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PREFACE

Regenerative Agriculture (RA) is being promoted as **the** solution to some of our contemporary farming problems. In particular it is claimed that RA can mitigate *climate change* and improve *soil health*.

In this issue of the Fertiliser Review, we will revisit RA, this time in greater detail, and within the context of some understanding of the carbon cycle in New Zealand's pastoral soils. With this background we will then assess whether the claims made for RA are valid.

REGENERATIVE AGRICULTURE

In *Fertiliser Review 40*, we discussed the origins of RA. It originates from ecosystems very different from our own – the prairies of the USA and the outback of Australia. These vast tracts of 'natural' grasslands were grazed intermittently by roaming herbivores. Typically, they have low soil fertility and biological activity, low pasture production and extremely poor feed quality. We need to be very careful about adopting RA and its concepts into our pastoral system.

At the broadest level, the concepts promoted by RA are set out in Table 1. From this analysis it is apparent that New Zealand's pastoral system looks very much like RA in practice. It seems that those promoting RA in New Zealand are "teaching grandma how to suck eggs"!

Table 1. Concepts promoted by Regenerative Agriculture (RA) *(from Fertiliser Review 40)*

RA Concept	Comment
Rotational, planned in situ grazing	This is the basis of New Zealand's pastoral agriculture.
Closed system, minimizing exploitive practices and replacing what is removed.	All biological systems contain inefficiencies but our in situ, grazed, clover-based, pastoral system is as good as it gets in terms of nutrient cycling.
Perennial crops/pastures	This is the basis of New Zealand's pastoral agriculture
Builds soil organic matter	As a consequence of our clover-based pastoral system the organic matter content in NZ soils are among the highest on the world.
Encourages biodiversity and riparian planting.	NZ farmers have been on this 'case' for some while now.
Healthy – soils, plants and animals including humans	These goals are a given for most farmers.

I have recently received an interesting report (August 2019) by Dr Charles Merfield of the Lincoln University entitled “An Analysis and Overview of Regenerative Agriculture” (www.bhu.org.nz/future-farming-centre) . It deserves further comment and discussion.

Merfield is upfront and accepts that RA “lacks a formally agreed definition.” He also suggests that while it shares some of the attributes of “Organic Farming”, it is fundamentally different, Merfield explains that Organic Farming is defined by a set of input rules whereas the focus of RA is on achieving certain outputs. Further, he notes that the origins of the organic movement predate the ‘climate change’ issue, making the point that mitigating ‘climate change’ is an explicit and important goal of RA.

In his paper he identifies and discusses many of the aspirational goals that RA is seeking to achieve. Some of these are ‘no brainers’ as far as New Zealand’s pastoral system are concerned. For example: ‘keeping soils covered at all times’, adopting ‘zero tillage’, ‘integrating livestock and cropping systems,’ optimising the use of ‘biologically fixed N’ (via legumes), and increasing ‘plant diversity in crops and pastures.’ These goals are accepted and are implicit in our modern understanding and management of our clover-based pastoral system.

This *Fertiliser Review* will therefore focus on those goals which RA aspires to, which impact on managing soil fertility. These are:

1. Mitigating climate change through sequestering atmospheric CO_2 as soil organic matter (soil carbon).

2. Enhancing soil health especially by building of soil organic matter and microbial activity.

3. Increasing soil fertility through biological means (e.g. composts, manures) and hence reducing the amounts soluble mineral fertilisers.

4. Utilising mycorrhizal fungi to access existing soil P reserves and adopting the Base Cation Saturation Ratio (BCSR) theory of soil fertility.

To make sense of some of these goals requires a basic knowledge of the carbon cycle and soil chemistry of pastoral soils.

THE SOIL CARBON CYCLE

Pasture is the dominant land use in New Zealand and our pastoral soils are rich in carbon (Table 2). It is estimated that soil organic carbon (SOC) represents over 50% of NZ’s carbon stocks. Knowledge of the carbon cycle in pastoral soils is therefore important (Figure 1).

