DON'T TREAT YOUR SOILS LIKE DIRT!

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What is a fertile, productive soil?

Managing your farm's soils is about improving and then looking after the physical, biological and chemical (mineral) aspects to sustainably meet your farm production goals. Soils are made up of at least seven components all of which are important for the proper functioning of your farm's soils as a successful medium in which to grow the pastures and crops to feed your productive dairy herd as well as young stock replacements.

The physical 'bulk' of the soil is made up of sand, silt and clay in varying proportions depending on the parent materials from which the soil was formed. The proportions of sand, silt and clay present affect the texture of the soil and whether or not the soil will be naturally freely or poorly drained, while the types of clay present will also affect the nutrient requirements and cycling of that soil. While it is virtually, and certainly economically, impossible to alter the proportions of sand, silt and clay in your soils, in order for them to grow as much quality feed as possible, your soils' physical condition is important - poorly drained soils or heavily compacted soils will not grow pasture or crops well until those conditions are fixed.

Provocative observation #1

On many visits to dairy farms, including Southland, over the last few years, I have observed significant treading induced soil compaction. This is a likely cause for reduced pasture performance, even though 'apparent' soil fertility is high. Wet soil management should be a priority area as soil compaction is the silent thief of pasture production!

Organic matter, which comes from dead and decomposed plant and animal matter returned to the soil, is a key component of not only the biological activity in the soil, as it represents the food that all soil 'life' (the soil macro-, meso- and micro-organisms) feeds on but also combines with the physical components above, particularly the clay, to help stabilise soil particles into crumb and granular particles which aids drainage and the movement of air and water into and out of soils. Organic matter which is broken down as food for soil organisms also represents a hugely significant source of nutrients for plant and animal production as the nutrient cycles in the soil/plant/animal system on your farm are established. Soil organic matter, soil dwelling organisms, water and air represent the other four important components required for a fertile productive soil.

Without water, and without life, soil isn't soil – it's just rock and dust! It is biology that makes soil what it is. Despite being present in huge numbers (a teaspoon of topsoil can have 500 million to a billion bacteria and hundreds of metres of filamentous organisms) for much of the time microbes exist in a “state of readiness”, mostly inactive but ready for rapid responses when conditions become favourable. Soil microbes have a slow metabolism and are very long-lived, with turnover times in soil ranging between 0.5–6 years.

Soil is a remarkably hostile place to introduced micro-organisms. For most soil organisms we cannot modify them directly, instead we alter the soil chemistry (e.g., by adding effluents, lime etc.) and hope the organisms adapt. They do adapt remarkably well, suggesting that most of the necessary organisms are already present in soil – they just need the right selective pressures to develop. Given the complexity of the soil community and the difficulty in introducing new organisms (and it’s doubtful they are really needed) this is a practical and pragmatic solution to ‘using’ soil biology.

By any criteria, soil microbes are a highly successful group. As farmers and growers what you need to do is to keep them housed and fed i.e., maintain your soil structure to allow water and air infiltration and produce as much soil organic matter as possible.

Provocative observation #2

There is an increasing plethora of so-called miracle products which will either stimulate existing soil microbes to ‘unlock’ seemingly vast reserves of nutrients unavailable to plants or to introduce ‘new and improved’ micro-organisms to your soils. If these claims seem too good to be true, they probably are! Ask to be shown the quality, peer-reviewed New Zealand based research which proves the claims made for these products.

What nutrients are important for both pastures and animals?

At last count there were 103 elements, known to humans, in the Periodic Table. Of these, science recognises that around 20 are essential i.e., required by either plants or animals or both (Table 1). If others are essential then they are required in such small quantities that plants and/or animals easily acquire them from the environment. Of the essential nutrients, your pastures and crops get their C, H and O from the carbon dioxide (CO_2) and oxygen in the air and from water (H_2O). They obtain N from the nitrogen cycle that exists on all grazed pastoral farms and fertiliser N additions. Phosphorus, S, K and Mg are all added as fertiliser nutrients where the soil parent materials (the rocks, volcanic materials or windblown sediments from which they are formed) do not supply enough for your production system. New Zealand soils are generally naturally well supplied with Ca i.e., between 1000-5000 kg exchangeable Ca/ha (Cameron and McLaren, 1996). Our soils are geologically young and Ca has not been substantially leached out of our soils as is the case in many old and ancient soils overseas. Additionally we apply Ca annually in the form of calcium phosphate fertilisers (e.g., superphosphate) and lime.

