

MANAGING SOIL ORGANIC MATTER

The importance of soil organic matter (SOM), or to use the colloquial term, humus, has been known for centuries – certainly long before the Organic Movement got in on the act. Most text books will list the benefits of SOM (relative to soil with little or no SOM) as a) improved soil structure b) improved water holding capacity c) improved storage of nutrients and d) better heat absorption. SOM is also home and the food for the myriad of soil micro and macro organisms from earthworms and insects down to bacteria and fungi, to the tiniest protozoa.

We are blessed in New Zealand because our well developed pastoral soils, taken in the international context, contain large amounts of organic matter (see table below). This is a consequence of our temperate climate, and our clover-based, grazed pastoral system. Typically pastoral soils in Australia and South Africa and soils used largely for cropping in the Northern Hemisphere have carbon contents often lower than our poorest soils, the Brown Grey soils found in Central Otago.

Table 1: The organic carbon and organic matter (humus) contents of the topsoil (0-18 cm) of well developed pastoral soils from the important soil groups in New Zealand (adapted from Perrott and Sarathchandra 1984)

Soil group	Carbon (%)	Organic matter (%)	Organic matter (tonnes/ha/)
Brown grey soils (eg Central Otago)	1 - 2	2 - 3	30 - 60
Yellow grey and yellow brown soils (eg East Coast)	3 - 5	5 - 9	90 - 150
Volcanic and pumice soils (eg Waikato/Central plateau)	6 - 10	10 - 17	175 - 300
Peat soils (eg Waikato)	25 - 50	40 - 80	370 - 750

What is SOM.

SOM - humus - comprises the breakdown-products of plant and animal (dung) material returned to the soil. The fresh plant material and dung returned to the soil is food (energy) for soil bugs who get to work in a sort of chain gang and break this material into increasingly smaller and more stable units, which are then often joined together (polymerised) into stable large complex organic substances. Humus is dark coloured and as a general rule the darker the colour and the deeper it extends into the topsoil, the better the soil. It is this colour which enhances heat absorption.

Soil chemists differentiate 3 types of humus. There is what is called humin (very stable), humic acids or humates (less stable) and fulvic acids or fulvate (least stable).

Indeed, if you take any source rich in organic matter (eg soils and particularly peats, compost or low grade coal (lignite) you can extract the humates. These extracts are often promoted as soil conditioners. But be wary. As discussed the amounts of organic matter already in normal soils are very large (30-700 tonnes per ha). Assuming that about half of this organic matter is humate (i.e. 15-350 tonne of humate/ha) the amount of humate you add when you apply your ‘magic brew’, for which you have paid large dollars, is likely to be pitifully small in contrast.

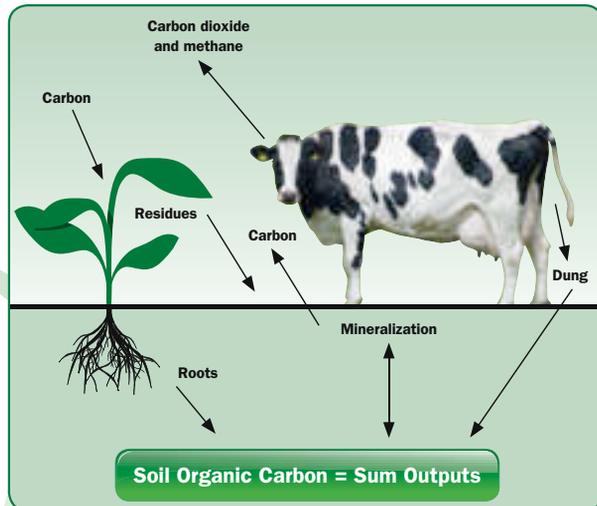
The same logic applies to the use of composts and other sources of organic matter. Prior to the development of chemical fertiliser in the mid 19th century, soil fertility was enhanced and maintained by applying large quantities of organic materials such as compost, seaweed, farm yard manure, blood and bone or human waste. The amounts required were large – 10-20 tonnes/ha. Squirting on a few litres per hectare of some magic brew or extract of these materials is most unlikely to be effective in terms of improving soil quality.

Where does it come from?

