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RECOVERY OF SOIL AFTER OVERIRRIGATING WITH DAIRYSHED EFFLUENT

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Introduction

Soil Quality Monitoring has developed into a vital tool for the environmental management carried out by Regional Councils across New Zealand and used in national reporting. After the initial research phase, popularly known as the ”500 soils” project, ended in 2001, separate regional councils took on soil quality monitoring for their regions soils, with coordination by the Land Monitoring Forum Special Interest group (consisting of regional council land and soil scientists). The state of soil quality and soil quality changes for different soils and land uses over time and across the region is now regularly assessed. Data is amalgamated up for national reporting. Additional data is used in regional reporting but, again, this is amalgamated up for individual site data. However, after many years of monitoring, case studies of individual sites can provide useful insights.

There are currently 150 actively monitored soil quality monitoring sites in the Waikato region (Figure 1) as some sites have been built over or otherwise lost to urban sprawl. Sites are representative of the main land uses and soil types and are sampled over a five year period, about 30 samples per year. Samples are topsoils only (0-10 cm) (Taylor 2021).

Soil quality is the chemical, physical, and biological condition of a soil type for a given land use. There is currently no single measure of soil quality because there are many things about the soil that affect its quality rating – the fertility, physical condition, amount of humus, and biology, while a change in a soil quality characteristic can improve the ability of a soil to provide one type of service but decrease its ability to provide another at the same time. This means there are trade-offs, e.g. increasing nutrients can increase production, but it also increases the risk of loss of nutrients to waterways and associated algal blooms. There are seven key measurements, which are termed indicators (Hill et al., 2003):

1. Olsen P: Olsen P (weight/volume) is the method used to derive the concentration of phosphorous that is available for plant uptake,
2. pH: a measure of soil acidity,
3. total carbon (C): a measure of soil organic matter and carbon stocks,
4. total nitrogen (N): a measure of soil organic matter and nitrogen stocks,
5. anaerobically mineralised N (AMN): a measure of mineralisable nitrogen used to assess soil microbial health and how much organic N is available to plants,
6. bulk density: a measure of physical condition,
7. macroporosity at -10 kPa (shortened to macroporosity for this publication): a measure of soil pores that air and water can use to enter the soil. Compacted soils reduce water or air penetration, restrict root growth and do not drain easily, so have increased potential for run-off carrying sediment, nutrients, and contaminants to surface waters.

Figure 1: Map of soil quality site locations.

In addition, indicators pertinent for specific land uses (e.g. aggregate stability for arable farming) and indicators under development (e.g. hot water extractable carbon for assessing readily available C) may also be measured. A visual soil assessment (VSA) was also carried out (Shepherd 2009). Only Olsen P, Total C and N, Hot Water Extractable C and N (HWC and HWN) and soil colour are reported in this paper.

Case Study

At one site, on a Taupo Sand, overirrigation of dairyshed effluent to land along with heavy fertilisation led to extremely high Olsen P values at a soil quality monitoring site. Not only was nutrient chemistry affected, but also pH and soil carbon. Effluent crusts were seen on the surface and soil colour was pale compared to an unimpacted sample from under the fence line (VSA test).

This farm was sold to YWuri Trust, an extensive dairy farming operation in an area to the North of Taupo, owned by Roger and Amanda Garland, with their daughter Brooke as Business Manager (Figure 2). Since then, many aspects of soil quality at the now Totora Valley farm has improved.

Figure 2 aerial photos of Totara Valley Farm. Top, in about 2006, bottom in 2017. Black border denotes the sampling site.

Soil organic matter, as measured by total C, has increased from its already acceptable level of 6 to 6.6% (w/v), while the labile fraction, measured by hot water extractable carbon (HWC) decreased considerably (Figure 3). The initial level of HWC, at 6500 mg/kg, was extremely elevated compared to levels in other mineral soils. This elevation was attributed to the effluent crusts and other “free” effluent in the soil at this time. Microorganisms are thought to consume labile C and use it as an energy source with by-products contributing to persistent SOM stocks (Domeignoz-Horta et al 2021). Soil colour assessed using the VSA also improved from between poor and moderate condition (0.5 out of 2 score) to between moderate and good condition (1.5 out of 2 score).