Table 1. Major and trace elements required by plants and/or animals

Major Nutrients	Trace Elements
Carbon (C)	Iron (Fe)
Hydrogen (H)	Manganese (Mn)
Oxygen (O)	Copper (Cu)
Nitrogen (N)	Zinc (Zn)
Phosphorus (P)	Chloride (Cl^-)
Sulphur (S)	Iodine (I)
Potassium (K)	Molybdenum (Mo)
Calcium (Ca)	Boron (B)[2]
Magnesium (Mg)	Selenium (Se)[3]
Sodium (Na)[1]	Cobalt (Co)[4]
	Fluoride (F)[3]

[1] Not required for plants (except fodder beet); [2]Not required for animals; [3]Not required for plants; [4] Not required for plants (Rhizobia bacteria in clover nodules require some)

With respect to trace elements, New Zealand soils are generally full of Fe and Mn and for most soils these trace elements as well as Cu, Zn, Cl^-, I and B (except for bulb brassicas and lucerne) are supplied in sufficient quantities from soil reserves to meet the production needs of the forage systems on your farm. Adding more will not increase yields. Legumes such as clovers and lucerne may require addition of Mo and/or B to overcome deficiencies on certain soils. Herbage testing must be used to diagnose the requirement for these trace elements and in the case of Mo and B, clover only samples are required, not mixed pasture samples. On many soils throughout the country Se, Cu and Co can limit animal production and addition of these in fertiliser has been proven to be a cost-effective method of overcoming the deficiency diseases associated with these trace elements.

Provocative Observation #3

Over the last 29 years I have seen countless recommendations to farmers involving the application of Fe, Mn and B to grazed pastures. While farmers are entitled to accept advice from anyone and act on it, I believe that considerable money is wasted on the unnecessary application of trace elements, in the hope that it will somehow transform farm productivity. It is a case of *caveat emptor* (let the buyer beware), do your homework and ask for more than one opinion.

How does fertiliser help my farm productivity?

The legume, principally white clover, is arguably the most important component in the New Zealand pastoral system. Rhizobia infect the roots of white clover, forming nodules and these bacteria use nitrogen gas (N_2) from the air and convert this to ammonium ions which they supply to the clover plant for protein synthesis. Grazing animals eat the clover and return a high proportion of fixed N to the soil in dung and urine. Nitrogen also returns through death and decay of plant material (see Figure 1). The N returned to the soil in this way adds to the soil organic matter pool, and becomes available to the grass in the pasture through the action of micro-organisms in the soil. In this way, the nutrient that is required in the greatest quantity i.e., N is supplied to the pasture. Fertiliser phosphate (P), potassium (K), sulphur (S), trace elements and lime are essential for good legume growth and N fixation.

