are a number of generally accepted guidelines for maximising chances of a large pasture production response to N fertiliser, drawn mainly from lowland rather than hill country experience (Roberts & Morton, 2007).

- Apply at rates of 40-50 kg N/ha per dressing (with a maximum of 200 kg N/ha annually)
- Responses are generally greater in spring and least in winter, and are greatest where pasture is rapidly growing
- Apply to pastures which are not very short (>1800 kg/ha) and spell for several weeks subsequently
- Apply when soils are moist to minimise volatilisation losses
- Apply when soil temperatures are going to be >6^{o}C for at least several weeks

These guidelines need to be applied within a practical context e.g. the requirement for extra feed is generally greatest in late-winter/early-spring and N application to provide a boost at this time generally involves application when soils are (sometimes very) wet and cold, and pastures are short and relatively slow-growing, and are set-stocked. However feed generated at this time is of much greater value than that generated when growth conditions are theoretically more favourable; lower response efficiencies at this time will be more than offset by the increased value of the feed generated. Uncertainty around availability of suitable conditions for aerial application sometimes influenced decisions around timing and rate of application; also cost of aerial application could be reduced by applying fewer dressings at a higher rate. Despite the best practice guidelines, reliable responses, although somewhat variable in size, were obtained in the focus farm project from August/September (and sometimes earlier) N application in less than ideal conditions.

In targeting N applications to generate pasture to mitigate deficiencies in feed supply at specific times, it is obviously important to apply the N at the right time. There is a lag between when N is applied and the associated responses, and assumptions around this lag are needed to complete a feed budget. Also an estimate needs to made regarding the amplitude and duration of the response e.g. an application of 30 kg N/ha in early August might be estimated to increase pasture growth rate by an average of 6 kg DM/ha/day, commencing 3 weeks after application and lasting 90 days i.e. a total response of 18 kg DM/kg N applied, during September to late November.

The concept of a lag to response is somewhat simplistic. In practice the length of the perceived lag probably represents the time taken for a **noticeable** increase in pasture growth, and this is longer at slow growth times and shorter in fast growth times. In reality increased pasture growth probably starts within days of applications, as soon as N uptake occurs (and often a change in pasture colour signals this has occurred). The 6°C minimum temperature guideline represents a temperature below which pasture growth is so low that responses to N will be minimal.

3. Animal responses to fertiliser N application

Responses in aspects of animal performance were noted in all demonstrations, the specific responses varying depending on how the demonstrations were configured. Most commonly the N treatments carried more ewes than the controls, and in some cases the ewes were heavier at weaning. However lambing % was generally not affected by N treatment, and in most cases lamb liveweight (LW) at weaning was similar across treatments. More grazing days and hence LW gain was captured by grazer cattle in the N treatments in many of the demonstrations. In general then, increased animal production in the N treatments vs. the controls was expressed as more ewes/ha weaning more lambs/ha (because of higher stocking rates) and more cattle LW gain/ha.

4. N fertiliser use and animal health

During the focus farm project potential issues around the effect of N-boosted pasture on ewe health were raised by several of the community groups. Various industry interest groups were making comment on this in the rural media at the time. In response to this interest this topic was comprehensively reviewed (Litherland, 2006). It was concluded there are a number of ways in which N fertilised pastures could positively or negatively directly influence stock health. However in pen or grazing trials the vast majority of experiments found that consuming high N concentration grass had relatively small effects on animal performance. The economic implications of these minor effects are insignificant compared to the effects of running out of feed at key times of the year or running farms at lower stocking rates through a reluctance to use carefully targeted fertiliser N applications. On one focus farm ewe death rates were monitored and found to be similar for control and two N treatments (Fraser & Lambert, 2007)

