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LESSONS FROM TWENTY YEARS OF SOIL QUALITY MONITORING: WHAT HAPPENS WHEN LAND USE CHANGES?

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Introduction

Monitoring soil quality in the Waikato region has resulted in site specific data over 20-25 years. Over this period, land use has changed at many sites allowing assessment of the long-term impacts of these land use changes on soil quality variables.

Methods

The WRC soil quality monitoring programme is a screening tool or early warning system designed to gather a large amount of information quickly and at a low cost to inform detailed environmental assessment of the region's soils. Currently there are 154 long-term monitoring sites. Soil quality monitoring sites were chosen and sampled according to the methods set out in the national guidelines of the National Environmental Monitoring Standard Soil Quality and trace elements, and the LMF manual (Hill & Sparling, 2009). This manual sets guidance for sample size, representativeness, sampling procedures, analytical methods, target values for results, and archiving of samples where this is not prescribed by the NEMS. For the WRC soil quality monitoring programme, about 30 sites (20%) are sampled annually, meaning that it takes about five years to sample all 154 current sites.

The sites chosen for the WRC soil quality monitoring programme represent dominant soils and land uses, sites capturing the effects of land use. Monitoring sites remain managed by landholders who may choose to change the land use. When this happens, it provides an opportunity to study the impacts of land use change on soil quality monitoring properties.

Soil quality is the chemical, physical, and biological condition of a soil type for a given land use. Seven key variables were measured (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.

In addition, a suite of trace elements was analysed, including cadmium (Cd), which is a contaminant found in mineral phosphate fertilisers and an element of environmental concern (CWG 2011).

Results and Discussion

Six land use changes were identified (Table 1). Not all variables responded to the land use change. Where responses were observed, different types of response were observed. Some land use changes resulted step change in a measured variable coming to a new equilibrium within 5 years, the time of a complete sampling round. A similar variation is where the measured variable has a delay in response and then changes. A third type was where there was a step change in the measured variable followed by a continued linear change and no new equilibrium being set. Other measured variables continued to change in a linear fashion after and use change. Graphs are presented for variables where responses were observed, but not where no change was observed to save space. Each site is presented on the graphs, with the change in land use represented by a change in symbol. Labels refer to the land use followed by the site number, e.g. Dairy 16 is dairy pasture land use at site 16.

Two sites (site 16 and site 30) changed from sheep & beef to dairy about 2000. Olsen P increased and is continuing to trend upwards, consistent with increasing fertility (Figure 1). Macroporosity decreased at the same time, consistent with increased stocking (Figure 2).

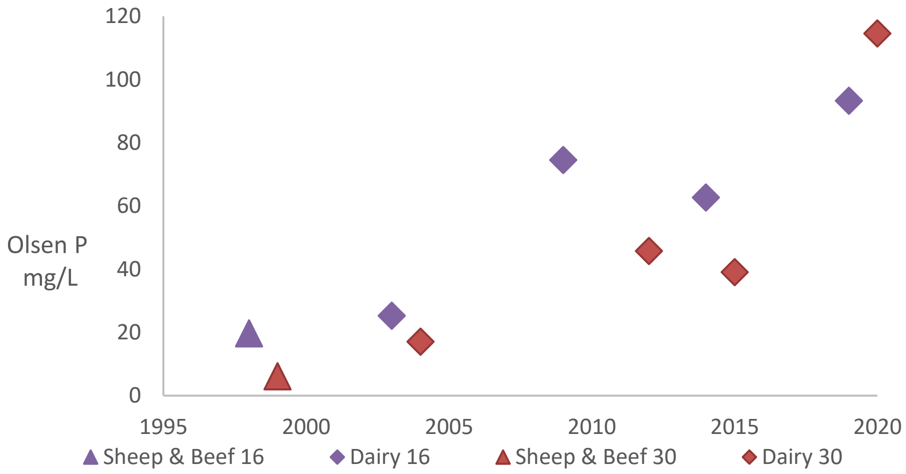

Figure 1. Change in Olsen P with land use change from sheep & beef to dairy.

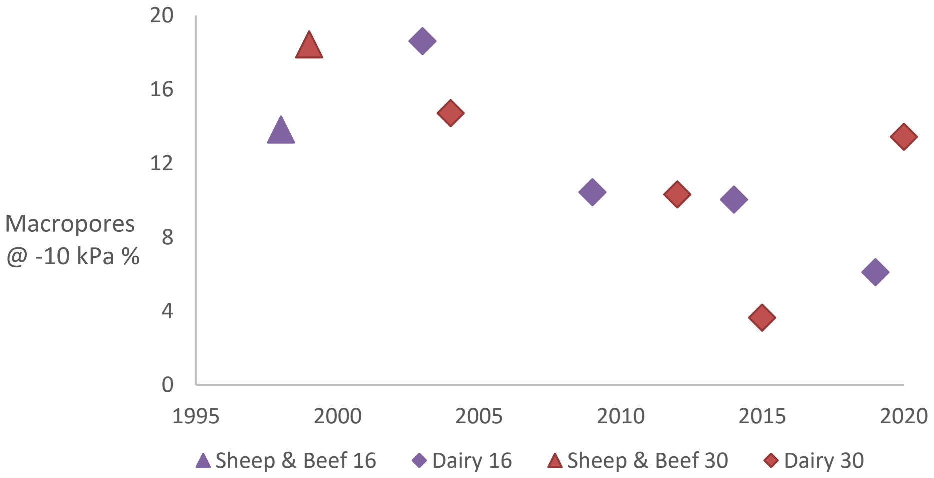

Figure 2. Change in macroporosity with land use change from sheep & beef to dairy.