The diagram below (Figure 1) shows a simplified carbon cycle for a grazed, clover-based pasture. Carbon comes into

the system from the atmosphere (as carbon dioxide) via the plant (photosynthesis), some of which goes into the soil as plant residues (from tops and roots) and some via the dung. The amount of carbon added from these sources is of the order of 1-3 tonnes/ha/yr annually. Losses occur from the animal because it breaths out carbon dioxide (respiration) and belches methane, and from the soil via the oxidation of organic matter.

Figure 1: The simplified carbon cycle for grazed clover-based pastures



The key point is this: if the sum of the inputs is greater than the sum of the outputs then carbon and hence organic matter is accumulating in the soil. So how should we manage our soils to ensure that this happens or at least ensure we are not depleting SOM levels and hence jeopardizing soil quality and contributing to green-house gas emissions.

Managing SOM

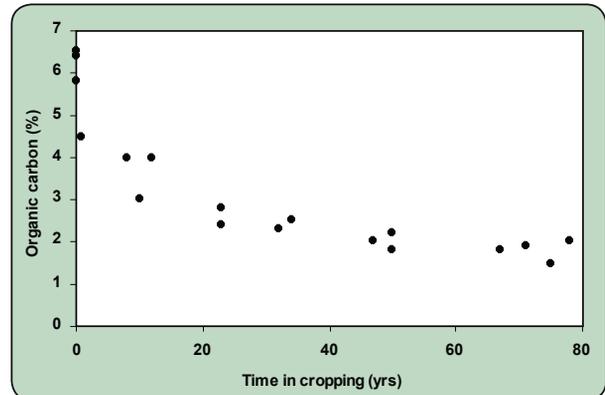
Our Initial Understanding

Several studies in the 1950s and '60s showed that SOM accumulated (inputs > outputs) following pasture improvement (i.e. clover + fertiliser + animal). This accumulation continues for about 20-50 years and then reaches a steady state (inputs = outputs). The time required to reach this steady state, and the amount of SOM present at steady state, depended on the climate and the soil group, as implied in Table 1. Generally, the wetter the environment the more SOM. This was and still is good news for pastoral farming system. The management recipe was simple; clover, fertiliser and the animal, plus time, equals more SOM.

The situation under cropping is very different. Cropping exploits SOM (outputs > inputs) and this is especially so when

the crop residues are removed, as shown for soils used for intensive horticultural in Pukekohe (Figure 2). So lesson Number One in terms of SOM management is: do not crop if you can help it! Or if you need to crop make sure there is a good rotation from clover-based grazed pasture to crop and then back again. Green manuring or heaps of compost are also helpful. Civilisations have failed by not following this simple rule.

Figure 2: The effect of time under cropping on soil organic matter levels in intensive horticultural soils (from Haynes and Tregurtha 1999).



New Research

A number of more recent studies suggest we need to modify slightly our understanding of SOM accumulation.

Tate (1997) compared the SOM contents of 43 topsoils sampled first in the 1960s and again in 1992. He concluded that there was no change over this period. This is consistent with the idea that the soils were at a steady state with respect to SOM accumulation, as discussed above. In contrast, Schipper et al (2007) reported an average decline (about 1% or 1 tonne OM/ha) in 37 sites over a period of about 20 years. How do we reconcile these studies – one suggesting no change the other indicating a small decline?

Other researchers have dug deeper into this apparent paradox and have reported results which indicate that SOM can be reduced by:

1. Land-use intensification – management practices which increase pasture utilisation (e.g. better grazing management, increasing stocking rate, introducing irrigation) and hence reduce the proportion of plant material (litter) being returned to the soil and thus result in the steady state SOM being reduced.
2. Changes in the quality of the litter returned to the soil – it is suggested that some of our newer management practices

(and this includes all those listed above plus the introduction of new pasture cultivars and the introduction of fertiliser N) result in a change in the chemical composition of the litter returning to the soil allowing it to be more readily broken down in the soil and hence less is conserved in the SOM pool.

Two points must be emphasised: First, even if the figures reported by Schipper are true, (i.e. a decrease in SOM at the rate of 1% per annum) there is no need for panic or alarm. As stated earlier, our developed pastoral soils already contain large amounts of SOM. Pastoral agriculture in New Zealand is not on the verge of collapse. I stress this point because of our propensity in this PC and environmentally sensitive age, to seize on and highlight the negatives, especially on environmental issues. Second, in the scientific sense, the possibility that modern management practices are depleting SOM levels is somewhat speculative. It is an emerging issue and more science is most definitely required.

