# SOIL QUALITY IN THE MARLBOROUGH REGION IN 2007: CHANGES SINCE 2000


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**Environmental Science and Monitoring Group**

MARLBOROUGH
DISTRICT COUNCIL

Peer Reviewed by:

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**Executive Summary**

The Marlborough District Council (MDC) has a duty under the Resource Management Act (1991) to monitor the "life supporting capacity of soil" and determine whether current practices will meet the "foreseeable needs of future generations". To help meet these goals the MDC undertakes a soil quality monitoring program that involves collecting soil samples from sites that represent the main land use activities and soil types in the Marlborough region and analysing samples for a suite of soil physical, biological and chemical properties that have been shown to be robust indicators of soil quality.

In this investigation soils were sampled from the same 25 sites that were first sampled in 2000. Sites included six different land use activities including vineyards, cropping, pasture, dairy, native bush and exotic forestry representing four different soil orders i.e. Brown, Pallic, Gley and Recent Soils. The reason sites were re-sampled is that it is hoped that periodic monitoring of the same sites will provide an early-warning of potential effects of primary land use on long-term soil quality and also provide an opportunity to track and identify issues relating to the effects of land use on long-term soil quality.

In general, soil quality in the Marlborough region was pretty good with 7 out of 25 sites meeting all their soil quality targets and 16 others only having one indicator out of the target range. However, monitoring has highlighted that there are some soil quality issues under some land use activities in Marlborough.

Cropping sites all had low total carbon concentrations and suffered from surface compaction and in some cases low macroporosity. These results put cropping soils at risk of poor aeration, poor drainage and structural degradation. It is possible that this was due to intensive cultivation and/or insufficient pasture rotations within the mixed cropping rotation.

One of the dairy pasture sites sampled had elevated anaerobically mineralisable nitrogen concentrations. This potentially poses a risk of nitrogen losses via nitrate leaching from soils. Furthermore, the same dairy site also had an elevated Olsen P concentration, which may result in phosphorus leaching if the volume of irrigation applied is greater than the water-holding capacity of this soil.

Two exotic forest sites had high C:N ratios which may limit nitrogen availability in a balanced ecosystem.

Trace element concentrations in Marlborough agricultural soils were generally low and were similar to concentrations found in other parts of New Zealand.

It is recommend that to obtain reliable, long-term detection and prediction of trends in soil quality, at least three and preferably five points along a time sequence should be obtained. Therefore repeat monitoring of sites should be conducted in the medium-term ( $\approx$5 years) to determine trends over time.

## 1.0 Introduction

Regional councils (and Unitary Councils) have a responsibility for promoting the management of the natural and physical resources of their region. One of these physical resources that we have a duty under the Resource Management Act (1991) to monitor in the region is the "life supporting capacity of soil" and whether current practices will meet the "foreseeable needs of future generations". The results of soil monitoring provide information that can be used to change or prioritise the way we manage the land environment. Furthermore, trends determined by the monitoring of soils can be used to develop policies and rules that will protect the sustainability of our land resources.

To help determine what effect land use practices are having on the health of soils in the region, in 2000 the Marlborough District Council began a soil quality monitoring program. The monitoring program was based on a Sustainable Management Fund Project, called Implementing Soil Quality Indicators for Land which was popularly referred as the "500 Soils Project". The monitoring program involved collecting soil samples from sites that represented the main land use activities and soil types within a region and analysing samples for a suite of soil physical, biological and chemical properties that have been shown to be robust indicators of soil quality. It was hoped that periodic monitoring of these sites would provide an early-warning to identify the effects of primary land use on long-term soil quality and also provide an opportunity to track and identify issues relating to the effects of land use on long-term soil quality.

It is recommend that to obtain reliable, long-term detection and prediction of trends in soil quality, at least three and preferably five points along a time sequence should be obtained (Wheeler and Edmeades, 1991). The aim of this study is to report on the results of the second round of soil sampling on a range sites that were originally sampled in 2000 and analysed for a suite of soil physical, biological and chemical properties.