Table 1 Summary of changes in soil quality monitoring variables with land use change

	Intensity	**pH**	**Total C**	**C:N ratio**	**Olsen P**	**Macroporosity**	**Bulk Density**	**Cd**	**AMN**	**HWC**
Drystock to Dairy	Increased	No change	No change	No change	Increased	Decreased	No change	No change	No change	NA
Pine to Beef	Increased	Increased	No change	Decreased	Increased	Decreased	No change	Increased	Increased	NA
Pine to Dairy	Increased	Increased	Decreased	Decreased	Increased	Decreased	Increased	Increased	No change	NA
Arable to Dairy	About the same	No change	Increased	No change	No change	Decreased	No change	No change	No change	NA
Dairy to Arable	About the same	No change	Decreased	No change	No change	Increased	No change	No change	No change	NA
Sheep to Pine	Decreased	Decreased	No change	No change	No change	No change	No change	No change	Decreased	Decreased

NA = first land use not analysed, so comparison could not be made

One site changed from pine to beef about 2008. The C:N ratio initially stayed the same then decreased although carbon concentrations stayed the same (Figure 3), while pH, Olsen P and Cd (Figures 4-6), increased, consistent with increased fertility and application of lime. AMN also increased, maybe due to increased fertility driving increased microbial activity (Figure 7). Macroporosity decreased at the same time, consistent with increased stocking (Figure 8). However, macroporosity remained well above the critical limit of 10% where decreased production can become apparent.

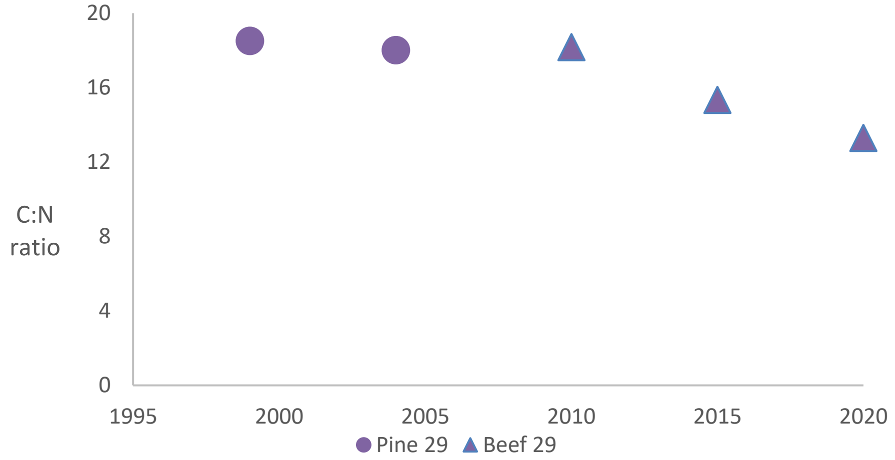

Figure 3. Change in C:N ratio with land use change from pine to beef.

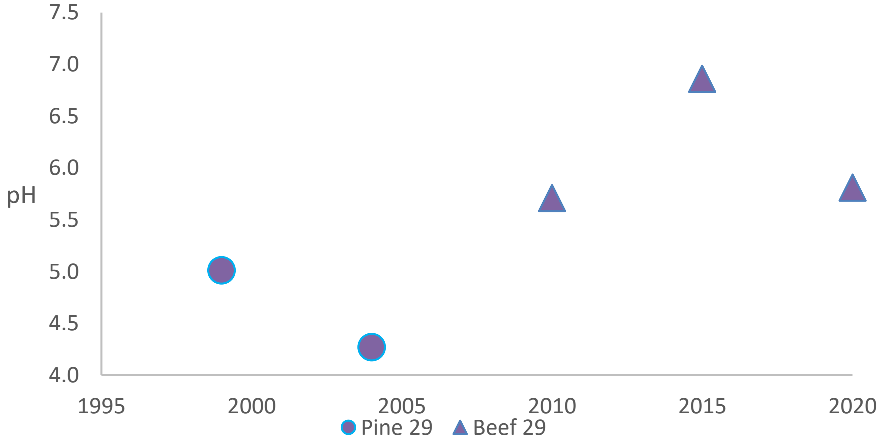

Figure 4. Change in pH with land use change from pine to beef.