5. Factors influencing profitability of fertiliser N use

The underlying drivers of N use profitability were seen as:

a. The cost of each extra kg DM generated

This is influenced by the cost of N purchase and application, and the response efficiency (kg DM/kg N) achieved. It is important to choose the most cost-effective fertiliser form. In the recent past the cheapest form has been urea, although other fertilisers may in some situations be cheaper where other nutrients, especially sulphur or phosphorus are also being applied. Fertiliser N and application costs vary over time and so it is important to factor the most current prices into economic calculations. As mentioned above, response efficiencies are inherently variable, and it is wise to develop contingency plans should pasture production responses be significantly more or less than anticipated.

b. The timing of the extra feed generated

It is critical that the extra feed anticipated is available at the right time e.g. if the N boosted feed is targeted at lifting or maintaining pasture cover pre- and immediately post-lambing, or at providing more feed to lift ewe LW during mid- to late-lactation, then the N needs to be applied at a rate and time that will provide the required extra feed at the right time.

c. The utilisation % by grazing animals of the extra DM generated

Consistent high utilisation will require careful planning to ensure animal intake demand is high at the time the extra feed becomes available. The demonstration farmers in many cases employed flexible “grazers”, usually finishing cattle to control feed surpluses within the demonstrations. This approach was relatively easy to implement within small scale demonstrations but having sufficient suitable animals available would be much more difficult at a whole farm scale unless planned for well in advance.

d. The efficiency of conversion of feed eaten into saleable product, and the product value

This will be influenced by the class of stock eating the feed e.g. finishing cattle or ewes and lambs, and the performance gains achieved. Furthermore, benefits may be realised in the shorter term e.g. increased numbers or liveweights of lambs or cattle sold, or may extend into the next production year, in particular with regard to influences on ewe weaning and subsequent mating LWs.

e. *Product value*

This will depend on the livestock enterprise and the timing of product sale with regard to changing schedule prices.

6. Economics of fertiliser N application in the focus farm demonstrations

Profitability of fertiliser N use was calculated using a variety of methodologies, in some cases by applying the demonstration results to a part of the farm, in others to the whole farm, and in a few cases both. In each analysis input costs and product prices for that particular year were used. Extrapolation of small scale demonstration results to whole farm economic performance was particularly challenging. Community group views on profitability differed widely across regions and years. This is not surprising because of the variety of climatic zones, livestock enterprise configurations, N application rates and timing of application, and demonstration designs used. Also, fertiliser N costs and product prices and their relativities changed significantly during the 3 years of the project.

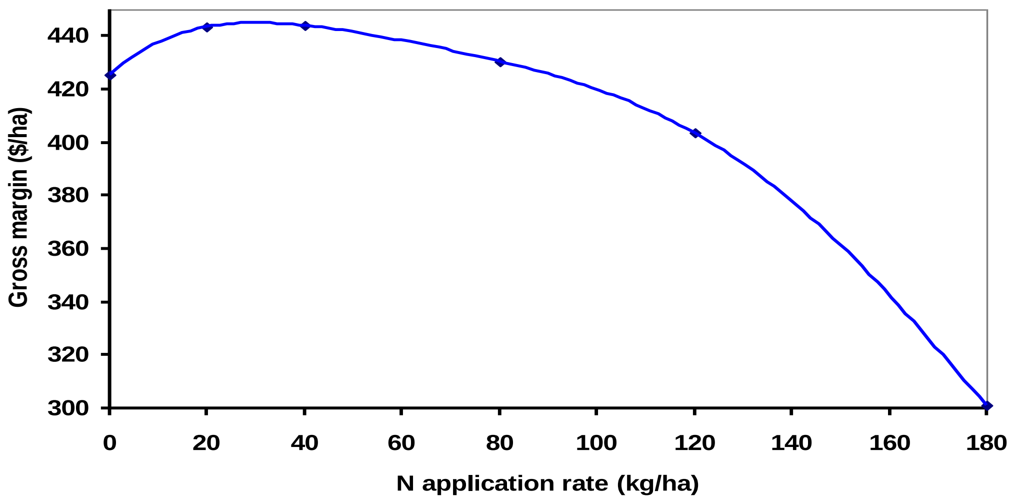
Calculated net economic benefit from the various N fertiliser treatments investigated ranged from -$322 to + $221/ha, with an average benefit of +$35/ha. If that average benefit was realised at a whole farm scale for a 600 ha hill property, increased profitability would total $21,000 which would be a significant improvement on status quo. Where rates of N application were compared, the lower rates e.g. <100 kg N/ha/yr were generally more profitable than higher rates. The economic response on a typical North Island hill country property to increasing N application rates was modelled (Lambert & Webby, 2006). The following relationship for gross margin vs. N application rate was derived, suggesting that at that time low (20-40 kg N/ha) rates of N applied across the whole farm could be profitable, even with the then prevailing unfavourable economic conditions.

