NITROGEN FERTILISER USE EFFICIENCY ON WEST COAST HUMPS AND HOLLOWS

Steve Thomas[1*], Abie Horrocks[1], Ross Bishop[2], Richard Gillespie[1], Micheal Keaney[3], Matthew Keltie[4], Chris Pullen[5], Noel Robb[6], Craig Tregurtha[1] and Colin van der Geest[7]

[1]Sustainable Production, Plant & Food Research, Private Bag 4704, Christchurch
[2]DairyNZ, 116-120 Tainui Street, Greymouth 7805
[3]Ballance Agri-nutrients, PO Box 65, Rolleston 7643
[4]Landcorp Farming Limited, PO Box 534, Wellington
[5]Westland Milk Products, 56 Livingstone St, PO Box 96, Hokitika
[6]Arahura Farm, Hokitika, [7]Logburn Farm, Blackball
**Email: steve.thomas@plantandfood.co.nz*

Abstract

The practice of humping and hollowing is widespread on the South Island's West Coast to improve drainage and enable more intensive dairying. Humps and hollows are designed to overcome drainage and aeration issues primarily to enable greater pasture growth and provide physical support for livestock. However, there is very limited information on how the resulting "new" soils function. Of particular agronomic interest is how soil fertility and fertiliser requirements change as the soils develop.

Initially after formation the topsoil of the humps and hollows has low fertility and high nutrient inputs are required. Soils tend to have high carbon to nitrogen ratios and pasture production is strongly limited by nutrient availability, especially nitrogen. To overcome this, initially high rates of fertiliser and lime are applied. Excretal returns from animal and pasture residues lead to improved soil fertility resulting in rapid increases in total soil organic matter and reductions in soil carbon to nitrogen ratios. As the modified soils "develop" fertility improves, greater pasture production is sustained and fertiliser inputs are reduced.

In this paper we present data from field trials and soil surveys that demonstrate how fertility changes as hump and hollow soils develop, including how nutrient responses differ between the humps and hollows. We will address how the tactical application of fertiliser may increase overall herbage production and provide economic benefits. This is further explored in a companion paper (Horrocks *et al*., 'Developing guidelines for fertiliser spreading on West Coast humps and hollows', FLRC proceedings 2015).

Introduction and background

Over the last couple of decades there has been a large increase in the practice of humping and hollowing and flipping of poorly drained soils of the West Coast of the South Island of New Zealand. The soils undergoing this extreme form of landform modification are acidic, infertile and often podsolised with distinct impermeable iron pans (Molloy 1998). The modifications are aimed to improve pasture productivity by the removal of drainage constraints in this high rainfall environment that typically range between 2000 and 4000 mm. Hump and hollowing has resulted in a growth of dairying on the West Coast by allowing for greater stocking rates and by bringing into production more land. Since 1990 the dairy herd has tripled in size to about 150,000 cows, between 2010 and 2014 the herd has increased by 6% (NZ Dairy Statistics, http://www.dairynz.co.nz/publications/dairy-industry). Postmodification, the landscape and soil characteristics are radically different. Surface drainage is improved, but typically low fertility subsoil material forms much of the new surface while much of the original organic matter is buried.

Large fertiliser applications are initially required following modifications to overcome the low fertility (Morton and Roberts, 2006). There is, however, a lack of information on how fertility improves over time and how to manage reducing fertiliser requirements (Thomas et al., 2007). To fill this gap, we have developed guidelines to apply nitrogen (N) efficiently on developing soils on humps and hollows, funded through a Sustainable Farming Fund project (SFF 11-091). In this paper we present data from a range of field trials and soil surveys that demonstrate how fertility changes as hump and hollow soils develop and how nutrient response differs between the humps and hollows. We also discuss the role of nutrient inputs and nutrient transfer and how tactical application of fertiliser may increase overall herbage production and profitability are also discussed.

Increases in soil organic matter amount and quality and improvement in soil fertility following hump and hollowing

Based on a survey of dairy paddocks at different ages of development there was strong evidence that total soil carbon (C) can build up very rapidly in humps and hollows ($p<0.05$) (Figure 1a). A similar effect was found for total soil N resulting in a decrease in soil C:N ratios (data not shown). The declining C:N ratio indicates increasing nutrient cycling, supported by increases in plant available N (Figure 1b).