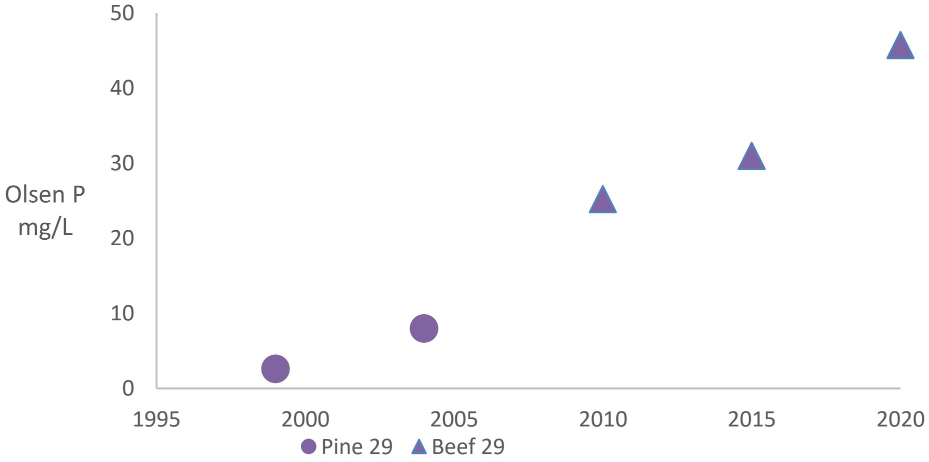

Figure 5. Change in Olsen P with land use change from pine to beef.

Figure 6. Change in cadmium with land use change from pine to beef.

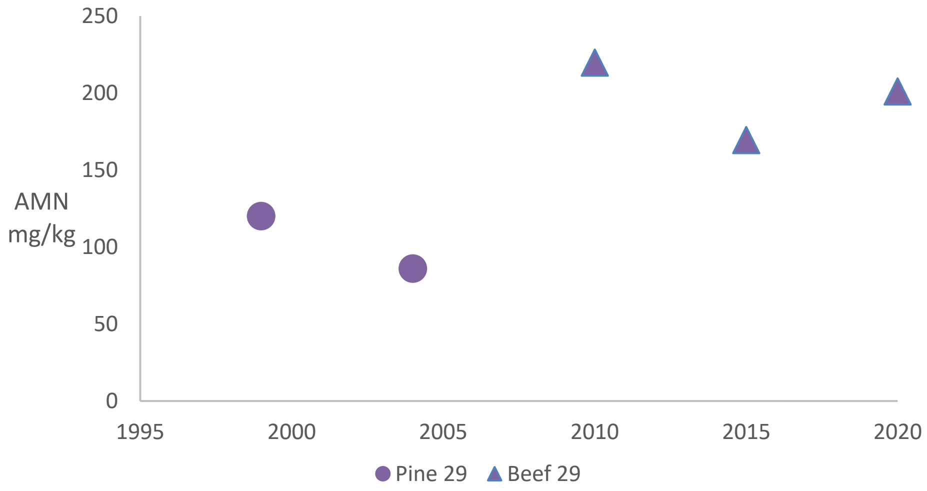

Figure 7. Change in AMN with land use change from sheep & beef to dairy.

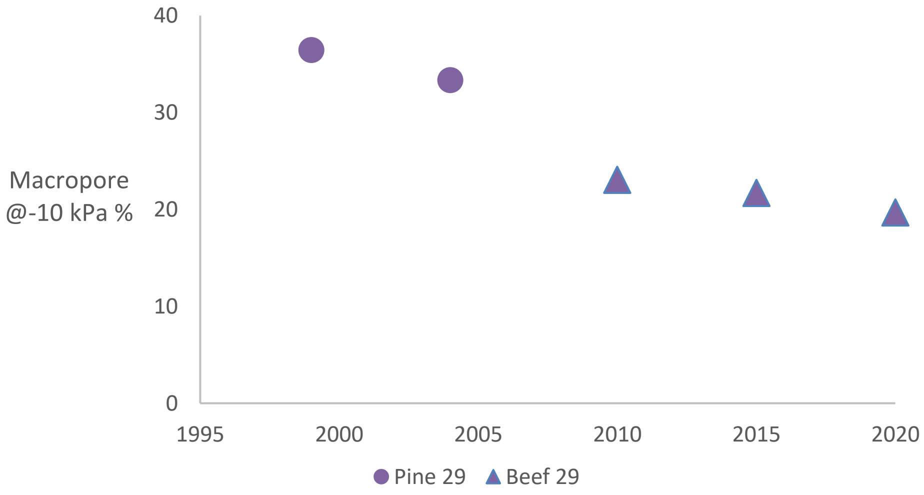

Figure 8. Change in macroporosity with land use change from sheep & beef to dairy.

Four sites changed from pine forestry to dairy about 2008 and one site about 2015. The pH increased consistent with the application of lime (Figure 9). C:N ratio decreased along with total C (Figures 10-11). However, the C:N ratio decreased steadily, while total C dropped considerably in one step in 2008 and then increases slowly. Olsen P, along with Cd, both increased, consistent with increased fertility (Figures 12-13). Macroporosity decreased, while bulk density increased, consistent with surface compaction (Figures 14-15).