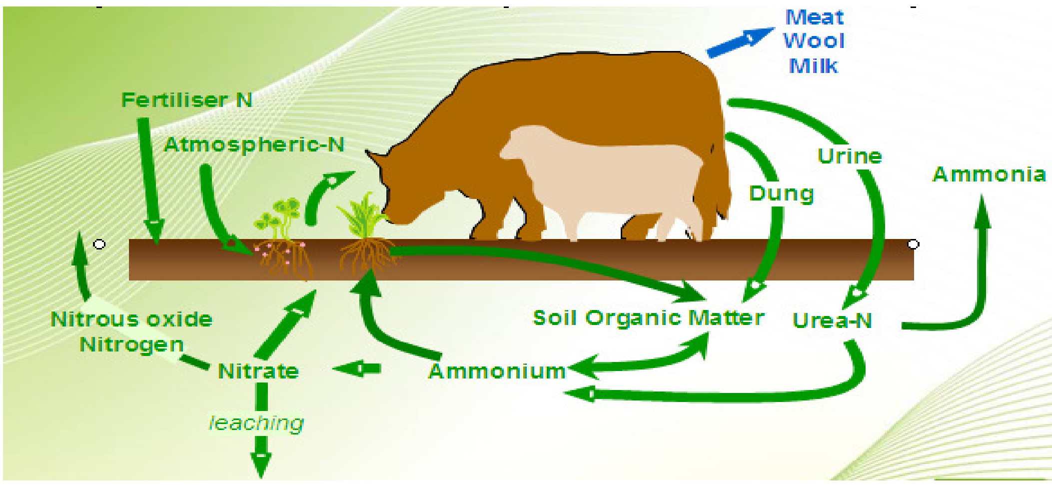

Figure 1. The N cycle in grazed pasture systems

The amount of nutrients required on a farm will depend on the stage of development. In the virgin state, most New Zealand soils are inherently deficient in N, P, S and to a lesser extent K and some trace elements for growing grass/legume based pastures. Large inputs of fertiliser (and often lime), together with the passage of time and recycling of nutrients through the grazing animal, are required to build up soil nutrient reserves and organic matter content. As soil nutrient status increases so, too, pasture production increases rapidly and this is often referred to as the development phase. In the development phase, more fertiliser generally means more pasture, and capital (large) applications of fertiliser will be required for one or more years.

However, eventually, further increases in soil nutrient levels will result in only very small increases in production. At this stage, the optimum soil nutrient status has been achieved and the soil has reached the maintenance phase. In the maintenance phase, fertiliser is required simply to replace the yearly losses of nutrients from the farm. These losses are in livestock or their products leaving the farm, dung and urine deposited in yards, laneways, gateways and around troughs, and shelter belts, plus the inevitable losses that occur in soils.

However, even when soil fertility is at optimum levels there will be periods of the year when N fertilisers, used strategically, will increase pasture production and profitability.

In grazed pastures, the build up of soil organic matter, even with regular fertiliser applications and irrigation (if required) can take many years, but does eventually reach a relatively stable equilibrium under the same farm management system. This sort of time period required will be especially so for recent dairy conversions from more extensive farming systems where lower pasture productivity has contributed to lower organic matter returns to the soil.

The increase in soil N content, and hence cycling, tracks in a similar pattern to increasing soil organic matter content (Figure 2). While the soil N content is increasing and until the carbon to nitrogen ration (C:N) decreases from the typically high level associated with extensive farm systems (likely to be 20:1 or greater) continuing inputs of fertiliser N will be required to provide enough quality pasture to reach the milk production goals of recently converted dairy farms.

As the C:N ratio decreases with time and stage of soil development the responsiveness of the pasture to N fertiliser also decreases as shown by research trial information for Ballantrae, Te Kuiti and intensive dairy farms (Figure 2).