These soil responses were supported in a 2-year field trial that measured the pasture responses from soils at different ages following development and how these were affected by the position on the humps and hollows (Horrocks et al., 2010). In their on-farm study, Horrocks et al. (2010) found that increases in pasture responses corresponded with increases in soil organic matter and soil quality, but also that this was affected by the position on the humps and hollows. Greater production occurred on the humps than the hollows (Figure 2).

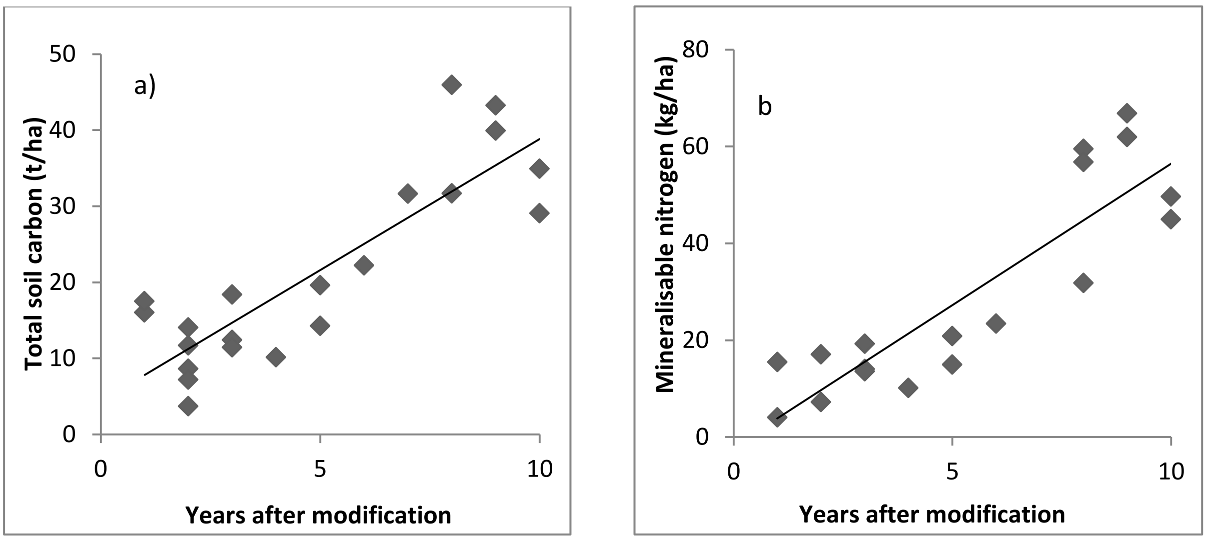

Figure 1. Change in the amount of a) soil organic matter (soil carbon) and b) mineralisable nitrogen in the top 15 cm of soil on humps following modification. Data are from a survey of paddocks developed from similar soil material.

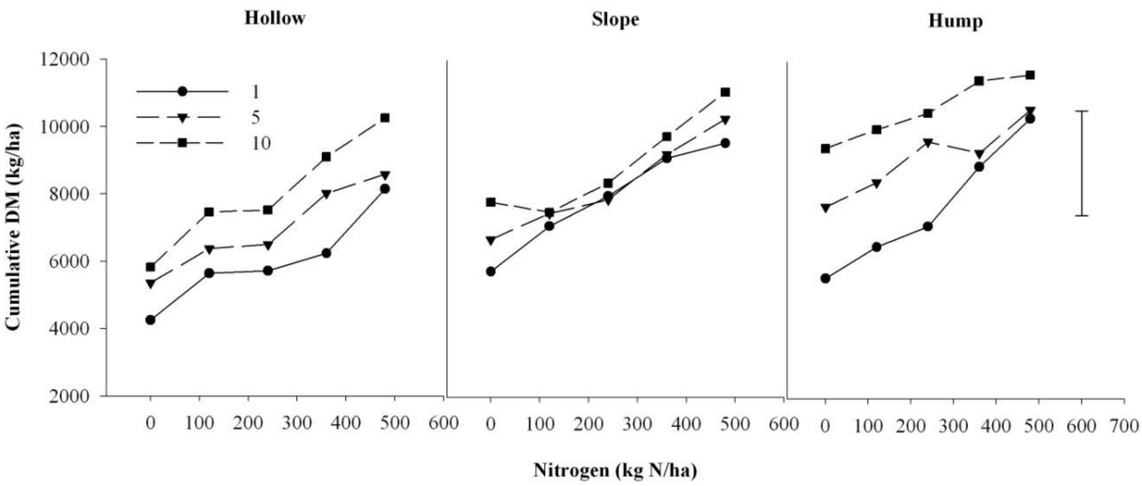

Figure 2. Effects of position, age and N fertiliser on pasture dry matter production. Bar represents average 5% LSD with 18.15 df (From Horrocks et al. (2010)).