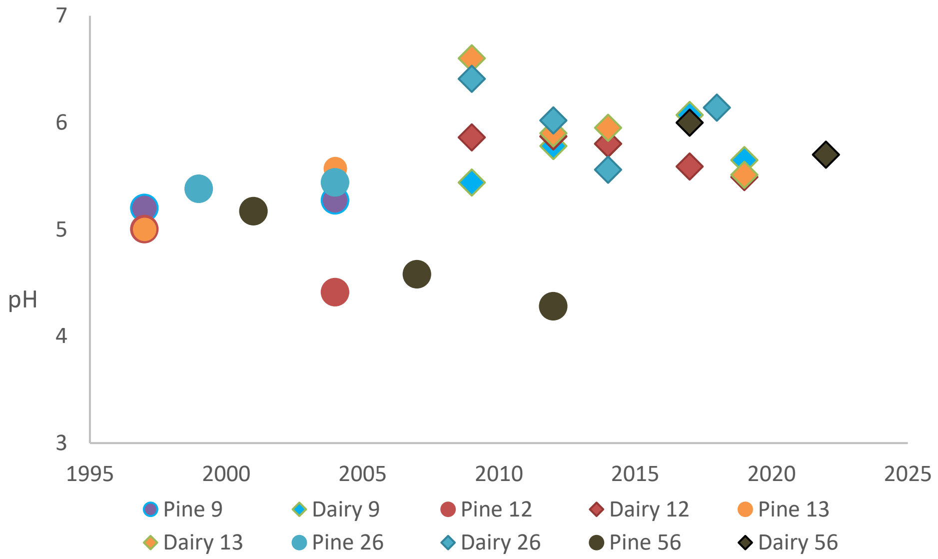

Figure 9. Change in pH with land use change from forestry to dairy.

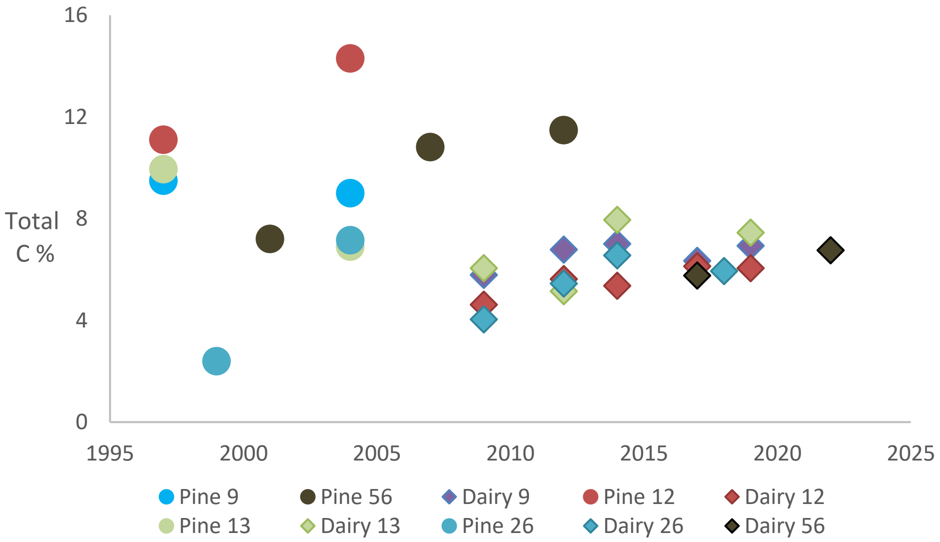

Figure 10. Change in Total C with land use change from forestry to dairy.

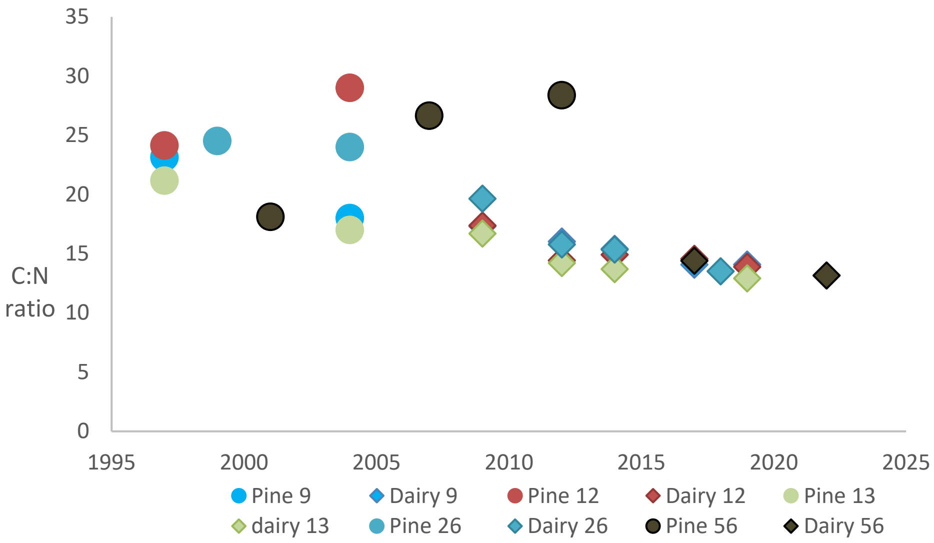

Figure 11. Change in C:N ratio with land use change from forestry to dairy.

