The role of differential fertiliser application in sustainable management of hill pastures

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Abstract

New targets for increased productivity from the sheep and beef industry are about 4% annually, at a time of ever heightening environmental awareness. A major part of this will occur by applying current technology to increase the productivity from the presently lower-than-average farms. However leading farmers will also have to increase efficiency or productivity if they are to remain economically viable.

One prospect is to examine the natural variability in hill pastures and determine if this can be more appropriately managed to improve economic returns.

Hill farms have soil and topographic variability, which can result in a wide range in pasture production. Yet a uniform rate of fertiliser is usually applied to such land. This results in under prescription of fertiliser for high yield potential zones, and similarly over prescription for low yielding zones.

The conversion of easier hill land to dairying has shown how pasture productivity can be improved by applying higher rates of fertiliser and utilising the extra pasture efficiently. This approach could be applied within parts of hill farms. The main fertiliser used on hill farms is superphosphate which supplies phosphorus (P) and sulphur (S) for legume growth. This assumes that there is enough clover present to make it worthwhile. However most hill pastures, especially on steep slopes, are low in clover and as a result most are predominantly nitrogen (N) deficient for a large part of the year. The pasture responses to P and S are therefore limited by low soil N levels and N fertilisers give a better economic return. The application of a high rate of N fertiliser to hill country could more than double pasture production.

The technology is almost ready to allow accurate, differential application of fertiliser to hill farms from fixed wing aircraft. This should further improve economic benefits.

A differential fertiliser management plan has environmental benefits through improved soil stability and associated water quality from hill catchments.

Keywords: differential fertiliser application, hill country, hill country variability

Introduction

The pastoral sector of the New Zealand economy generated in excess of 15 billion dollars in 2001. However in order to retain economic viability and international competitiveness, it has been estimated (McKinsey & Co. 2000) that the livestock industry must grow at about 4% per annum. In recent years the dairy industry has rapidly expanded and now occupies considerable land areas previously used for sheep and beef farming. This poses even greater demands on remaining sheep and beef properties to better utilise their hill and steep land in order to maintain viability, and do this at a time of ever heightening environmental awareness. A major part of this increase will occur by increasing the productivity of the presently lower-than-average farms. However leading farmers will also have to increase efficiency or productivity. What options are there to do this?

One prospect is to recognise the natural variability in pastoral productivity within hill farms and to more appropriately provide the inputs necessary for contrasting land units. The use of modern technology will allow some gains that were previously not possible. This paper discusses the opportunities available and provides some examples of how it can be done.

What causes hill pasture variability?

Slope and aspect

The variability in pasture growth across any hill farm is largely associated with differences in land slope (Gillingham & During, 1973; Lambert *et al.* 1983) and associated mainly with a decline in soil moisture storage and availability for most of the year. This results from a combination of reduced rainfall intensity, increased surface runoff and reduced soil depth as a result of more erosion, as soil slope increases. Soils on steep slopes therefore rely on frequent rainfall to keep pasture growing. In drier areas steep slopes dry out first and the clover content is usually low. The main effect of aspect is on soil temperature, and the associated seasonality of production. Generally there is more white clover on south aspects which are more moist and cool in late spring-summer, and more annual species such as subterranean clover or native legumes on the drier, warmer, north aspects. The pasture species differences between aspects means that they often have to be fenced into separate paddocks to obtain satisfactory pasture control and to avoid preferential grazing. It may also mean that they have differing fertiliser needs.

Table 1 Changes in farm production and economics after 4 years of a SUBS programme (from Mackay *et al.* 2001).

Total farm area = 858ha	Base year	Year 4 of SUBS
Average pasture production-kg DM/ha	6530	8600
Stocking rate	11.4	15.0
Lambing %	100	110
Economic gross margin /ha	$322	$345
Fertiliser cost	$ 39000	$ 31000
Area in bush /forestry (ha)	60	268

Soil type and fertility

Differences in soils across a farm are usually evident as different land forms and show as differences in winter wetness or summer dryness or in their differing fertiliser requirements. On most hill soils the P test is similar over a range of slopes (Gillingham *et al.* 1984; Lambert *et al.* 2000) because the same P fertiliser rate is usually applied overall. A major factor causing variability in soil tests in hill paddocks is the transfer of nutrients from slopes to flat campsites by grazing sheep (Gillingham & During 1973; Gillingham *et al.* 1980). As a result, campsites have high levels of soil P, potassium (K) and N and need no fertiliser so can be omitted from topdressing where feasible.

The soil P level on most hill farms is moderate to low, mainly because farmers have to budget for the average production response across a hill block. Pastures on steep slopes (eg 25^0 slope or greater) often get more fertiliser than they require but give much lower pasture responses at the same P test compared with easier slopes (Gillingham *et al.* 1984; Lambert *et al.* 1983) and so lower the average return from fertiliser.