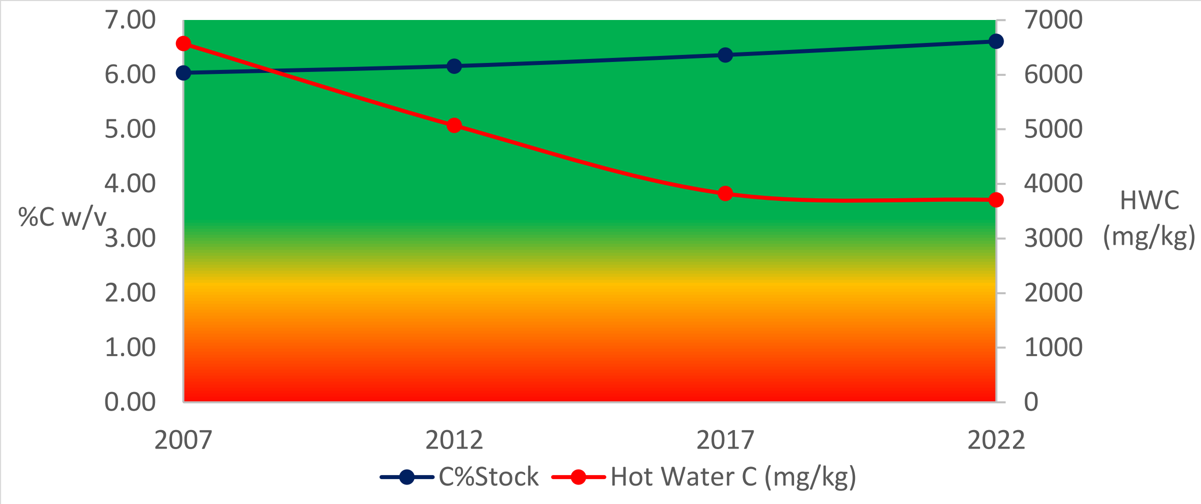

Figure 3. Organic matter behaviour. Total C increased while labile hot water extractable C decreased. Outside soil quality targets is shown by the red colour.

Interestingly, looking at 4 farms monitored >20 years in the same area, on similar Pumice Soils, Total C has increased with the average being 6.8% C prior to 2000 and 8.4% C at the last sampling (Figure 4) suggesting C sequestration could have been even better at the site if it had been undamaged when the Garlands took over.

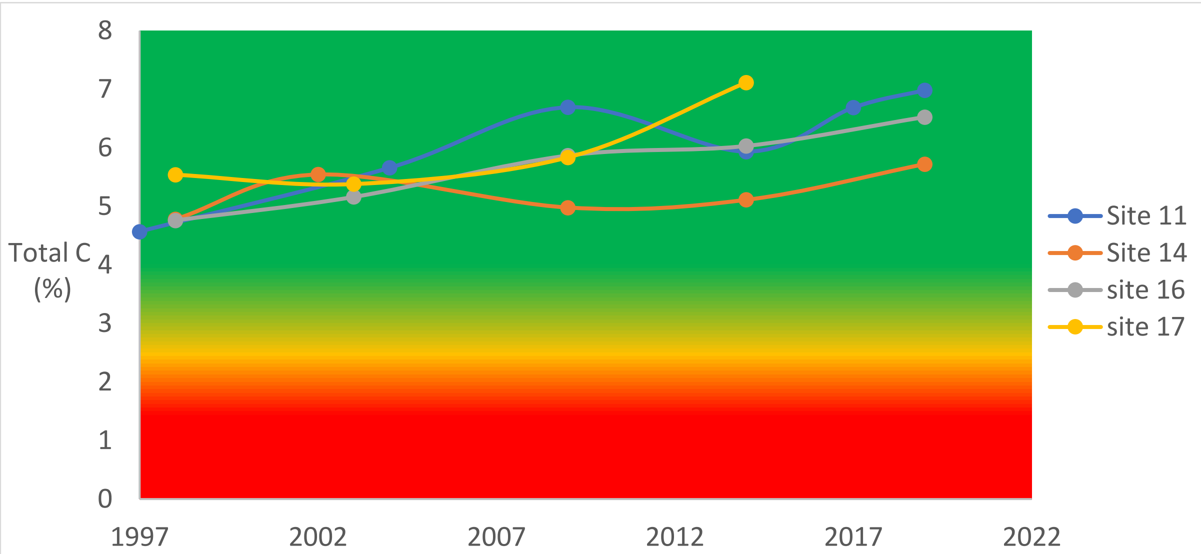

Figure 4. Total C at sites on dairy farms in the same area and on similar Pumice Soils (note the longer monitoring period and site 17 became a dairy shed effluent pond after 2017, so is no longer an active monitoring site).

The farmers response to this result was "It is very interesting carbon levels have increased, does this mean that on average our pastures are sequestrating quite a significant amount of carbon, surely this is a story that needs to be told by someone like you that would be invaluable for our farming future" (Roger Garland).

However, like many things environmental, it is not quite so simple. Pumice Soils are relatively young and expected to accumulate soil organic matter under long-term pasture. So, total C should naturally increase if the soil remains undisturbed. Thus, land use management plays a large part, e.g. Both soil total C and HWC, on farms in the same district and on similar Pumice Soils, declined when pasture was renewed but these values increased once pasture was re-established (Figure 4) suggesting Soil Organic Matter can and does increase in Pumice Soils under some pastoral management systems.

Similarly, total N increased and HWN decreased, following the soil total C and HWC, respectively (Figure 5).