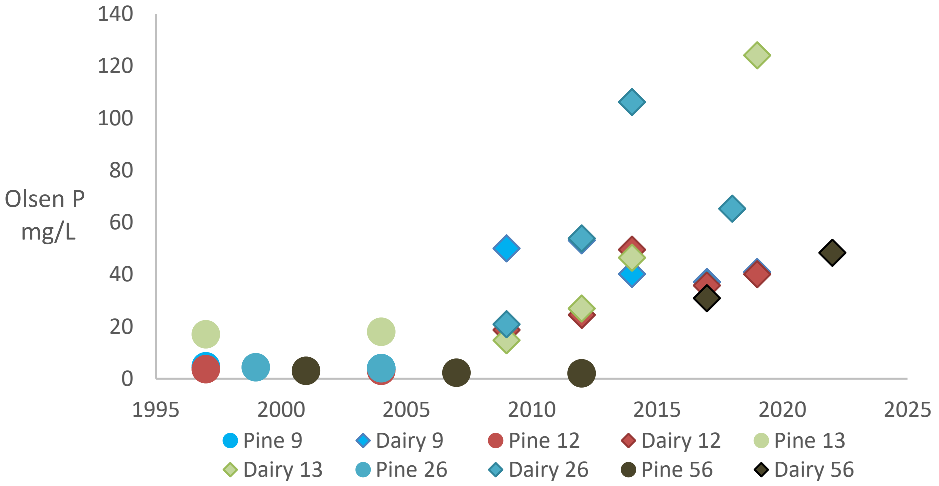

Figure 12. Change in Olsen P with land use change from forestry to dairy.

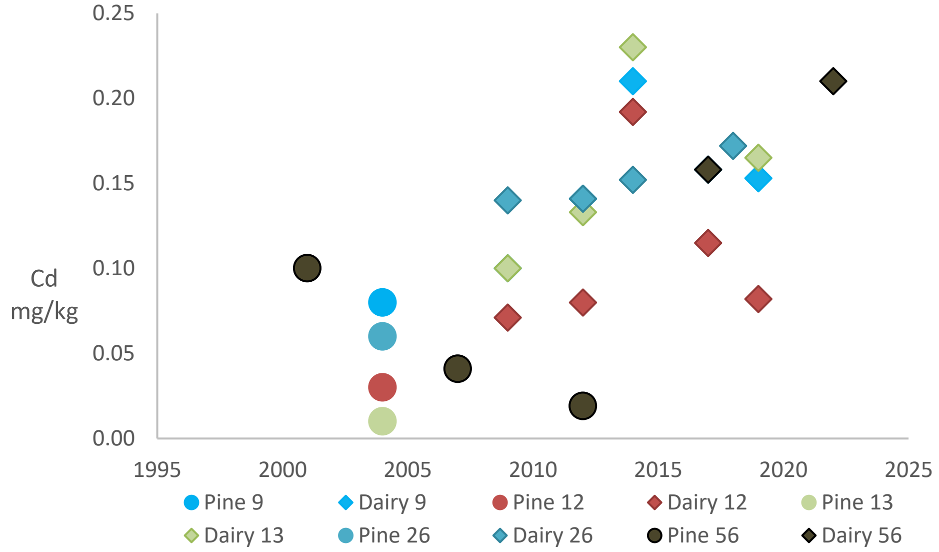

Figure 13. Change in cadmium with land use change from forestry to dairy.

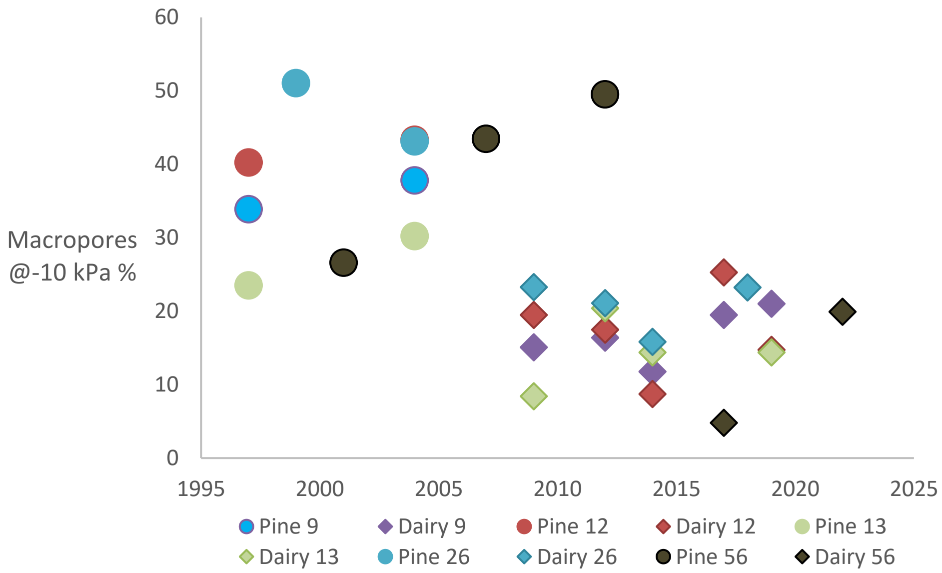

Figure 14. Change in macroporosity with land use change from forestry to dairy.