In summary there are several factors that contribute to the variability in pasture production within hill farms. Most of these are considered beyond the control of the manager and so tend to be ignored when planning management. As a result land areas with a wide range in productivity are treated similarly.

How can hill pastures be better managed?

A manager must first be able to identify land units with different management needs and potentials. This includes areas that are contributing less than average economic returns for the fertiliser and other inputs provided. A system that has been successful in a number of North Island regions is the SUBS approach, standing for "Soils Underpinning Business Success" (Mackay *et al.* 2001). A number of these SUBS groups have been funded by Meat NZ and Wool*Pro*.

Each farmer produces a soil map of their farm, compiles a list of strengths and weaknesses of each soil unit, develops a list of Land Management Units, (LMU) and a list of options and constraints for each. An example of this approach is given for a local hill farm and shown in Table 1.

The SUBS programme involved applying more (capital) fertiliser to the blocks with better growth potential and planting forestry on the LMU that was steep and dry and producing the most expensive pasture. ie the lowest pasture production for the fertiliser applied. The net result was a 7% increase in Gross Margin from a reduced area of pasture. The forestry will incur extra costs up to year 8 for planting and pruning of $1980/ha which is covered by the higher GM from the farm. At the end of the forestry rotation the net return is calculated to be an additional $21100/ha or near double the returns that would be obtained over the same period if the forested land remained in pasture.

The SUBS analysis may provide the opportunity for a completely new land use on part of the farm such as cash or horticultural crops. SUBS can be rapidly understood and used by farmers and in many cases provides the confidence to make the changes to their farm management that they inherently wanted.

More P and S fertiliser

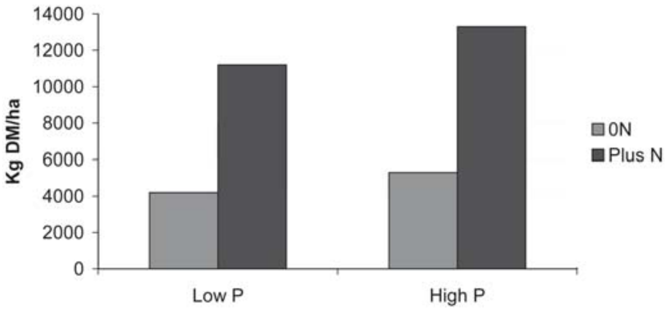
What evidence do we have of the potential production that can be obtained from hill country with superphosphate? The conversion of many sheep and beef farms to dairying with the accompanying input of higher rates of fertiliser on easy to moderate slopes, has resulted in large increases in productivity. Many such areas now carry 3 cows/ha where they previously supported only 12 SU/ha as sheep and beef. These areas of course generally also get N fertiliser which optimises the P responses. The application of high fertiliser rates to similar topographic areas within existing sheep and beef farms, can provide similar benefits.

On steeper slopes the situation is not so clear. In summer-moist locations the results from increased P fertiliser are consistent. At Ballantrae, on moderate-

Table 2 Effect of increase in soil P status on productivity in summer wet and summer dry locations.

	Range of Olsen P increase (µg/ml)	Increase in pasture production (kg DM/ha)
Ballantrae (summer wet)	8 to 15	3100 (35%)
Waipawa (summer dry)	9 to 28	1200 (52%)

Figure 1 Effect of nonlimiting N fertiliser application on annual pasture production at both low and high soil P levels (mean of easy and steep slopes and north and south facing aspects) at Waipawa.



steep hill country, high rates of P (ie 55kg P/ha; Olsen P = 15 µg/ml) for several years produced an average of 3100 kg DM/ha (35%) more pasture than areas getting only 12kg P/ha with an Olsen P level of 8 µg/ml (Lambert *et al.* 1983; Table 2). This gave an average increase of 32% in winter carrying capacity.

In drier areas the benefits of increased P and S fertiliser are limited by low overall pasture growth rates, and by the variability of summer rainfall (and low clover content) and therefore the risk of having a dry summer and not reaping the full benefit of increased fertiliser. For example on steep slopes of summer dry hill country at Waipawa (Gillingham *et al.* 1998; Table 2) a capital fertiliser dressing raised Olsen soil P from 9 up to 28 µg/ml but increased annual pasture production (average of easy and steep slopes) by only 1200 kg DM/ha (52%).