7. N fertiliser use and risk

Nitrogen fertiliser can be used as a means of managing uncertain feed supply in hill country. On the other hand, the use of fertiliser N itself has associated risks.

a. Tactical use of N fertiliser

Nitrogen fertiliser can be used as a cost-effective supplementary feed to cover imbalances between feed supply and animal demand in winter and early-spring or in the autumn following drought. This approach substantially reduces production risk. It appears this will be the most frequently used role for N fertiliser on hill farms going forward. Most effective use of N for this purpose involves a proactive approach and construction of a forward feed budget. This ideally involves knowledge of current feed cover, calculation of animal demand and pasture growth over the next few months, and identification of probable mismatches. Decision-support tools are very useful for this purpose however less formal approaches can also be used.



In practice N application is often used in early spring when it has become very apparent feed supply is going to be inadequate. If this reactive approach (i.e. waiting until it is about to happen) is to be adopted, the sooner the decision is made to apply N the better. Feed budgeting allows future feed deficits to be identified in terms of timing and size, and solutions involving increased feed supply and/or reduction in demand to be identified, evaluated and implemented. Economics of various approaches can be evaluated, and if N fertiliser use is a chosen option an application strategy can be formulated and implemented at the most appropriate time. Extra feed is of the most value at the exact time it is required.

The beauty of this approach is that the N fertiliser option can be compared with alternatives on a rational economic basis, and if it is decided to apply N the actual amount applied can be fine-tuned as the season progresses. As an example of this approach, on one of the WUN focus farms fertiliser N was used in 2006 to lift winter stocking rates. A feed deficit was predicted for 2007 and knowledge from the 2006 experiences plus from previous years was used to develop a plan to resolve this issue. In this instance lamb prices were predicted to fall and the fertiliser N price had increased. Analysis suggested N use would be less profitable than reducing stocking rate, accepting lower per animal performance and delaying cattle purchases (Ellingham, Litherland & Shepherd, 2007). It was estimated the farm was $3,200 better off that year as a result of this analysis and implementation of the most economically rational options.

b. Strategic use of fertiliser N

Nitrogen fertiliser can be incorporated as part of the feed supply programme i.e. it can be used to grow more feed through the cooler months of the year and stocking rates or animal performance can be permanently lifted to utilise the extra feed grown. Experiences with this approach in the focus farm project were mixed. Where relatively low rates of N were used (<60N) in some cases it was felt the extra feed generated could be captured as increased performance from the existing stock, while in others it was felt more stock were required to fully utilise the feed generated. It was generally found finishing cattle were a flexible option for this purpose. Where higher rates of N were used more stock were required to fully utilise the feed. This in itself increased risk through a dependence on the predicted N response occurring at the right time in order to sustain the extra stocking rates, but on the other hand if inadequate stock were on hand pasture utilisation declined, pasture quality issues occurred during spring, and the economics were less convincing. Also, and particularly on summer-dry farms, if increased capital stock were carried through winter difficulty might be experienced in feeding them through the subsequent summer drought. Use of fertiliser N on part of the farm was seen as less risky than use across the whole property.