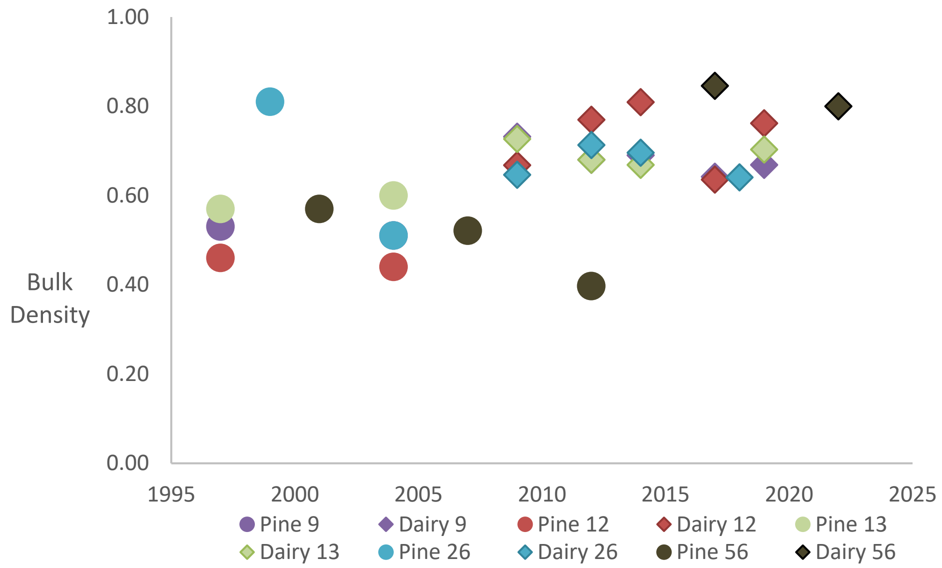

Figure 15. Change in bulk density with land use change from forestry to dairy.

Two sites changed from arable to dairy pasture about 2007. Total C increased but the change appears small at this stage (Figure 16). Macroporosity decreased sharply at site 67 but had already decreased to below 10% at site 46, reflecting different arable management practices at the sites (Figure 17). Site 46 was a market garden with intense vegetable production, while site 67 was used for growing pumpkins but there is no information on other crops or how long the site was previously in arable land use. This highlights the importance of long-term monitoring including collecting data on land management.

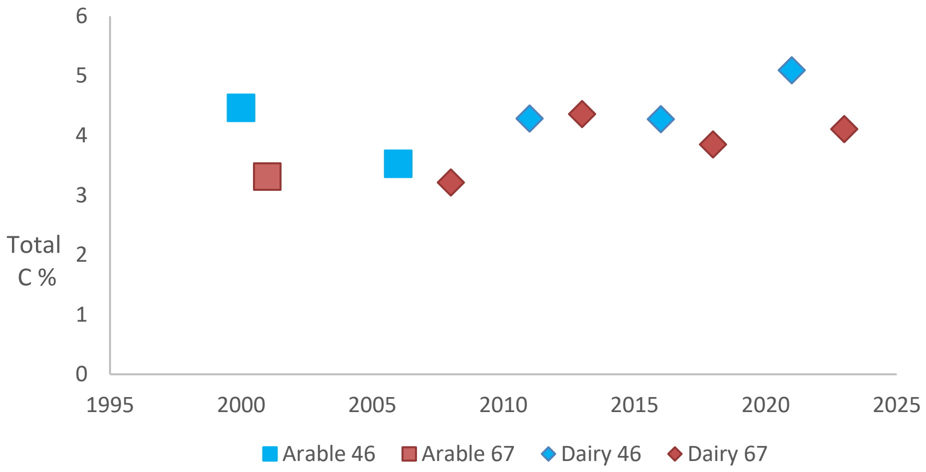

Figure 16. Change in Total C with land use change from arable to dairy.

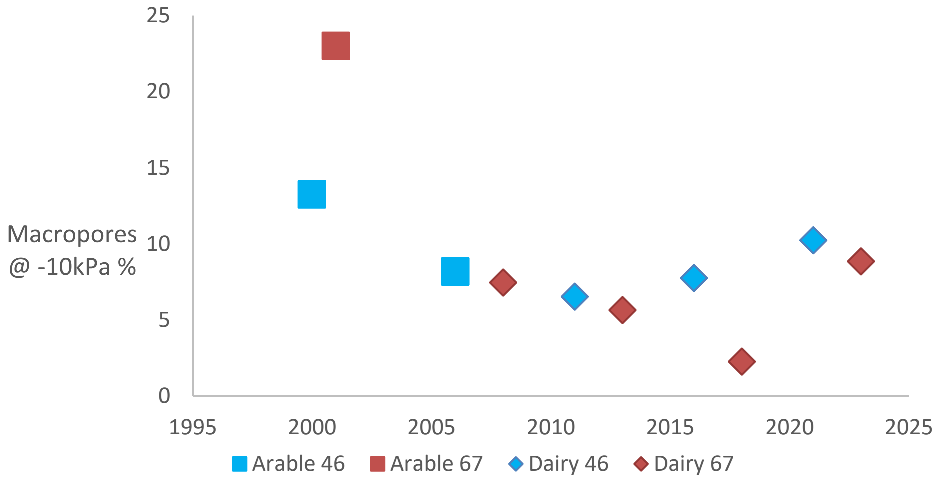

Figure 17. Change in macroporosity with land use change from arable to dairy.