N fertiliser

The use of N fertiliser on most hill farms has been limited to lowland sites for hay or silage or extra winter-early spring production. However, very good pasture responses in late winter and early spring can also be obtained from N application to slopes, and offers better economic returns than from P fertilisers alone. (Gillingham & Gray 1998; Ball *et al.* 1976; Lambert & Clark 1986). Recent results from Waipawa (Gillingham *et al.* 2003) confirm the earlier estimate by Gillingham *et al.* (1998), that a differential fertiliser policy using P fertilisers on areas with good clover growth and using N fertiliser on steeper drier areas with little clover will provide a 10% better economic return than from a overall topdressing of P fertiliser only.

There is little information as to the potential growth that can be obtained from high or frequent N fertiliser use on hill pastures. At Waipawa regular applications of high rates of N (Blennerhassett 2002) on all slopes and aspects, and under both low and high soil P conditions, increased pasture production by 7000-8000kg DM/ha ie responses of 150-167%. (Figure1). The response to N was greater at the high P level.

Hill country pastures in other regions could show similar responses as reported by Lambert *et al.* (2003), for moist hill country.

Differential fertiliser application technology

Most of the ways discussed for improving farm productivity or efficiency involve differential management, and mainly fertiliser management. To date it has been difficult for aerial topdressing pilots to differentially apply fertiliser except to sizeable hill areas of similar slope or aspect or areas such as stock camps on ridge crests or ponds or forest areas. In complex topography the task is much more difficult.

In order to differentially and accurately fertilise specific areas, without having wide buffer strips, there are some basics that must be followed. The pilot must allow for the time, and associated distance, it takes for the fertiliser hopper door to close, and the carryover distances of fertiliser after door closure. The same factors must be known in recommencing fertiliser application. For accurate placement the fertiliser has to be well granulated so that random wind effects do not spread fertiliser outside the target zones.

New technology promises more accuracy in the differential application of fertiliser. The development of GPS triggered hopper door controls on a topdressing plane offers the prospect of being able to automatically adjust fertiliser rate according to a previously prepared prescription map for each farm (Figure 2). An on-board computer recognises both the topdressing aircraft position, and upcoming positions on a farm through GPS reference, and, with a hydraulic mechanism to speed hopper door action, anticipates fertiliser delivery rate allowing for aircraft speed and forward projection distances of the fertiliser. The transition zone (between full and zero application rate) on either side of a stream or track receiving no

Figure 2 Example of flight paths for GPS controlled differential aerial fertiliser application showing swath lines and a no-application zone.

fertiliser will be as narrow as 20m so an intricate pattern of fertiliser spread is possible.

This technology has been developed by Wanganui Aero Work (aircraft and hopper technology), Comtel Systems Ltd, Wanganui (electronics), New Zealand Centre for Precision Agriculture, Massey University (software development), and AgResearch (fertiliser distribution measurements and recommendations).

In order to use the technology a farmer will have an accurate, digitised farm map with areas mapped to receive differing fertiliser rates. In most instances the map will separate out such areas as north and south aspects and flat, easy and steep slopes and areas with differing soil types or soil test for different fertiliser rates. Once a digital map is prepared for a farm it needs only updating annually with the latest fertiliser programme.

Implications for sustainable management

Will differential intensification be sustainable? The main environmental concerns relate to the effects on water quality and soil stability. Any increase in P fertiliser application usually has an associated effect in increasing the P content of runoff water (Gillingham *et al.* 1997), whether as a result of direct application to wet lands or waterways, or indirectly by increasing pasture and animal productivity. Increased pasture production may reduce runoff volumes and so the total P loss into waterways may be little changed (Lambert 1985), although rotational cattle grazing leads to higher losses than from sheep grazing because of more sediment loss. Sediment loss is the main form of P loss to waterways in New Zealand (Gillingham & Thorrold, 2000). So long as any heavy grazing, especially with cattle, is planned on free draining areas, or when runoff source areas are dry, then the effects on P loss will be minimal.

Direct application of fertiliser into waterways can account for a significant proportion (eg 20%) of the annual total nutrient export from small catchments (Cooke 1988) so savings in this aspect are worthwhile. The distance of travel of surface runoff and nutrient and sediment transport within a pasture is generally not more than 5-10 metres in most storms, except in channels or basins in the pasture. It is only a few heavy storms a year that cause most of the surface runoff, and nutrient loss (Gburek *et al.* 2000; Gillingham & Gray 2000). Therefore fertiliser can be safely applied to the majority of a farm so long as the predominant runoff source areas, sometimes called variable source areas (McColl *et al.* 1985), close to waterways are omitted.

There is very little information on which to assess the effects of N fertiliser application on water runoff quality from hill pastures. The high soil carbon:nitrogen (C:N) ratios in most hill soils suggest that any available N not being utilised by plants is rapidly immobilised and be unlikely to contribute significantly to N leaching.