Carbon is one of the 16 essential nutrients required by plants. Plants capture carbon (as CO_2) – the process is called photosynthesis – and this carbon is used mainly to build the structural components (carbohydrates) of the plant. In our animal-based pastoral system, some of this C is ingested by animals and what is not utilised in this manner is emitted as methane and carbon dioxide or deposited in dung. Thus dung is an important source of C entering the soil (Figure 1).

Plants also contribute directly to the soil C. They die – senesce - and hence the C in the tops and roots gets incorporated into the soil (Figure 1). This process is enhanced during grazing. Consider a pasture growing 10 tonnes/ha. If the utilisation is say 80% then there are 2 tonnes DM/ha being returned to the soil. However, not all of this C becomes part of the soil organic matter – some is oxidized (burnt off) back to atmospheric CO_2.

It is via these two mechanisms that C is added to pastoral soils. If the sum of inputs is greater than the outputs, C accumulates.

Initial Research

This process of organic matter accumulation was beautifully demonstrated in the late 1950s and early 1960s by several soil scientists (Walker et al. 1959 and Jackman 1964) who measured the carbon content in grazed clover-based pastoral soils at different stages of development, commencing with virgin soils.

Initially, soil C increased (the inputs were greater than the outputs). As a rule of thumb the rate of accumulation during this development phase was about 1 tonne C/ha/yr. But this accumulation phase does not go on forever. Given time (20-50 years depending on the soil group and climate) an equilibrium – a steady state - is reached where the C inputs are equal to the outputs and no further C sequestration occurs (Figure 2).

Figure 1 The carbon cycle in pastoral soils.