My advice: If you want to conserve SOM, and I think you should, then put away the plough (zero tillage – bring it on), go 100% pastoral, feed the clover, avoid over grazing and think of ways of optimising the return of plant litter to the soil but at the same time optimising animal production.



FERTILISER PRICES: LIVING WITH INCREASING COSTS.

You are all aware that fertiliser prices are on the rise (see Price Watch). Using super as the example, its price increased in February 2008 from \$194 per tonne to \$267, an increase of 38% in 12 months. Sulphur (Durasul) has also increased by 66% and potash by about 37% over the same time period. We are warned to expect further changes in the months ahead. These are serious increases – what to do?

Dairy Farmers

Adopting a positive attitude, I think in the longer-term these increases will turn out to be good for the dairy sector – they could be a blessing in disguise. Why?

We know that many dairy farms are operating at soil nutrient levels above the economic and biological optimal. This is especially so for P – the most expensive nutrient (see Price Watch). This of course is senseless – it costs extra money to maintain high soil P levels and there is no production advantage. Worse still it results in avoidable P runoff into waterways.

We also know, at least this is my experience working with dairy farmers, that many dairy farms do not have the soil nutrient balance correct. The soil P levels may be right but pasture production and in particular clover growth is being limited by

low soil K (most frequent), soil S (often) or soil Mo (sometimes). The consequence is poor clover growth which is being masked on many farms by high fertiliser N inputs – a crazy scenario given that clover N is about 5 times cheaper than fertiliser N.

I believe that as fertiliser prices increase dairy farmers will be forced to adopt a more rational and objective approach when developing their fertiliser policies. By that I mean; farming at and not above the economic optimal nutrient soil levels, making sure the nutrient inputs are balanced so that there are no nutrients limiting clover growth and hence clover N inputs. And making proper use of all the valuable nutrients in the effluent – for the average dairy farm this alone represents about \$5,000 annually from the fertiliser bill.

Not sure how to do it? – give us a ring. You will get no sympathy, but you will get a more profitable dairy farm. In our experience adopting these principles typically pulls out about \$5,000 to \$10,000 worth of fertiliser expenditure while maintaining and in many cases increasing production. (check out www.agknowledge.co.nz 'testimonials' for examples)

Sheep & Beef Farmers

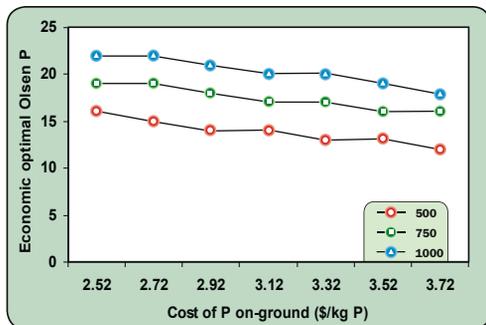
This is where I start to bleed. This sector does not currently enjoy the 'luxury' of strong commodity prices. In some cases these increases in fertiliser prices could be disastrous. But let us try to be positive.

There is a quote: "Those who do not learn from history are bound to repeat it". This wisdom applies directly. Remember 1985 when fertiliser subsidies were removed? Many farmers stopped applying fertiliser. Meat and Wool did a survey in the late 1990's comparing farms who continued fertiliser inputs with those who put the cheque book away (see Fertiliser Review 16). The message was clear; you will be better off financially in the longer-term if you can continue with fertiliser inputs – at least some.

Now here is some good news. The graph below (Figure 3) shows the relationship between the economic optimal Olsen P level (i.e. the Olsen P level which maximises farm profit) and the cost of P on the ground (In this example it is assumed that transport and spreading are collectively \$80/tonne and that the soil is sedimentary). This has been done for three levels of farm productivity (i.e. gross margins of \$500, \$750 and \$1000 per hectare).