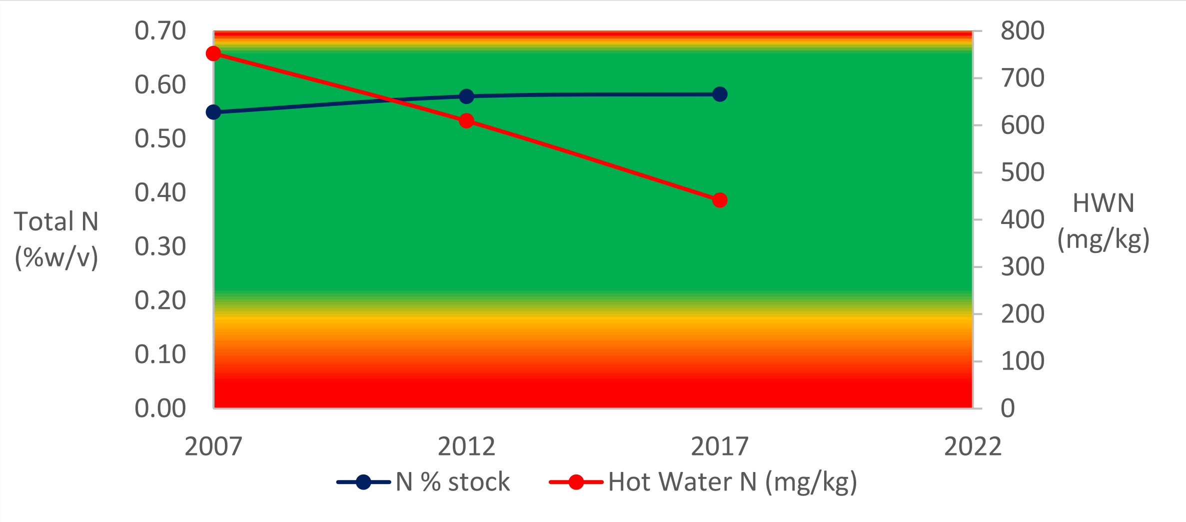

Figure 5. Nitrogen behaviour. Total N increased while labile hot water extractable N decreased. Outside soil quality targets is shown by the red colour.

Concurrent with the changes in soil carbon, Olsen P has declined considerably, from extremely high levels to levels often found on similar dairy farms (Figure 6). This decline is attributed to reductions in mineral P fertiliser as well as reduction in effluent organic P application. Thus, the risk of P loss to water has reduced somewhat, but Olsen P remains above agronomic guidelines and is greater than ideal for environmental protection. Further reductions in fertiliser P application could be considered so that Olsen P levels match agronomic requirements.

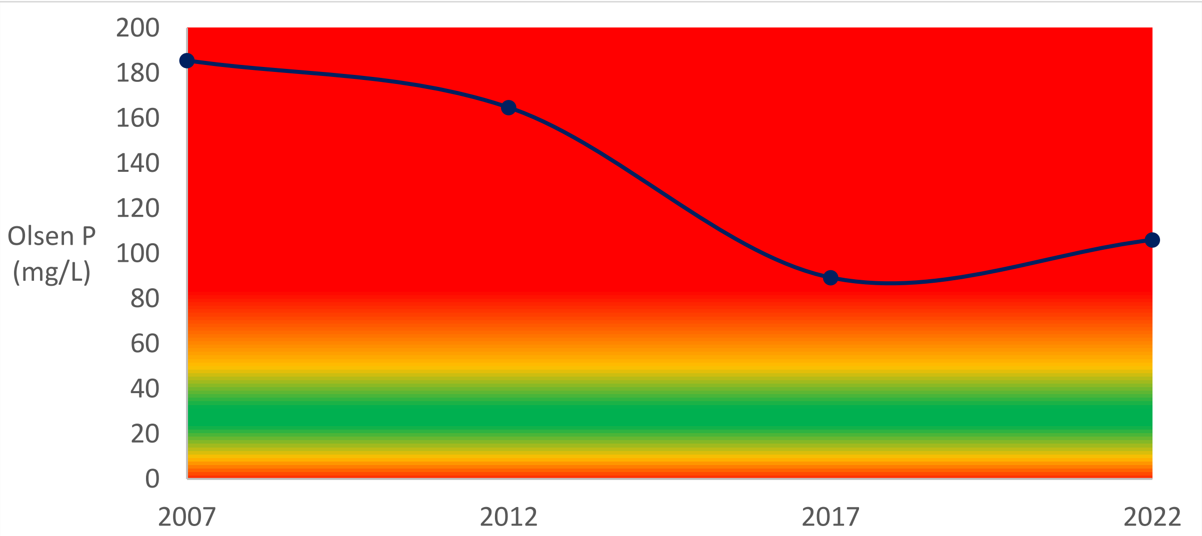

Figure 6. Phosphorous behaviour. Olsen P decreased from extremely high levels but are still well above soil quality guidelines. Outside soil quality targets is shown by the red colour.

Conclusions

Soil initially overirrigated with dairyshed effluent recovered under “typical dairy farm management” to have soil quality more similar to soil quality on other dairy farms in the area over about a decade. Specifically, soil total C was shown to increase under pastoral management, while excessive nutrients in the soil reduced, although Olsen P remains above agronomic guidelines. Further reductions in fertiliser P application are recommended so that Olsen P levels match agronomic requirements.

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