One site changed from dairy pasture to arable in 2014. Total C showed an immediate decline (Figure 18), while AMN showed a larger decline, likely due to cultivation (Figure 19). Macroporosity initially stayed the same but then increased, also probably due to cultivation (Figure 20).

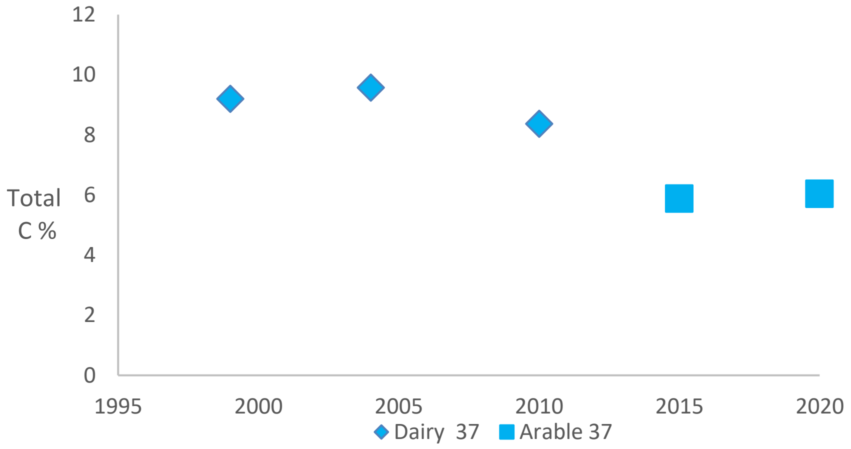

Figure 18. Change in Total C with land use change from dairy to arable.

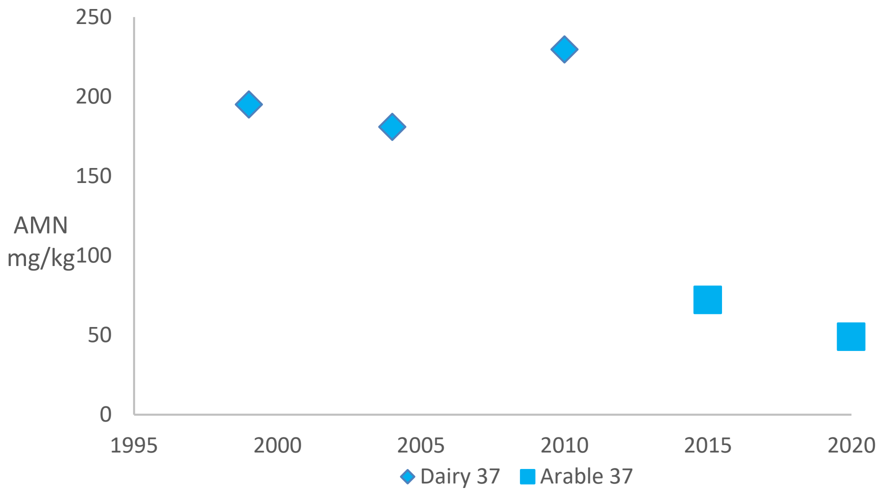

Figure 19. Change in Olsen P with land use change from dairy to arable.

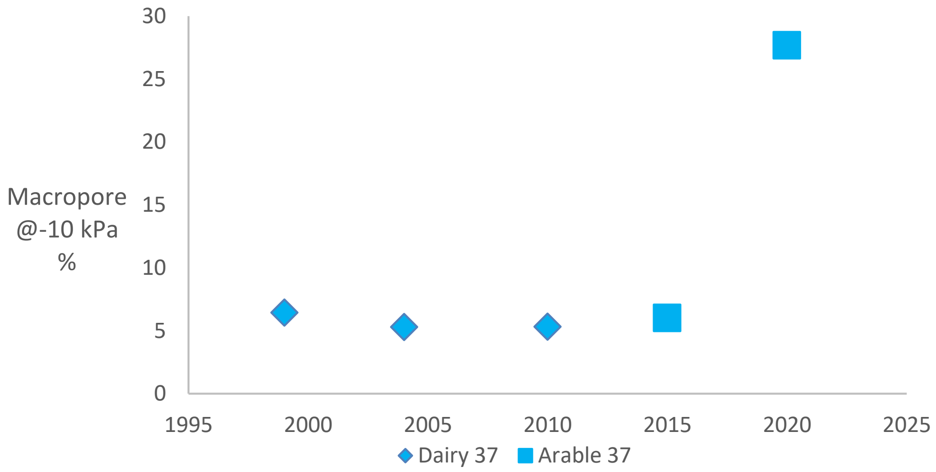

Figure 20. Change in Olsen P with land use change from dairy to arable.