[Note that Gross Margin (GM) in this context means gross income minus the variable costs which include animal health, supplements, shearing and electricity. If the income from one sheep (i.e. 1 su) is \$60 and the sum of the variable costs is \$10/su then the GM/su is \$50. This is what Meat and Wool are predicting for the next 12 months. If you are running 10 su/ha then the GM/ha is \$500. This is a typical average for New Zealand sheep and beef farmers].

Figure 3: The relationship between the economic optimal Olsen P and the costs of P on the ground for three levels of gross margin (GM).



What does this data tell us? In February 2007 super cost about \$195/tonne or \$2.50/kg P on-the-ground, adding \$80/tonne for transport and spreading. That meant that the economic optimal Olsen P level was about 16, 19 and 22 for GM/ha of 500, 750 and 1000.

[Note that because of the natural variability in Olsen P levels, we talk about target ranges in Olsen P and not specific numbers. In this case the ranges would be 14-19, 17-22 and 20-25. Similar ranges would apply to volcanic soils but for pumice soils they would be all about 5 Olsen P units higher]

Super is now \$266/tonne (i.e. \$3.12/kg P on the ground). The respective economic optimal P levels are 14, 17 and 20. Projecting ahead it is anticipated that super will go to about \$300/tonne (\$3.60/kg P on the ground) and the associated Olsen P level are 13, 17 and 20.

Thus as a rule of thumb the economic optimal Olsen P level declines by 1 unit for every \$25/tonne increase in super. Therefore for our Mr Average (GM \$500/ha) I would, in 1997, have been advising him to farm at an Olsen P of about 20 (range 18-23). By the end of this year my advice will be about 15 (13-17). Surprisingly the economic optimal is not very sensitive to changes in the cost of fertiliser – the big driver is the gross margin.

The other good news is that P does not run away quickly - it stays where it is put. So if you have already built up soil P levels (say currently at 20) then 1 to 2 years without fertiliser P will have no measurable effect on Olsen P levels (at least at the level of accuracy with which it can be measured) You can afford to 'mine' the existing reserves without any loss in production, in the short-term. When things improve though, you will need to apply above maintenance P to top-up the soil P pool.

The emphasis above is on P because it is the most expensive nutrient (see Price Watch). But our hill country soils also need S

and K and Mo. These are cheaper inputs and they can become depleted quickly (quicker than P). So if you are planning to reduce or withhold P do not do the same for these other nutrients - make sure that they are not limiting production.

The real problem is for those farmers starting out who have just purchased a rundown property, with currently low soil fertility. My advice is this: In the long-term (5-10 years) fertiliser is always a good investment on infertile soils (see Fertiliser Review 15), assuming other things being equal. Also we now have the tools to offer fertiliser advice based on the long-term economic outcome. We can calculate for various scenarios what the return on the fertiliser investment will be, given certain assumptions. With this sort of information your bank manager will look favourably at your situation. Need help – this is what we do.

STOP PRESS: SOIL CARBON TRADING.

As this edition of the Fertiliser Review was in preparation there have been some very speculative and silly things being said in the farming press about trading soil carbon (see my blogg at www.ruralnetwork.co.nz/carbon-farming-take-off-or-rip-off/ for details).

For the sake of clarification:

- 1) It is not possible in my view to assess soil carbon levels by visual inspection.
- 2) There are many laboratory techniques available for measuring soil carbon concentrations (see your soil testing laboratory).
- 3) Changing from soluble phosphate and nitrogen fertiliser to lime and RPR, as has been suggested as a mechanism to enhance soil carbon levels, is plain nonsense.

Referring to the article 'Managing Soil Organic Matter' in this issue it must be obvious that undeveloped pastoral soils can sequester (accumulate) carbon for a number of years. Farmers on such land I guess could claim financial credit for this by trading on a Carbon Exchange. But the bulk of New Zealand farmers are on developed soils where carbon inputs are equal to carbon outputs (ie at steady-state) - on a Carbon Market they have nothing to buy or sell. And then there are those in cropping or horticulture and possibly intensively managed pastoral soils who may need to buy carbon credits to offset the carbon losses from their soils. So as I see it the possibilities for farmers to "get rich quick" by solely manipulating soil carbon stocks are rather slender.

In any case, soils are but one of many sources/sinks of carbon on the farm. Consider trees, belching cows, running the machinery and so forth. I would have thought that all these would need to be considered – it is the net loss or gain that is important - before running off to the Carbon Exchange or indeed changing the fertiliser policy. To focus on soil carbon alone is well silly.