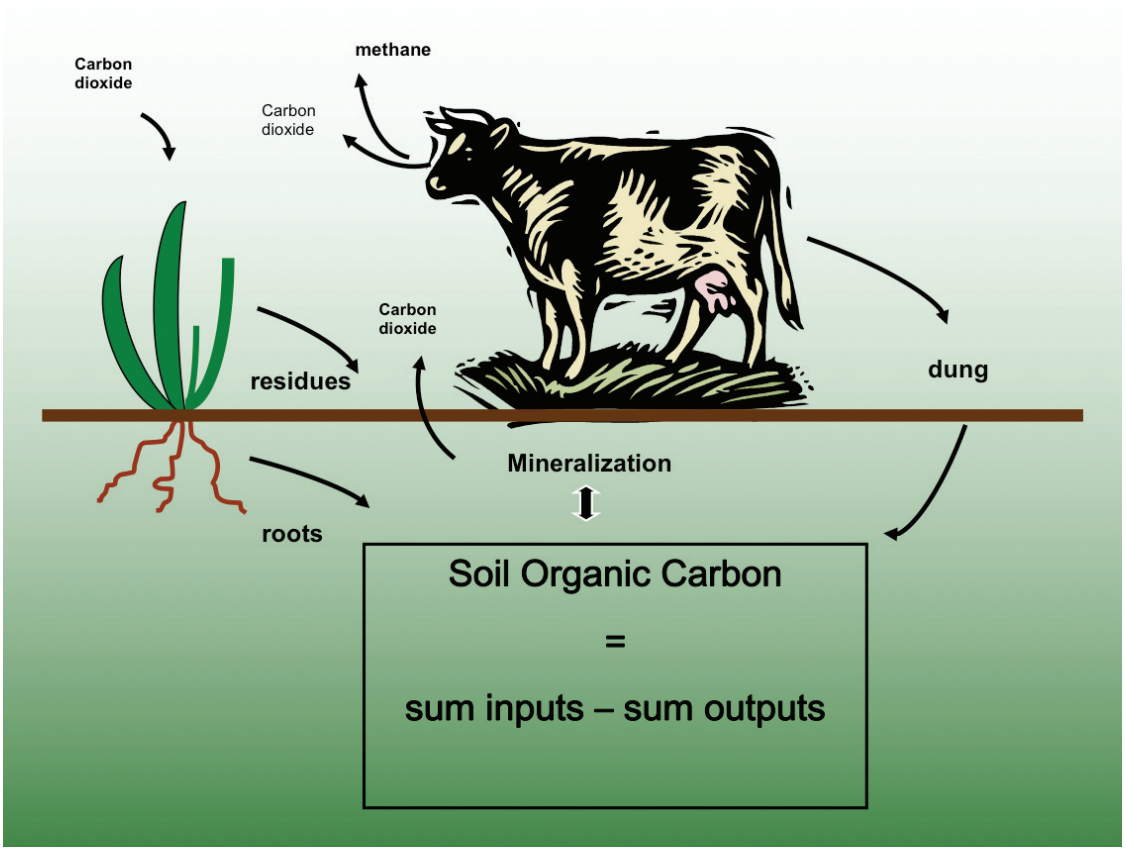
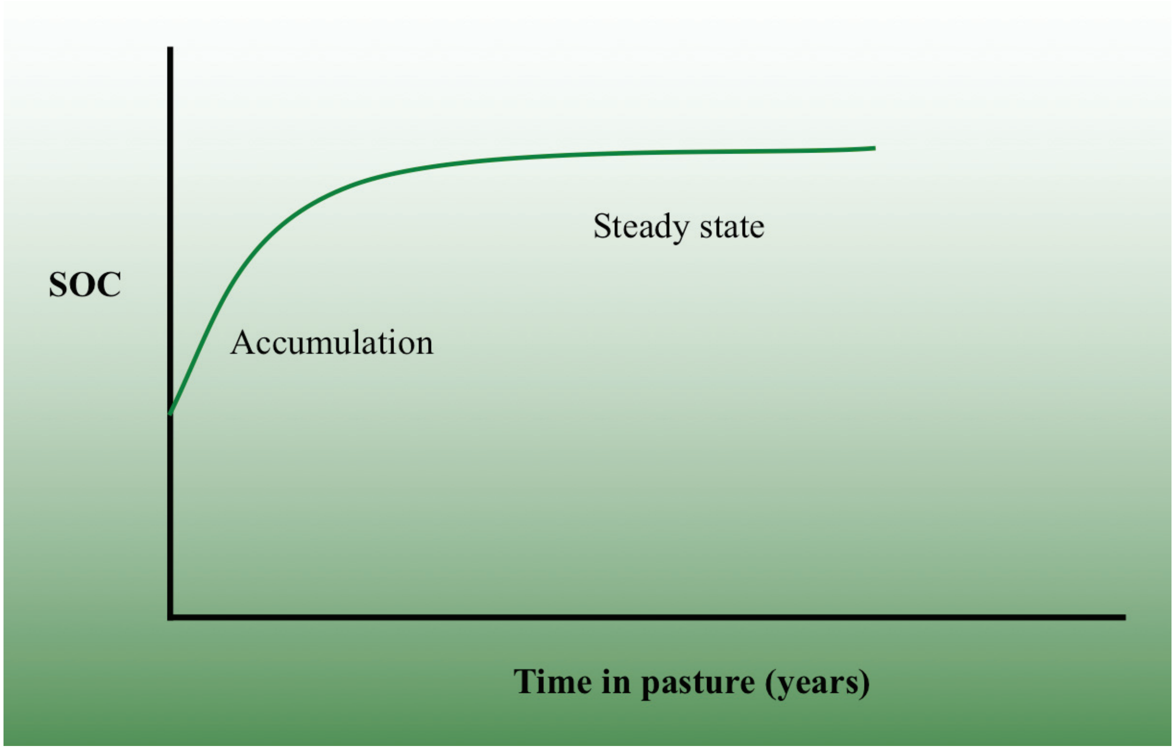


Figure 2 Schematic diagram showing the accumulation of soil organic carbon (SOC) over time.



It is important to appreciate the key components that make this C cycle work: the clover-based pasture which contributes free nitrogen from the atmosphere; fertiliser P, K and S etc. to feed the clover, and the grazing animal to complete the nutrient cycle - all enhanced by a benign climate which allows year-round pasture growth and animal grazing.

It is for these reasons that NZ pastoral soils are rich in C and hence organic matter (C is the major component of soil organic matter) (Table 1). In an international context a soil C content of 2% is regarded as high, noting that most soils world-wide are used for cropping.