Nutrient transfer in hump and hollow systems

In the early years of development the pasture response to nitrogen fertiliser (kg DM per kg of N fertiliser, the slope of the lines in Figure 2), is often similar between the humps and hollows. Both the lower and upper slopes of the humps and hollows are largely N deficient. As development continued (from 5 to 10 years onwards) there was evidence from mown plots in a fertiliser response trial that the pasture dry matter (DM) response to N fertiliser was greater on the lower slopes than on the upper slopes (Figure 3).

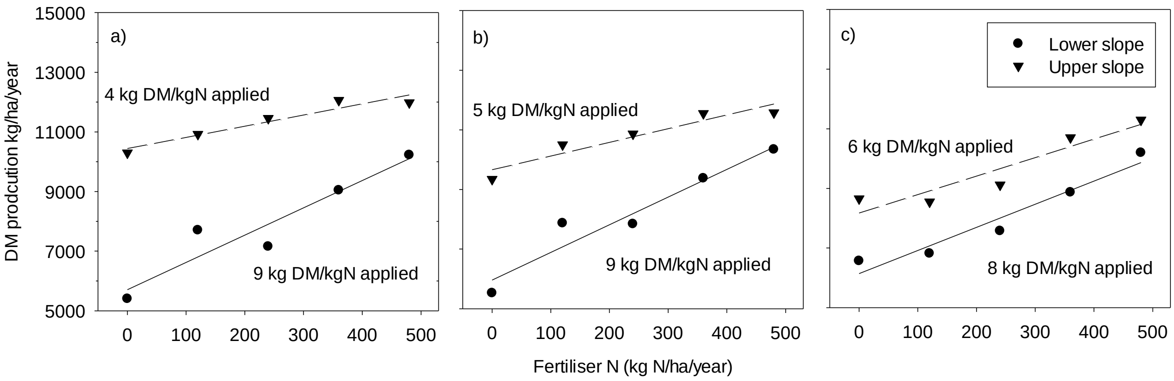

Figure 3. Pasture responses to fertiliser N from the upper and lower slopes from three paddocks 10 years after modification.

We hypothesised that the difference in responses were due to relatively larger animal excretal returns and plant-soil nutrient cycling to the upper slopes, i.e. a net nutrient transfer upslope. This results in the upper slope being less N deficient than the lower slope, consequently the DM response of the more N-deficient lower slopes is greater. This was tested in a 2-year field study (spring 2011 to spring 2013) on a grazed 10-year-old hump and hollow system. The experimental design allowed us to test whether: (i) there were differences in DM response to N fertiliser between the humps and hollows, and (ii) applying equal or different rates of N to the upper and lower slopes but achieving the same average application paddock rate would change the overall paddock production.

Similar to the mown trials, the pasture DM response per unit of fertiliser N was much lower from the upper slopes than from the lower slopes (Figure 4 and Table 1).

