# Fertiliser nitrogen requirements reduce as soil organic matter accumulates following modification of podzolised soils in New Zealand.

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**Abstract**
Humping & hollowing is a land development practice used in the high rainfall West Coast region of South Island of New Zealand to improve drainage and pasture dry matter production (DMP) of podzolised soils. The resultant soils and landforms are radically different from the original landscape. On-farm field trials were established to investigate how DMP was affected by the time following modification (1, 5 and 10 years) and how position (i.e. humps, slopes and hollows) and fertiliser N rates (0 to 480 kg N/ha/yr) affected this response. SOM increased with time, with most accumulation in the humps and slopes. The amount of DMP was greatest on the older modified soils and more DMP was produced on the humps and slopes. DMP per unit of fertiliser N applied was much lower in the newer soils than the older soils. Building up SOM in these recently modified soils is important for nutrient cycling and especially for supplying nutrients. This information can help farmers adjust N fertiliser applications in more targeted ways leading to more efficient N use and reduced environmental risks of nutrient losses from these soils.

**Key Words**
Nitrogen, fertiliser, soil carbon, pasture production.

**Introduction**
Poor drainage is a major agricultural production constraint for large areas of West Coast “pakihi” soils of the South Island of New Zealand. These soils are acidic, infertile and podzolised with distinct impermeable iron pans. To overcome water-logging and nutrient availability constraints in this high rainfall environment an extreme landform modification - humping and hollowing is practiced. Large machinery is used to excavate the “hollows”, removing the soil and breaking through the upper iron pans, creating wide surface drains. The “humps” are built up from the excavated spoil deposited on to the original soil surface. This practice drastically alters the landscape with the hump-hollow sequence recurring every 20 to 30 m across the farmland. The height difference from the bottom of the hollow to the top of the hump is about 3 m; the actual gradient of the contours depends on the depth to the iron pan. The wide hollows underlain by impermeable iron pans and the increased relief of the humps improve the surface drainage and thereby reduces water-logging. This practice has increased the productive capacity of the land and in particular has enabled dairy expansion in the West Coast region over the last twenty years. However, land managers have very little information on how to manage the modified soils of these new landforms.

A recent fertiliser response study by Morton and Roberts (2006) on newly modified “pakihi” soils concluded that high rates of N, P and K are required to maximise dry matter production (DMP) in the early stages of post-modification development. In another study, the amount and quality of soil organic matter was found to rapidly increase from low levels post-modification; total soil C range from about 10 t C/ha post modification to 45 t C/ha ten years after modification (Thomas *et al.* 2007). They also found that the rates of accumulation were affected by the landform type, i.e. humps accumulated organic matter faster than hollows.

These findings have important implications for managing nutrients for pasture production. In this study we report the results from field trials established to understand how the changes in soil organic matter following soil modification affect nutrient supply and in turn the fertiliser N requirements for pasture growth.

**Methods**
Field trials were conducted on three dairy farms that had extensive areas of hump and hollowing of a range of ages since modification located within 35 km of Greymouth on the West Coast of the South Island. The annual rainfall in this area is typically >2500 mm per year and the mean annual temperature at Greymouth is 12.1 ºC.

The objectives of the field trials were to determine how dry matter production (DMP) responded to the age of the trial site (time since modification), position on the landform (hump, slope or hollow) and to fertiliser rates. Field trials were established on nine hump and hollow sites across the three farms. The experiment was designed as a randomised split criss-cross design. The main treatment was time since modification (Age) with three Ages - 1, 5 and 10 years since hump and hollowing and three replicates of each. Each of these nine sites was made up of fifteen 4 m long x 1 m wide plots with three Position treatments (hump, slope and hollow) and five N treatments (0, 120, 240, 360, 480 kg N/ha/yr) applied in a criss-cross layout. Typically the distance from the midpoint of the hollow to the midpoint of the hump was 16 m. The slope plots were midway between the hollow and the hump plots. N fertiliser rate plots ran horizontally across the hump and hollow sequence. There was at least a 1 m buffer between plots.

Fertiliser N treatments (as urea) were applied starting in late-winter (August 2008) until late autumn (May 2009) with the number of applications varied depending on the N treatments and were applied at rates of 40 or 60 kg N/ha with the applications timed to meet anticipated seasonal pasture requirements. Animals were excluded from the field trial sites throughout the trial, and three months previously, to reduce the effect of residual N from urine and dung on dry matter responses to the N. Dry matter production was determined 11 times between August 2008 and July 2009 from mown strips taken from each plot. Total soil C and N were determined from duplicate soil samples (0 to 15 cm) in February 2009 at each of the three positions (hump, slope and hollow) at the nine sites. Treatment effects on total soil C and N and dry matter production were analysed by ANOVA; an estimate of the variability associated with estimated means are given by 5% Least Significant Differences (LSDs).

**Results**

There is strong indication that soil organic matter was rapidly increasing with time after modification (Table 1). Levels of soil C and N after 10 years were about twice those of the 1 year old sites for all positions. The amounts of soil C and N were also affected by Position (p=0.001) as well as time, i.e. there was more soil C and N in the humps and slopes than the hollow, and that the rate of SOM accumulation was greatest in the humps than the slopes and hollows (Table 1). The range of total soil C did not vary greatly between Position at the first year post-modification sites (with a C range of 1.8%), whereas, after five and ten years following modification the differences in total soil C and N between Position was much greater (with a total soil C range of 3.2 and 2.9 % for the 5 year and 10 year Age plots, respectively).