Table 2. Typical carbon and organic matter contents in developed pastoral soil in NZ.

Soil group	C (%)	organic matter (%)	organic matter (tonnes/ha)
Brown grey	1-2	2-3	30-60
Yellow grey Yellow brown	3-5	5-9	90-150
Volcanics Pumice	6-10	10-17	175-300
Peats	25-50	40-80	370-750

from Perrott and Sarathchandra 1984

It is instructive to consider cropping in this context. If pastoral farming accumulates and conserves C, then, by comparison, cropping is exploitive. The amount of litter and plant residues being returned to the soil during cropping is minimal and cultivation (leaving aside zero tillage) exposes the soil organic matter to oxidation and hence C is lost. It is no surprise that soil C is depleted (inputs are less than outputs) under continuous cropping (Figure 3).

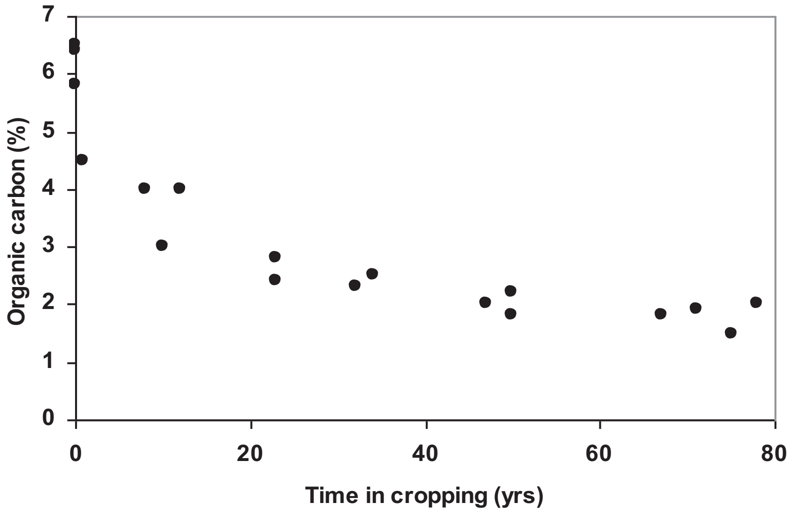


Figure 3

Cropping depletes soil organic carbon (from Haynes and Tregurtha 1999).