An increase in production on easy land and the reduction of fertiliser inputs to steeper, less productive parts of a farm, perhaps also involving planting trees, as in the example above, will have long term benefits in reduced runoff sediment sources and increased soil stability. A close examination of costs and returns associated with the less productive parts of a farm may show that they are actually costing money under the present management. In most cases a differential management approach offers the scope to improve economic returns and system sustainability.

REFERENCES

Ball, P.R.; Field, T.R.O. 1982. Nitrogen on hill country, pp 45-64. *In* Nitrogen Fertilisers in New Zealand Agriculture. Ed. P.B.Lynch. New Zealand Institute of Agricultural Science.

Blennerhassett, J.D. 2002. Pasture growth constraints on steep dry East Coast hill country. PhD thesis. Massey University. 220pp.

Cooke, J.G. 1988. Sources and sinks of nutrients in a New Zealand hill pasture catchment. *Phosphorus Hydrology Processes 2*:123-133.

Gburek, W.J.; Sharpley, A.N.; Heathwaite, L.; Folmar, G. 2000. Phosphorus management at the water shed scale: A modification of the Phosphorus Index. *Journal of Environmental Quality 29*: 130-144.

Gillingham, A.G.; During, C. 1973 Pasture production and transfer of fertility within a long established hill pasture *New Zealand Journal of Experimental Agriculture 1*: 227-232.

Gillingham, A. G.; Syers, J. K.; Gregg, P. E. H. 1980. Phosphorus uptake and return in grazed, steep hill pastures 2. Above ground components of the phosphorus cycle *New Zealand Journal of Agricultural Research 23*: 323-330.

Gillingham, A. G.; Richardson, S.; Riley, J. 1984. Rationalising topdressing of hill country. *Proceedings of the New Zealand Grassland Association Conference 45*: 92-197.

Gillingham, A.G.; Thorrold, B.S.; Wheeler, D.M.; Power, I.L.; Gray, M.H.; Blennerhasset, J.D. 1997. Factors influencing phosphate losses in surface runoff water. *Proceedings of the. New Zealand Fertiliser Manufacturers' Research Asssociation Technical Conference 24*: 144-153.

Gillingham, A.G.; Gray, M.H. 2000 : Strategies for fertiliser use on dry hill country. *Proceedings of the New Zealand Fertiliser Manufacturers' Research Asssociation Technical Conference 26*: 38-45.

Gillingham, A.G.; Thorrold, B.S. 2000. A review of New Zealand research measuring phosphorus in runoff from pasture. *Journal of Environmental Quality 29*: 88-96.

Gillingham, A.G.; Sheath, G.W.; Gray, M.H.; Webby, R.W. 2003. Management and nitrogen fertiliser options for increased pasture productivity in dryland hill *Proceedings of the New Zealand Grassland Association Symposium "Legume Options for Dryland Systems"*: (in press).

Lambert, M.G.; Clark, D.A. 1986. Effects of late autumn nitrogen application on hill country pastures and sheep production. *Proceedings of the New Zealand Grassland Association 47*: 211-215.

Lambert, M.G.; Clark, D.A.; Grant, D.A.; Costall, D.A.; Fletcher, R.H. 1983. Influence of fertiliser and grazing management on North Island moist hill country 1. Herbage accumulation. *New Zealand Journal of Agricultural Research 26*: 95-108.

Lambert, M.G.; Clark, D.A.; Mackay, A.D.; Costall, D.A. 2000. Effects of fertiliser application on nutrient status and organic matter content of hill soils. *New Zealand Journal of Agricultural Research 43*: 127-138.

Lambert, M.G.; Devantier, B.P.; Nes, P.; Penny, P.E. 1985. Losses of nitrogen, phosphorus and sediment in runoff from hill country under different fertiliser and grazing management regimes. *New Zealand Journal of Agricultural Research 28*: 371-379.

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.

McColl, R.H.S.; McQueen, D.J.; Gibson, A.R.; Heine, J.C. 1985. Source areas of storm runoff in a pasture catchment. *New Zealand Journal of Hydrology 24*:1-19.

McKinsey & Co (2000) Report to NZ Woolgrowers on Improving Profitability. McKinsey & Co. Auckland.

Mackay, A.D.; Palmer, A.S.; Rhodes, A.P.; Cooper, G.K.; Grant, L.; Withell, B. 2001. Development and use of the "Soils Underpinning Business Success" package. In: *Precision tools for improving land management.* (Eds. L D Currie and P Loganathan). Occasional report No. 14. Fertiliser and Lime Research Centre Workshop, Massey University, Palmerston North. pp 79-87.

Morton, J.D.; Roberts, A.H.C. 1999. Fertiliser use on New Zealand sheep and beef farms. NZ Fertiliser Manufacturer's Research Association publication, Newmarket, Auckland. 37pp.