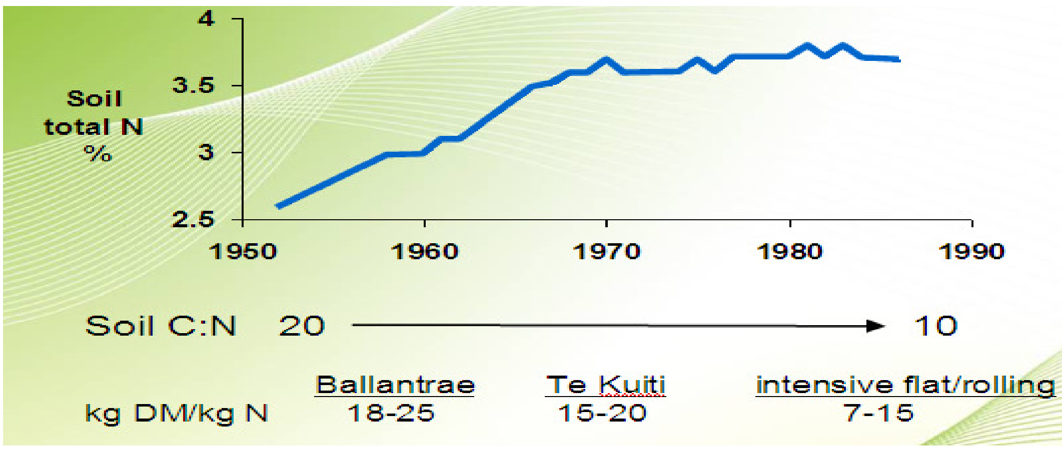

Figure 2. Effect of time and stage of development on soil N content

Provocative Observation #4

In recent years, and supported by visits to many dairy farms throughout the country, including Southland, I have become aware that many dairy farmers have lost sight of the fact that this sort of soil husbandry takes years, and that many are expecting their newly developed soils, and hence their pastures, to be at maximum productivity within 18-24 months. Possibly driven by highly leveraged borrowings or high costs versus lower returns this is understandable, but nevertheless even modern technology can do little to speed up this natural soil development process.

Is fertiliser economic to use on dairy farms?

One way to answer this question is to tell you all to stop putting any fertiliser P, K or S on your farms for the next 10 years and observe what happens to both pasture and animal performance. Provided you operate a 'closed' system i.e., you do not purchase nutrients and bring them on to the farm in the form of bought in feed ,in most cases, production will decline. In fact, past research supports this contention (Feyter et al. 1988; Roberts et al. 1991). The reason is that pastoral agriculture is 'leaky' and nutrients are lost from the farm through sale of milk and stock, gaseous losses (mostly N) from soil and dung and urine, leaching losses of mobile nutrients as well as redistribution of nutrients to non-productive areas through dung and urine deposition in gateways, races and so on.

However, bringing this question closer to home is the observation that the marginal cost of pasture grown on your farm will range somewhere between 6-12c/kg DM. Year in and year out, this will be the cheapest feed you will be able to provide your cows.

Using the AgResearch developed P, K and S econometric model (Metherell 1999) we can examine the economics of fertiliser use by determining the economically optimum soil test values given a range of milk production and milksolid prices. The farm we will use is a Southland dairy farm producing 1300kg MS/ha with some bought in feed and N fertiliser (variable cost $350/cow). Initial soil test values are Olsen P 30, Organic-S 8 and Quick test K 8 (and a medium reserve K of 3) and the current on-ground prices of $3.50/kg P; 0.31c/kg S and $2.37/kg K .

The economically optimum Olsen P increases very slightly for this example while K and S levels should be maintained (Table 2).

Table 2. Optimum soil test levels for different milk production levels at $5/kg MS

Milksolids (kg/ha)	Olsen P	QT K	Organic-S
1300	31	9	8
900	27	9	8
1500	33	9	8

Changing production by up to 600 kg MS/ha only changes the optimum Olsen P in this instance by 6 units and is grouped around the upper end of the target range for near maximum pasture production for sedimentary soils (Roberts and Morton 2009). The cheaper nutrients K and S are recommended to be maintained at their current levels in or near the target ranges, although with the medium reserve K (K made plant available from weathering of clay minerals) on this farm K fertiliser will not ordinarily be required.

Similarly, the economically optimum soil test levels are not too sensitive to payout within the range of $4 to $6 (Table 3). As above, optimum K and S test remain the same.

Table 3. Effect of milksolids price on optimum Olsen P at 1300 kg MS/ha

Milksolids price ($/kg)	Optimum Olsen P
4.00	28
5.00	31
6.00	34

While the economic analysis of the optimum fertiliser strategy is farm specific and should be undertaken for your farm, the general conclusion is that it is economic at the current fertiliser P, K and S costs and milksolid payout to develop and then maintain your farm's soils to achieve the biological soil test ranges for near maximum pasture production for sedimentary soils (Roberts and Morton 2009).

Nitrate leaching on dairy farms

While the increase in soil organic matter and hence soil N cycling is exactly what we want to drive pasture production, the down side is that there are losses of N associated with the N cycle (Figure 1). Most of the N losses from grazed dairy pastures are either gaseous losses of nitrogen gas, nitrous oxide or ammonia from soil, dung and urine and N leaching from urine patches, rather than N fertiliser applications as many people believe. One issue that is concerning many Regional Councils throughout the country is the impact of farming on ground and surface water quality, particularly with respect to nitrate levels.