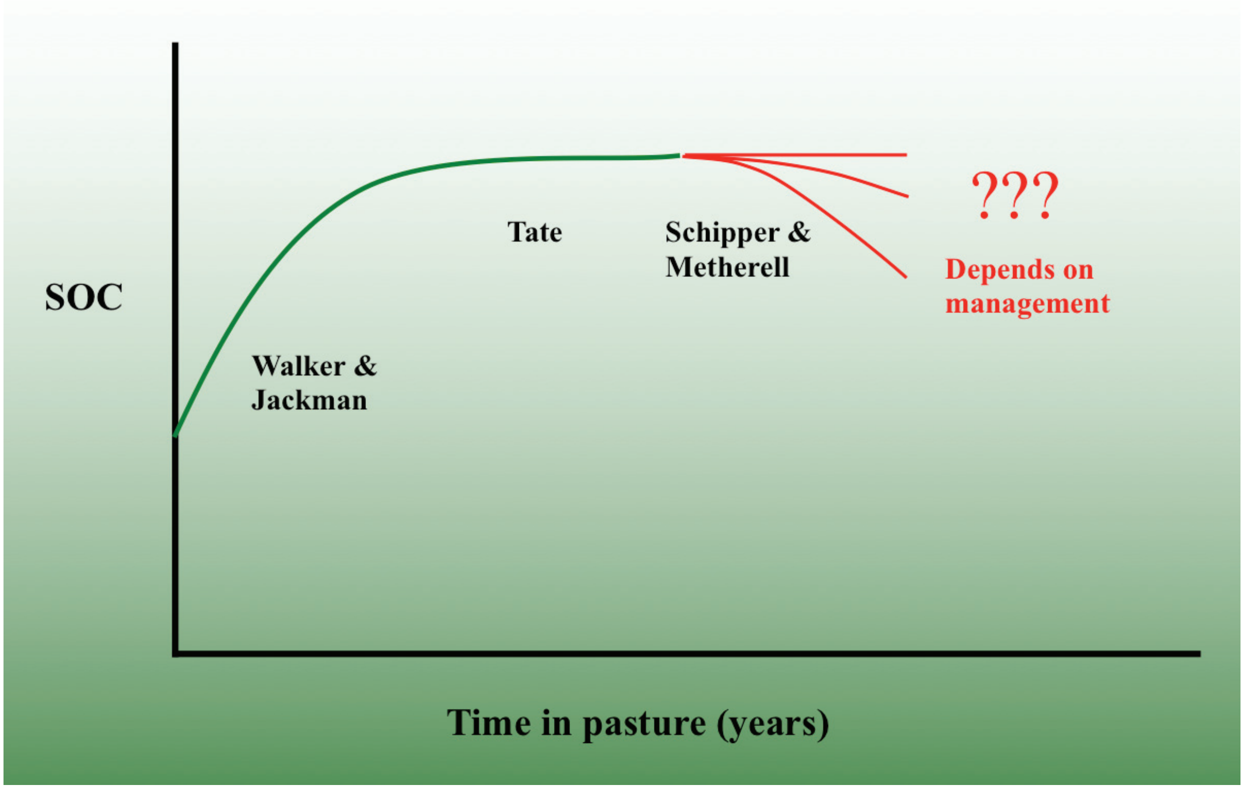
Recent Research

This initial understanding of soil C has been reinforced in more recent studies (1997) and in particular by the work of Tate (1997), who measured soil C levels over 30 to 50 years in 43 developed grassland sites. On average there was no net change over time.

But this recent view is now being challenged. For example, Schipper and co-workers (2007) sampled 31 developed pastoral top-soils, to a depth of 1m, over a period from 1997 to 2005. They reported declines in soil C of about 1 tonne C/yr on average (see Figure 4). These losses are small in relation to the background levels of soil C.

Metherell (2003) has suggested several reasons for this and they can all be reduced to the possibility that some of our modern pasture management systems and practices ***may be*** (my emphasis) reducing the amount of C being returned to soil. For example, high pasture utilisation minimizing the return of plant residues to the soil (outputs greater than inputs). As indicated in Figure 4 'the jury is still out' on this matter and further research is in progress on this important issue.

Figure 4. Progress over time in the understanding of soil organic carbon (SOC).



MITIGATING CLIMATE CHANGE

The Zero Carbon Bill (ZCB) and the Emission Trading Scheme (ETS) are being introduced in New Zealand to manage C emissions and set New Zealand on the pathway to becoming carbon neutral (inputs = outputs) by 2050.

The question arises: should soil carbon be included in the ETS and can soil C stocks be manipulated as part of the goal to achieve zero carbon emissions? The answer is no, with some caveats.

Figures 2 and 4 show that during pasture development large amounts of C accumulate in soils. But this effect only lasts about 20-50 years and hence most of NZs pastoral soils are past this development phase. For most farmers the possibility of sequestering more soil C is now past. Most of NZ pastoral soils are now C neutral or, in some cases, such as under intensive farming, may be net emitters of soil C.

It has been suggested that we could invert topsoils, bringing to the soil surface undeveloped subsoil which could then be developed and hence accumulate more C. This is nonsense of course. The mechanical costs, and the capital fertiliser costs, to re-establish pastures on such infertile 'subsoils' would be enormous. And this is leaving aside the point that cultivation results in the loss of soil C (Figure 3).

Conclusion

Harnessing NZ's well-developed pastoral soils in the fight against climate change is in my opinion 'not a goer.'

SOIL HEALTH

Soil health is difficult to define and one reason for this is that soils are complex. To simplify matters we normally adopt a pragmatic approach – we define soil health in terms of the land use we have in mind. Thus, we would describe a healthy grassland soil as one which has:

- Good soil fertility (nutrient content) to optimise the growth of a clover-based pasture.
- Good soil organic matter content to aid the storage of nutrients and water.
- Good biological activity to optimise the cycling of nutrients.
- Good physical structure such that it is well drained and will support grazing livestock in all weather conditions.