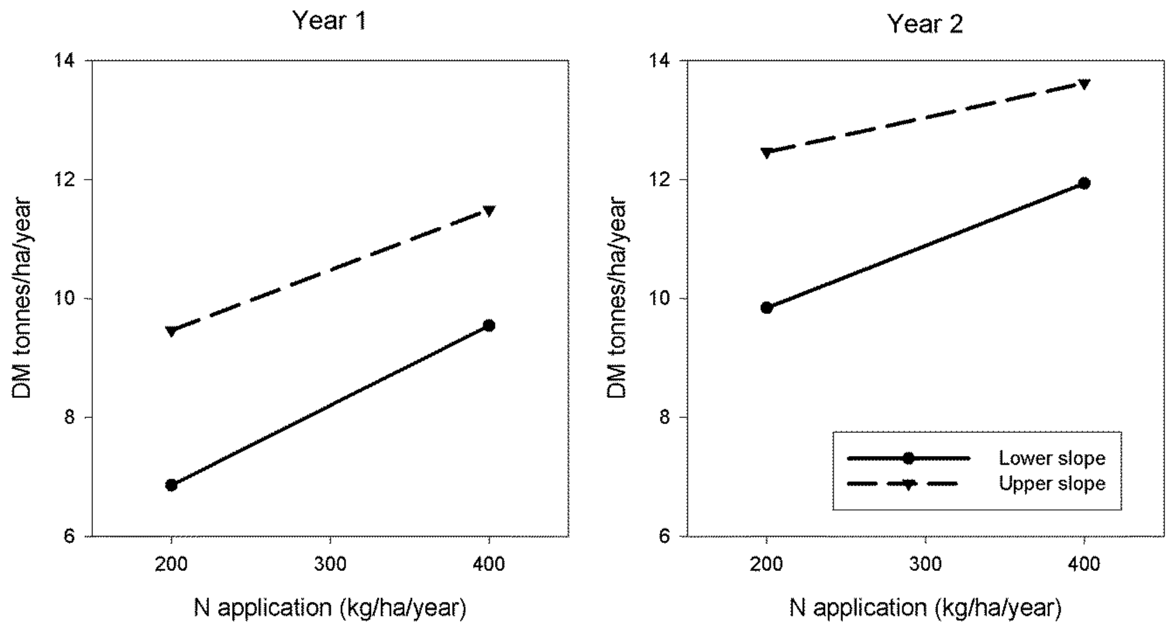

Figure 4. Annual pasture dry matter (DM) production for 2 years measured from the lower and upper slopes of 30 m wide humps and hollows established for 10 years with two rates of N fertiliser applied.

Table 1. Two years of pasture dry matter responses to nitrogen fertiliser (kg DM/kg N) from lower and upper slopes of 30-m wide humps and hollows established for 10 years.

	DM response (kg DM/kg N) between rates of 200 and 400 kg N/ha		
	Lower slope	Upper slope	LSD (p=0.05)
Year 1	13.4	10.1	4
Year 2	10.5	5.8	3.8
Average of Year 1 & 2	11.9	8.0	3.4
Overall paddock average	10		

The number of dung patches measured across the upper and lower slopes indicated that there was a net transfer of nutrients upslope. More dung patches would be expected on the upper slopes due to higher DM production. There was approximately a third more dung patches on the upper slope than the lower slope. This number was disproportionately higher than might be expected based on the amount of pasture produced (Table 2).

Table 2. Number of cow dung patches per ha and the average of dung patches per kg dry matter (DM) grown measured following eight grazing events over a 2-year period.

	Average patches per ha	**Average no. of dung patch per kg DM produced**
Upper slope	970	1.06
Lower slope	742	0.89
Difference	31 %	19 %
LSD (<0.05) d.f. = 79	58	0.13

Potential economic benefits from applying differential rates of fertiliser to the upper and lower slopes of narrow humps and hollows

Based on the greater DM responses per kg of N fertiliser from both the grazed and mown field trials, there is the potential to increase the overall production and fertiliser N use efficiency by strategically applying relatively more fertiliser to the lower slope. In practise this translates to increased feed or milk production or to saving costs by reducing fertiliser applications while maintaining the same production. To illustrate this we have selected two examples described below.

Example 1 – changing feed production costs due to differences in fertiliser use efficiency

Using the values from the measurements in Table 1, this fertiliser response can be converted into the cost of producing a kg of DM. When assuming a kg of N in urea costs $1.90, there was a response of 7.1 kg DM per $1 spent on N fertiliser in the first year from the lower slope (or 14.2 cents per kg DM), compared with 5.3 kg DM per $1 from the upper slope (or 18.7 cents per kg DM), highlighted in bold in Table 3. In this case, there would be benefit in applying relatively more N fertiliser to the lower slope. The paddock average of 19 cents/kg DM is on a par with current (2015) feed prices.

Table 3. Dry matter (DM) production per kg of N, per dollar and cost per kg of DM based on 2 years of field measurements on lower and upper slopes of 30-m wide humps and hollows.