The ideal situation, from a water quality perspective only, would be to capture all the dung and urine from your herd over the whole year (zero grazing) because then you could apply this back to land at a relatively low N loading (kg N/ha) rate during soil and plant growth conditions which will maximise the re-use of the N and minimise the losses. While this is not necessarily economic or practical for most dairy farms, farm management techniques such as feed pads and herd homes which minimise the deposition of dung but particularly urine before and during the drainage season (May to September approximately) onto paddocks will assist in reducing nitrate leaching. However, nitrification inhibitors have been shown (Di and Cameron 2002 ; Moir et al 2007) to be a successful means of reducing nitrate leaching, nitrous oxide emissions and increasing pasture production. There has been disagreement amongst researchers and practitioners about the efficacy of the dicyandiamide based inhibitors, such as Ravensdown's eco-n. Most of the debate revolves around whether or not there is a pasture production benefit, with all parties now being satisfied that there is a reduction in both nitrous oxide and nitrate leaching. In fact, recently most researchers involved in inhibitor research have agreed that the following annual effects from using eco-n could be reasonably expected in the South Island:

Reduction in nitrate leaching: 25-40%

Reduction in nitrous oxide: 30-50%

Increase in pasture production: 10-20%; 1-15% (Southland and South Otago)

Nitrification inhibitors then represent one of the tools that farmers can use to help minimise the off farm effects of dairy farming, which is and will become increasingly important in the years ahead.

Conclusion

Most soils in New Zealand do not contain enough or all of the essential minerals required for the levels of crop, pasture or animal production that most commercial dairy farmers want. This is where the appropriate application of fertiliser nutrients, which are insufficient or deficient, is an economic and sustainable strategy.

The situation of high input costs in all agricultural sectors, coupled with comparatively low returns means that farmers are looking for the most cost effective way of keeping their farms productive. It is at times like these that many non-conventional ideas and products are offered to farmers and are 'sold' by invoking the perceived 'evils' of conventional and science-based agriculture, at an apparently 'cheap' cost. While at times, conventional soil scientists may not openly discuss all aspects of soil physical integrity or soil biological activity as discussed briefly above, fertiliser advice is given in the knowledge of the importance of both those aspects of soil function to maximise the cost-effective benefits from the addition of fertiliser nutrients, lime and trace elements where required.

References

Di H J and Cameron K C. 2002. The use of a nitrification inhibitor, dicyandiamide (DCD) to decrease nitrate leaching and nitrous oxide emissions in simulated grazed and irrigated grassland. *Soil Use and Management* 18:395-403.

Feyter C, O'Connor M B, Fris B J and Addison B. 1988. The effects of restricting or stopping fertiliser application to Waikato dairy pastures. *Proceedings of the NZ Grassland Association* 49: 157-160.

McLaren R G and Cameron K C. 1996. Soil Science: Sustainable Production and Environmental Protection'. Oxford University Press, Melbourne, 304.

Metherell A K. 1999. Economic assessment of fertiliser strategies for pastoral farms. *Best Soil Management Practices for Production.* (Currie, L.D., Hedley, M.J., Horne, D.J., Loganathan, P. eds.) Fertilizer and Lime Research Centre, Massey University. Occasional Report No. 12: 127-142.

Moir J L, Cameron K C and Di H J. 2007. Effects of a nitrification inhibitor dicyandiamide on soil mineral N, pasture yield, nutrient uptake and pasture quality in a grazed pasture system. *Soil Use and Management* 23:111-120.

Roberts A H C and Morton J D. 2009. Fertiliser Use on New Zealand Dairy Farms. 3rd Revised Edition. N Z Fertiliser Manufacturers' Association, Auckland. 52p.

Roberts A H C, Edmeades D C, O'Connor M B and Thomson N A. 1991. The importance of fertiliser for milk production. *Proceedings of the Ruakura Farmers' Conference* 43: 60-65.