There is often very little that can be done to modify the physical properties of soils, apart from improving soil drainage. We can and do readily modify the soil fertility by the application of fertiliser and lime. But how can we manipulate soil organic matter and the biological activity of the soil?

As shown in Figures 2 and 4 pastoral farming typically increases and cropping decreases SOC (Figure 3). Thus, maintaining clover-based pastures and managing them such that the amount of organic matter being returned to the soil is optimised is a good soil management practice. You could say it is restorative. Cropping, unless using zero tillage, has the opposite effect. It is exploitive.

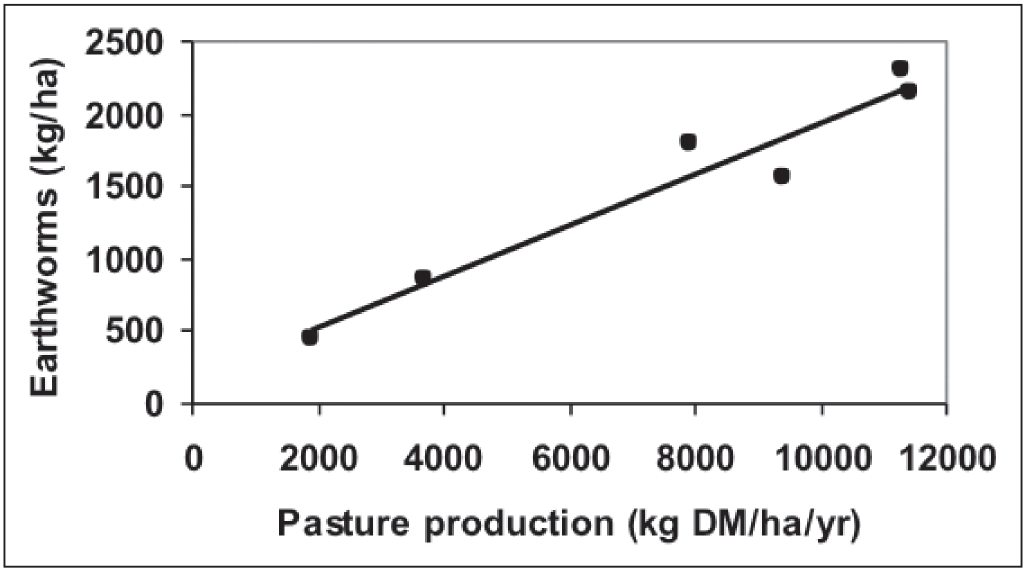
What about the soil biological activity – can it be manipulated?

One of the earliest soil fertility experiments in New Zealand looked at the effects of applying fertilisers (yes, chemical fertilisers), introducing a legume (clover in this case) and the return of dung, urine and some of the pasture clippings, on pasture production (Table 2). All of these inputs increased pasture production and as pasture production increased so too did earthworm numbers (Figure 5).

Table 2. The effect of clover, fertiliser and the return of nutrients in clipping, dung and urine on pasture production (from Sears et al. 1954).