PRICE WATCH

Fertiliser prices were increased significantly in the last 12 months (see below) and we are told to expect adjustments of a similar magnitude within 6 months. As is our practice the costs of the important fertiliser nutrients N, P, K and S are given below, comparing the prices on a per kg of nutrient basis for February 2007 and 2008.

Table 2: Indicative prices for the major fertiliser nutrients (\$/kg nutrient)

		Cost (\$/kg nutrient) ex works ^{1,2}		
		February 2007	February 2008	Change (%)
Phosphorous	Superphosphate	1.65	2.16	+31
	RPR	1.75	2.50	+43
	DAP ³	1.79	3.33	+86
	Triple super	2.36	4.31	+83
Nitrogen	Urea	1.13	1.51	+34
	Coated urea (Ballance only) ⁴		1.71	
	Ammonium sulphate standard ³	1.50	1.65	+10
Potassium	Potassium chloride	0.89	1.22	+37
	Potassium sulphate ³	1.32	1.77	+34
Sulphur	Durasul (Ballance only)	0.35	0.58	+66
	Ammonium sulphate standard ³	0.67	0.70	+4
Magnesium	Serpentine super ³	0.75	0.57	-24
	Magnesium oxide	0.73	1.09	+49

- Notes:**
- 1) The figures are the average of the prices quoted by Ballance AgriNutrients Ltd and Ravensdown Fertiliser Co-operative Ltd on their websites.
 - 2) Ex-works excluding GST and any rebates
 - 3) After deducting the value of the companion nutrient (s).
 - 4) Price available on request

Key points:

- P is still the most expensive nutrient and the cheapest source is superphosphate
- The cheapest source of N is urea but it is noted that Ravensdown have a product called ammonium sulphate standard. It is not granulated and hence should not be mixed with other fertiliser. It is cheaper than urea as a source of N (i.e. \$1.15/kg N) after deducting the value of the S.
- Potassium chloride (potash) is cheaper than potassium sulphate as a source of K.

- Durasul is the cheapest form of S
- Serpentine super is cheaper than causmag as a source of Mg.

My Advice: As before, stick with the basic products, super, potash and urea. If Mg is required, along with P and S, then serpentine super is the best option.



MAINLAND MINERALS AGAIN!

The Fertiliser Review has commented previously about the products and services from Mainland Minerals (Fertiliser Review 5 and 17). The information below was prepared by a Farm Consultant for one of his clients. He compared the costs of purchasing and applying a fertiliser mix recommended by Mainland Minerals with the cost of purchasing all the same ingredients from Ballance AgriNutrients Ltd.

It is published in the Fertiliser Review because it has been suggested that we have a vendetta against Mainland Minerals – we do not – we simply publish information for the benefit of our readers. In this case someone independent of us has reached the same conclusion – purchasing nutrients from Mainland Minerals can be an expensive option.

The fertiliser mix recommended by Mainland Minerals contained the following ingredients: Lime flour (83%), sulphate of ammonia (10%), salt (5%) and the following trace elements, Zn, Cu, B, Co and Se comprising 2% of the mix. Fifty tonnes of this mix was recommended to be applied to a 250 ha block at 200 kg/ha.

Company	Cost (\$/ha on ground)
Mainland Minerals	112
Ballance AgriNutrients Ltd	36

The difference in prices is enormous. For the whole block of 250 ha this represents \$27,930 (for Mainland Minerals) or \$9,000 (from Ballance). Remember this difference is not because Mainland Minerals put more goodies in their mix – the comparison above is for the same amounts of all the ingredients!

How can this be justified? Frankly I do not think it can be. I assume that Mainland Minerals applied the brew as a slurry – what is called Fine Particle Application (FPA). But the available trial evidence (see Fertiliser Review 3) shows that this is of no benefit – the plant does not care whether it is fed solid, liquid or slurried food. That is what the science tells us.

The major component of the mix is lime flour (83%) – very fine lime. But consider this: At an application rate of 200 kg of mix/ha this represents an application of 166 kg lime per ha. We know that lime increases the soil pH by about 0.1 pH units per

1000 kg/ha. In other words the likely increase in the soil pH will be about 0.001 pH units! No doubt Mainland Mineral will claim that, because it is fine, only a small amount is required. This defies chemistry (see Fertiliser Review 15).