	Year 1		Year 2		Years 1 and 2		
	lower slope	upper slope	lower slope	upper slope	lower slope	upper slope	Paddock average
kg DM/kg N	13.4	10.1	10.5	5.8	11.9	8.0	10
Difference between upper and lower slopes	32%		81%		49%		
Av. kg DM/$ (@$1.90/kg N)	**7.1**	**5.3**	5.5	3.1	6.3	4.2	5.3
Cents/kg DM	**14.2**	**18.7**	18.2	32.7	15.9	23.8	19.0

Example 2 – applying relatively more nitrogen fertiliser to the lower slope increases overall paddock production

Assuming an application rate of 300 kg N/ha/year to the paddock and the average responses over the 2 years in Table 3 (i.e. 11.9 and 8 kg DM/kg N), the effects of applying different rates of fertiliser to the lower and upper slopes of the humps and hollows can be estimated. Applying two-thirds of the fertiliser onto the lower slope (at a rate of 400 kg N/ha/year) and one-third onto the upper slope (at 200 kg N/ha/year) would increase dry matter production by 166 kg DM/ha/year compared with an even application across the paddock, or by 392 kg DM/ha/year if compared with the scenario where two-thirds of the fertiliser was applied to the upper slope, and one-third to the lower slope (Figure 5).

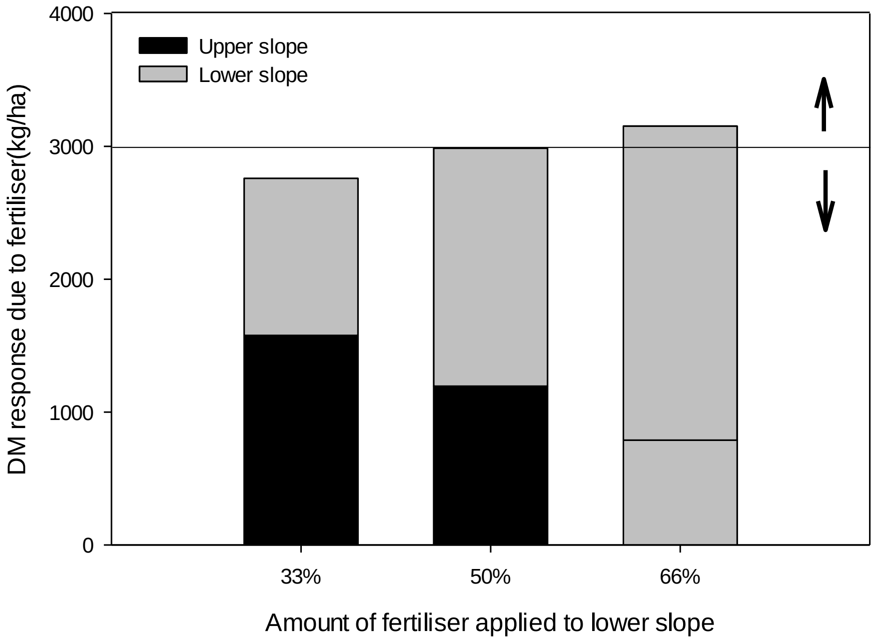

Figure 5. Dry matter produced from 300 kg of nitrogen fertiliser applied to upper and lower slopes. Responses are based on field trial measurements for a two-year period on 10-year-old, 30-m wide humps and hollows for fertiliser rates between 200 and 400 kg N/ha/year. The horizontal line shows the response when the fertiliser was applied uniformly. Arrows indicate the positive or negative benefits of applying nitrogen to the upper or lower slopes of the humps and hollows.

Summary and conclusions

Building up pasture production potential in humps and hollows takes time and is linked to nutrient cycles and building up soil organic matter. These rates also vary across hump and hollows and this is partly influenced by nutrient transfer between the lower and upper slopes. Differences in these responses provide an opportunity to improve overall N fertiliser use efficiency by applying proportionally more to lower slopes. Because of the rapid changes in soil organic matter and nutrient cycles regular soil testing is important. We recommend that tests are made annually and split between upper and lower slopes. Furthermore, fertiliser spreading is affected by hump and hollow topography, spreader machinery and product type.

Guidelines for applying improved fertiliser use and soil nutrient management

Building on this work, the previous studies by Morton and Roberts (2006) and recommendations for phosphorus application based on studies in the Inchbonnie catchment (McDowell, 2008), we have produced a guide for fertiliser practice on West Coast dairy farmers on humps and hollows (Thomas et al., 2014). This guide also includes recommendations for spreading fertiliser on humps and hollows that is the subject of a paper by Horrocks et al. (2015) in this proceedings.

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