**Table 1. Total soil Carbon and Nitrogen (%) levels (0-15cm) from sites of three different ages since modification (3 reps) measured from humps, slopes and hollows.**

| Years since modification | Hollow | Slope | Hump | LSD (5%, 12 df) |
|---|---|---|---|---|
| *Carbon* | | | | |
| 1 | 2.16 | 4.05 | 3.28 | 3.03 |
| 5 | 3.27 | 5.88 | 6.55 | |
| 10 | 4.20 | 6.52 | 7.06 | |
| *Nitrogen* | | | | |
| 1 | 0.10 | 0.19 | 0.17 | 0.17 |
| 5 | 0.20 | 0.36 | 0.41 | |
| 10 | 0.31 | 0.44 | 0.48 | |

Both Age and Position affected DMP (Figure 1). Most dry matter was grown on the older plots and least on the newly developed soil. Most dry matter was produced on the humps followed by slopes then hollows e.g. for the zero N treatment there was 53% more DMP in the humps then the hollows.

Fertiliser N had a strong effect on the DMP ($p<0.001$), DMP increased approximately linearly with increasing N fertiliser rates up to the highest N rate of 480 kg N/ha/yr. These results indicate that more N fertiliser is required in the humps and hollows in the 1 year old plots to grow dry matter than the humps and hollows in the 10 year old plots. For example, 2500 kg DM/ha more was produced on the humps after 10 years post-modification that had 240 kg N/ha/yr applied than the 1 year old plots. Importantly, there was a large difference in DMP between plots of different ages which had no fertiliser N applied (Figure 1), especially on the humps. This has important fertiliser and production management implications. For example, in order for the 1-5 year old sites to reach the same DMP on the humps as the 10-year-old site without N applied, 400 kg of N would need to be applied.

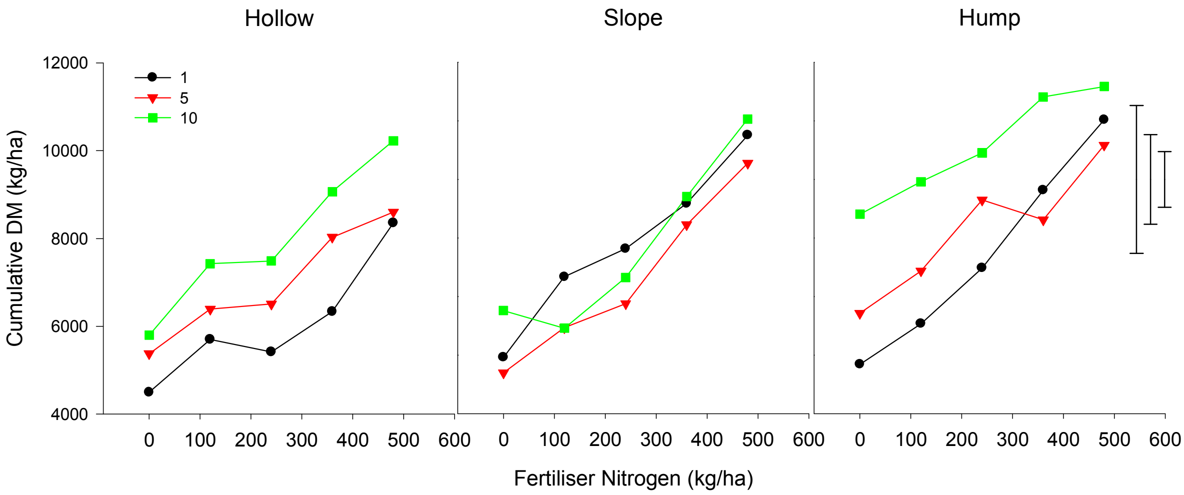


**Figure 1. The effect of Position, Age, N fertiliser on DMP. Bars represent 5% LSDs; the largest applies to all values, the next should only be used when comparing effects of age and N and the smallest only when comparing effects of age and position.**

The differences in DMP affected by Age and Position followed a similar pattern to the increase of total soil C and N. This suggests that increases in DMP are strongly affected by the accumulation of SOM. Lower DMP in the hollows is most likely to be a function of the low levels of SOM as the original soil was removed and deposited to construct the humps. Low SOM levels would affect pasture growth by limiting the cycling and supply of nutrients and the ability of the soil to store water.

## Conclusion

Following humping and hollowing the newly formed soils have low SOM. However, SOM may accumulate rapidly over a relatively short time frame (ten years). As SOM accumulates, the annual rates of DMP also increase. While high rates of application of fertiliser N will increase DMP in newly modified soils, the amount of dry matter produced per kg of fertiliser N added will still be much lower than on the older modified soils. Building up SOM in these recently modified soils is important for nutrient cycling and especially for supplying nutrients. In addition to building up soil organic matter and nutrient cycling over time, the position on the hump and hollows also affects both SOM accumulation and DMP.

These findings have implications for soil nutrient management. Pasture fertiliser requirements will change as soils develop and will depend on whether the soil is part of the hump, slope or hollow. Current fertiliser application practices do not take into account the changing SOM status and treat the humps and hollows in the same way. Based on these findings there is an opportunity to manage the soil fertility and fertiliser applications in more targeted ways to meet pasture production needs. This information can be used to help inform farmers of the benefits of adjusting N fertiliser rates for pasture production and lead to more efficient N use and reduced environmental risks of nutrient losses on these modified soils.

## References

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