Where N use was used to support greater stocking rates several of the community groups stressed the need for the farmer and staff to have high levels of stockmanship and feed budgeting skills; for careful planning and monitoring of animal demand and feed supply; for timely implementation; and for the presence of a contingency plan if things don't work out as planned. It was felt that other limiting aspects in the farm system e.g. subdivision, water, tracking, base soil fertility, and individual animal performance should receive attention before using N fertiliser as a strategic tool to increase stocking rate.

c. Sources of risk

Sources of risk were seen as: difficulty in forward prediction of stock prices; difficulty in predicting N response efficiencies and timing of the response; difficulty in getting N applied at the right time; unpredictable weather (particularly rainfall and temperature) and its effect on pasture growth and also on N responses; the time and effort needed to plan and monitor carefully to implement the fertiliser N plan, especially where this involved higher stocking rates; and increased pugging damage associated with the extra stock carried to utilise the extra pasture.

Conclusions

Nitrogen fertiliser demonstrations were run over 3 years on 16 commercial hill country farms throughout New Zealand. Community groups designed, implemented, monitored, and analysed them, and reported the results. Innovative and ingenious approaches were adopted by these groups. Nitrogen application, mostly in late winter/early spring, yielded positive but variable pasture production responses averaging 22 kg DM/kg N applied. Animal production responses were also exhibited, and net economic benefits of N application averaged $35/ha but ranged from significant losses to significant profits. Responses were most profitable at low rates of N application. Potential direct effects of N-boosted pasture on animal health are unlikely, and would be insignificant compared to the advantages of increased animal nutrition.

The most likely future use of fertiliser N on hill farms will involve tactical applications at low rates on parts of the farm to generate feed to increase feeding levels of responsive stock and fill identified seasonal feed gaps. Nitrogen fertiliser application has large potential for use in this manner to mitigate production risks associated with an uncertain feed supply/animal demand balance in the cool-season. The likelihood of profitable N fertiliser use on hill country is high when its use is well planned, the plan is well implemented and monitored, and the plan is flexible.

Acknowledgements
The farmers that made their properties available for this project, and in addition the consultants, scientists, farmers and other community group members who worked with them to design, conduct and report on the demonstrations. The funders, without whom such work would not be possible: MAF Sustainable Farming Fund, Ballance AgR-Nutrients, Ravensdown Fertiliser Cooperative, and Meat & Wool NZ (now Beef + Lamb NZ).

References

Ball, P.R.; Luscombe, P.C.; Grant, D.A. (1982). Nitrogen on hill country. *In* Nitrogen Fertilisers in New Zealand Agriculture Ed. P.B. Lynch. pp. 133-148. N.Z. Institute of Agricultural Science.

Fraser, Roy; Lambert, Greg (2007). Hawke's Bay monitor farm report. http://www.wisenuse.co.nz/Portals/0/PDF/annual/AnnualConferenceMay2007.pdf

Litherland, Annette (2006). What is the relationship between nitrogen fertiliser use and stock health/performance?

http://www.wisenuse.co.nz/Portals/0/PDF/FAQs%20and%20Newsletters/9%20%20What%20is%20the%20Relationship%20Between%20Nitrogen%20Fert%20Use%20and%20Stock%20Health-Performance.pub.pdf

Ellingham, Stuart; Litherland, Annette; Shepherd, Greg (2007). Nitrogen decision making. http://www.wisenuse.co.nz/Portals/0/PDF/annual/AnnualConferenceMay2007.pdf

Hoogendoorn, Coby (2006). Nitrogen fertiliser responses on New Zealand hill country. http://www.wisenuse.co.nz/Portals/0/PDF/2006%20conference%20Combined.pdf

PCE (2004). Growing for Good: Intensive Farming, Sustainability and New Zealand's Environment. Parliamentary Commissioner for the Environment, Wellington, New Zealand.

Roberts, Ants; Morton, Jeff (2007). Using N fertiliser – Best Practice. http://www.wisenuse.co.nz/Portals/0/PDF/annual/AnnualConferenceMay2007.pdf