One site changed from sheep pasture to pine forestry in 2014. The pH initially stayed the same but then decreased as the pine forest became established (Figure 21). AMN decreased, consistent with AMN data for long established pasture and cropping (Figure 22, Taylor 2021). This was the one site where hot water extractable carbon (HWC) had also been carried out on the earlier sampling and this data showed similar results to AMN (Figure 23). HWC is being considered as an improvement and replacement for the AMN measurement in soil quality monitoring so is expected to provide similar results, but with greater precision and stronger response to land disturbance (Taylor et al. 2022).

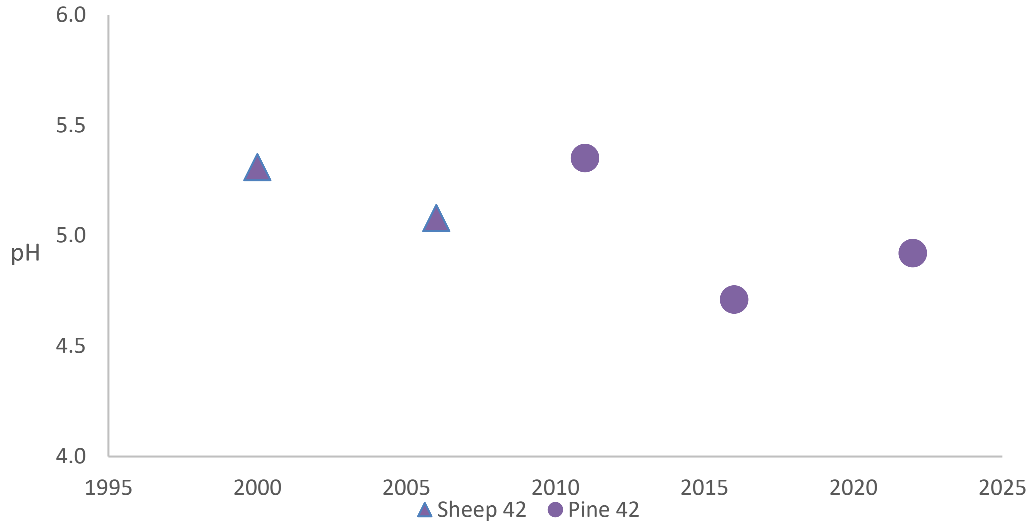

Figure 21. Change in pH with land use change from sheep to pine.

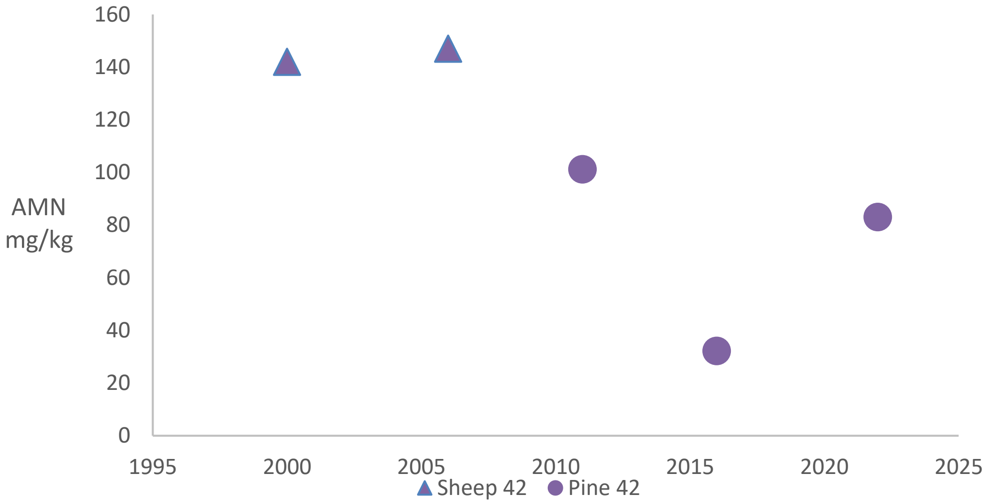

Figure 22. Change AMN with land use change from dairy to arable

Figure 23. Change in Olsen P with land use change from dairy to arable.

The actual number of samples in each land use change category is very low so results should be taken as indicative until validated by additional research and data. However, increased Olsen P and decreased macroporosity was consistent where intensity of land use increased. The issues of excessive nutrients and soil surface compaction in intensive farming systems have been documented in New Zealand for several years (MfE & Stats NZ 2021). Limiting fertiliser application to stay within agronomic recommendations and applying farm management to minimise surface compaction are recommended to minimise adverse effects.

Conclusions

Changes in measured variables were generally explainable with standard land management, e.g. increased pH due to the application of lime.

Some impacts of land use change or change in land management become apparent almost immediately, while other impacts can be delayed. Impacts can be step changes, linear changes over time, or a combination of step change and linear change.

Long-term monitoring and data collection is useful for understanding the impacts of different land management and land use systems.

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