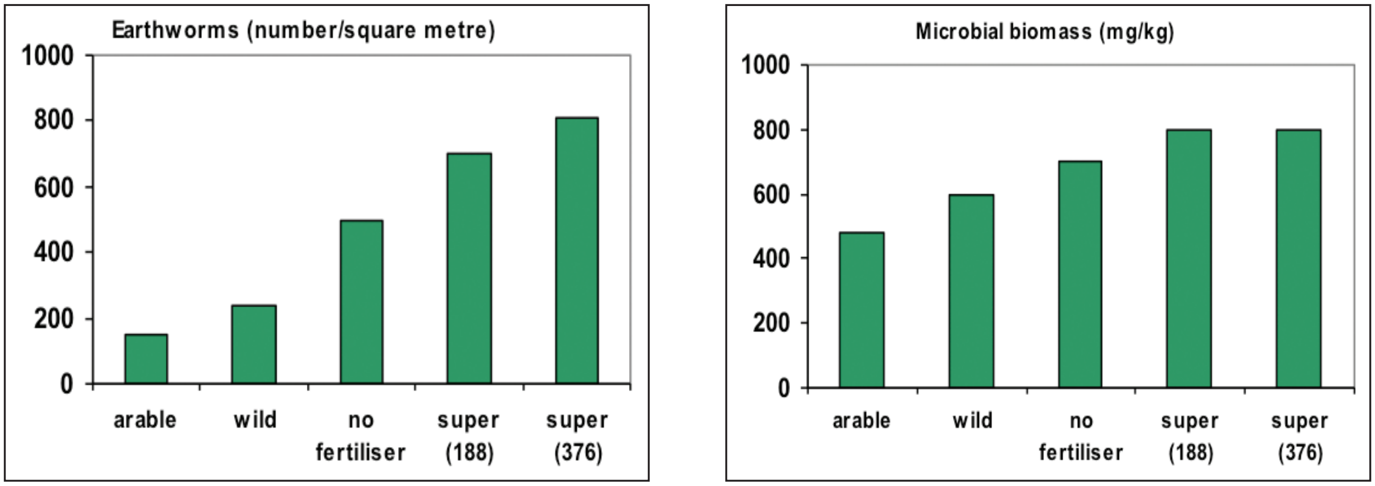
Treatment	Pasture production (kg DM/ha/yr	
	No return of nutrients (clippings, dung, urine)	Full return of nutrients (clippings, dung, urine)
Grass only	1900	3700
Grass + clover	7900	11300
Grass, clover, fertiliser	9480	11400

Figure 5. Effect of pasture production on earthworm numbers (Sears et al 1954).



This same effect has been measured in the long-term trial (commenced 1950) under irrigation at the Winchmore Research Station in Canterbury (Figure 6). Increasing fertiliser inputs (as superphosphate) increased earthworm numbers and the total biomass (biological activity) in the soil. Note also that the biological activity in the soil under pasture was greater than that in the virgin soil (wild) and under cropping (arable).

Figure 6. The effect of fertiliser (superphosphate applied at two rates) on earthworm numbers and microbial biomass in the long-term trial at Winchmore.



Conclusion

New Zealand's pastoral farming system, including the use of chemical fertilisers, enhances and maintains soil health, soil organic matter and biological activity.

COMPOSTS & MANURES: REDUCING MINERAL FERTILISER USE?

Those promoting RA appear to hold the view that soluble chemical fertiliser have detrimental effects on soil health. We should, Murfield suggests, minimise the use of chemical fertilisers by using composts and manures to enhance soil fertility.

It should be clear from the discussion above that soluble chemical fertilisers have beneficial effects on soil health. This truth can be boldly stated: As far as our clover-based pastoral soils are concerned, any source of nutrients (whether chemical or biological), when applied to a nutrient depleted soil, enhances soil health, biological activity and the accumulation or organic matter. I cannot understand why chemical fertilisers are so demonised in this regard.

This fertophobia, now reflected in the RA literature, is rife in the organic movement, and appears to come from the mid 1800s when the first chemical fertilisers were made. The fear was that, relative to composts and animal manures, chemical fertiliser would somehow damage the soil, or at least they could not possibly be better than organic sources of nutrients.

It was for this reason that trials were commenced comparing the performance of manures/composts with their chemical counter parts. I had the pleasure of reviewing the results from this international set of trials. There is data from 14 trials long-term which ran for at least 50 years.

I concluded (see Fertiliser Review 4) from the data:

1. That the chemical fertilisers are no better, or worse, than organic manures, in terms of sustaining crop production. The average difference in plant yields, between the fertiliser and manure treatments, was about 4% in favor of fertilisers.

2. If soil quality is defined as the sum of those properties that affect soil productivity, and includes a soils potential to affect water quality, and its loading with pollutants, then it must be concluded that, in the long-term, manures decrease soil quality relative to the use of fertilisers.

It appears from this large body of research that replacing chemical fertilisers with manures and composts would not be beneficial from a soil quality perspective. There is however a further problem - a logistical problem.