It seems to me that this company survives by confusing farmers as to the real costs and benefits of its products and services. But then – I guess that’s why I am in business – the more confusion the more work I get. It is hardly fair on the farmer though.

A NEW SOIL TEST FOR SULPHUR?

AgResearch recently announced what they called a ‘break through’ in soil testing - a new test for soil sulphur. What was that all about?

We are all familiar with the sulphate S soil test – it was introduced for routine advisory work into New Zealand agriculture in the 1970’s. However scientists have known for many years that it has limitations. It can be extremely variable because the amount of sulphate S in a soil at a given time decreases rapidly when leaching occurs and increases rapidly when fertiliser sulphate S or urine is applied. More importantly scientists realised that sulphate S was only a small part of the total soil S available for plant growth. There was a larger and more important pool of S – the organic S pool. The problem was – how could it be measured?

This was solved by Dr John Watkinson of Ruakura in the 1990’s. He did some brilliant work and showed conclusively:

- There are two pools of plant available S in soils. The sulphate pool which is very small (< 5%) and the much more important organic S pool making up > 95% of the available S.
- The source of the organic S in pastoral soils is from dung and from plant litter returned to the soil.
- These two pools are in equilibrium (see Figure 4): If the soil sulphate pool is depleted (as occurs during leaching events or via plant uptake), the soil bugs get to work and convert some of the unavailable organic S into plant available sulphate S. The reverse applies; when sulphate S is added to the soil (as in fertiliser) some of this is used by the bugs and converted to organic S.
- The pool of plant available organic S was not only much larger than the pool of sulphate S but more importantly was not subject to leaching, fertiliser additions and urine deposition. It is stable.
- Dr Watkinson also developed a quick method to measure this important pool of plant available S. He called it the extractable organic S test (EOS). It was introduced into commercial laboratories in the late 1990s.

- The EOS test extracts a small portion (about 1-2%) of the total organic S (TOS) pool and very importantly he showed that EOS was directly related TOS – they are one in the same thing as far as measuring available organic S.
- And he calibrated the EOS test in field trials showing the relationship between relative pasture production and the amount of plant available organic soil S.

Figure 4: The important pools of available soil S – sulphate S, extractable organic S and total S are in equilibrium.

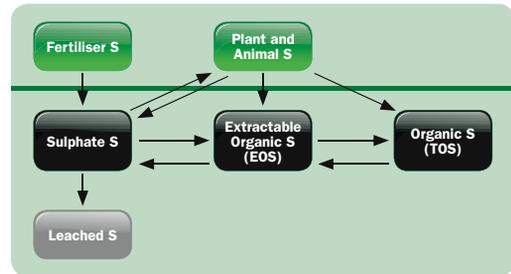
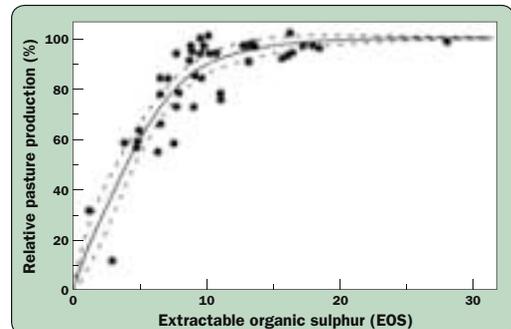


Figure 5: The important pools of available soil S – sulphate S, extractable organic S and total S are in equilibrium.



At last we (and it was a world first) had a reliable test for the pool of available soil S. I use it as a matter of routine in all my advisory work and I would encourage other professional to do likewise. In fact these days I virtually ignore the sulphate test results as unreliable.

To my great surprise the test has not been adopted by the industry as it should have been. This I understand was because some laboratories did not have the technical equipment to measure EOS. Why this is so I could never fathom out. They could however readily measure TOS.

The upshot of all this is that laboratories are now measuring and reporting results for sulphate S and TOS, rather than sulphate S and EOS. Now, because EOS and TOS represent the same thing the so-called “new” test adds nothing to what we already knew. So why the hype – you work it out - I don’t give a TOS!