Norman Boulag, regarded as the father of the green revolution, famously pointed out some time ago now, that the world produces about 100 m tonnes of fertiliser N. To replace this with animal manure would require about 5 b tonnes of animal manure. In turn this would require about 7.5 b cattle. Currently we have about 1.5 b head. Thus, to meet the demand for manure, a fivefold increase in cattle would be required together with a similar increase in the land use. Think about the effects of this on water quality and biodiversity!

The same logical impossibility applies to composts. Because composts have a low nutrient content, tonnes of compost would be required to replace the use of mineral fertilisers. For example consider an average dairy farm of 100 ha. Assume the farm required 50 kg P/ha/yr (550 kg superphosphate/ha/yr) to maintain the soil P levels. This would require an input of 5 tonnes/ha of compost or 500 tonnes compost for the whole farm, every year. There are about 1200 dairy farms in New Zealand and hence nationally we would need to make about 6m tonnes of compost every year!

This problem is exacerbated in the drystock sector where aerial application of fertiliser is required. Assume that 20 kg P/ha/yr is required to maintain soil P. This would require applying about 2 tonnes of compost/ha/yr. Leaving aside whether this is feasible given the physical form of the material, think of the enormous transport and spreading costs!

In any case, it can be argued that pastoral farming, as we practice it, is already based on the use of compost and manures. Consider again the results in Table 2. The system is optimized, and this includes the soil biology, by returning the manure (dung and urine) and compost (plant residues) to the soil. As noted previously if pasture production is 10 tonnes DM/ha/yr and pasture utilisation is 80% that means 2 tonnes/ha of plant material is returned to the soil. For our average dairy farm that amounts to applying the equivalent of 200 tonnes of organic residues every year.

Conclusion

Substituting chemical fertilisers with manures and compost would be very expensive and will not necessarily improve soil quality, soil health or soil productivity.

Furthermore the nutrients in compost and manure are not free - they have come from somewhere, normally a productive soil. Mining one soil to feed another is not sustainable.

MINING SOIL P & THE BCSR CONCEPT

Dr Merfield reports that those interested in RA are:

1. Of the view that P fertiliser is being overused and that it is desirable to "utilise existing soil P reserves by increasing the biological activity of the soil, especially via mycorrhizal fungi."

2. Interested in the "base-cation saturation ratio (BCSR), soil nutrient testing approach, also called that Albrecht-Kinsey system."

Our pastoral soils are teeming with naturally occurring mycorrhizal fungi. Attempts to introduce more effective and efficient strains into NZ soils have failed simply because the new strains are 'swamped out' by the indigenous populations. In any case utilizing existing soil P reserves is exploitive and will result in mining down soil P levels. This idea only has merit when soil P levels are above the economic optimal range which in my experience is not common.

We have dealt in detail with the BCSR concept in the Fertiliser Review (4,26). It is a nonsense – it is pseudo-science. It has no scientific basis and at best results in an increase in fertiliser costs for no benefit.

Conclusion

Attempts to utilise mycorrhizal fungi to mine down soil P reserves have not worked to date and adopting the BCSR concept would be a step back to pseudo-science.

CONCLUSION

Of the many goals that RA espouses, some are unscientific (BCSR), some are not based on sound science (mitigating climate change). Some are implausible and likely to be very costly (replacing chemical fertilisers with compost and manures), some are based on a false premise (chemical fertilisers are bad for soil health), or can be achieved more cheaply by other means (i.e. improving soil health using chemical fertilisers).

But of deeper concern is that at is core RA is anti-science. To quote Murfield “Fundamentally RA (and organic agriculture) is a values system and the only way to decide which value system is preferred is through debate / political processes. At its highest level RA is beyond the reach of scientific method.” He goes on to say: “While the scientific method is incapable of questioning RA’s philosophy and values, this is not to say that the information produced by science cannot be used to help decide which values RA (and individual and society) wish to pursue.”

This is what is now called Post-Normal-Science: the goal of science is no longer the pursuit the truth. Rather its role is to support the narrative.