## 2.0 Materials and Methods

### 2.1 Sampling Sites

Soils were sampled from the same 25 sites that were sampled in 2000. In 2000, sites included six different land use activities including vineyards (6), cropping (5), pasture (5), dairy (4), native bush (3) and exotic forest (2) representing four different soil orders, i.e. Brown, Pallic, Gley and Recent Soils. However, as a result of changing land use in the intervening seven years since the last sampling, there were two more vineyards sites and one less pasture and cropping sites i.e. site 11 and 13 respectively. A summary of the soil type, land use and management of sites sampled are given in Table 1. The location of the 25 sites sampled are presented in Figure 1.

## 2.2 Soil Sampling

Two types of soil samples were collected from each site. Firstly a composite sample comprising 25 individual cores taken at 2 m intervals along a 50 m transect at a depth of 100 mm. These samples were used for chemical and biological soil analysis. In addition, three undisturbed soil cores (100 mm diameter by 75 mm depth) were sampled at 15-, 30- and 45-m positions along the transect. The soil cores were removed as one unit by excavation around the liner, bagged and loaded into padded crates for transport to the laboratory for analysis. These soil samples were used for physical soil analysis.

**Table 1** Soil type, land use and management of sites sampled in Marlborough Region

| Site Code | Soil Type | New Zealand Soil Order | Land use; management |
|---|---|---|---|
| Site 1 | Wairau silt loam | Recent | Vineyard; grass in inter-rows |
| Site 2 | Wairau silt loam | Recent | Arable; mixed cropping |
| Site 3 | Wairau fine sandy loam | Recent | Pasture; dairying |
| Site 4 | Renwick shallow silt loam | Pallic | Vineyard; grass in inter-rows |
| Site 5 | Renwick silt loam | Recent | Arable; mixed cropping |
| Site 6 | Renwick shallow silt loam | Pallic | Pasture; deer |
| Site 7 | Paynter clay loam | Pallic | Vineyard; grass in inter-rows |
| Site 8 | Paynter heavy silt loam | Gley | Arable; mixed cropping |
| Site 9 | Paynter heavy silt loam | Pallic | Pasture; dairying |
| Site 10 | Omaka fine sandy loam | Recent | Vineyard; grass in inter-rows |
| Site 11 | Omaka fine sandy loam | Recent | Vineyard; grass in inter-rows |
| Site 12 | Seddon fine sandy loam | Pallic | Vineyard; grass in inter-rows |
| Site 13 | Seddon fine sandy loam | Pallic | Vineyard; grass in inter-rows |
| Site 14 | Seddon silt loam | Pallic | Pasture; sheep |
| Site 15 | Ronga silt Loam | Recent | Indigenous; Bush with beech and Matai trees |
| Site 16 | Ronga silt Loam | Recent | Pasture; dairying |
| Site 17 | Kaituna silt loam | Recent | Indigenous; Bush remnants - Beech & Totara trees |
| Site 18 | Kaituna silt loam | Recent | Pasture; Dairying |
| Site 19 | Kenepuru steepland | Brown | Indigenous; regenerating, mainly Kanuka Bush |
| Site 20 | Kenepuru steepland | Brown | Exotic Forest; *Pinus radiata* forest |
| Site 21 | Kenepuru steepland | Brown | Exotic Forest; *Pinus radiata* forest |
| Site 22 | Kenepuru steepland | Brown | Pasture; sheep |
| Site 23 | Seddon silt loam | Pallic | Arable; continuous cropping for 100 years |
| Site 24 | Wairau fine sandy loam | Recent | Pasture; sheep |
| Site 25 | Renwick silt loam | Pallic | Vineyard; grass in inter-rows |

## 2.3 Soil Quality Measurements

A number of different soil properties were measured to assess soil quality (Table 2). Soil chemical characteristics were assessed by total carbon, total nitrogen, carbon:nitrogen ratio, soil pH and Olsen P. Soil biological activity was determined by measuring anaerobically mineralisable nitrogen (AMN). Soil physical conditions were assessed using bulk density, particle density and water release characteristics which in turn were used to calculate total soil porosity, air capacity and macroporosity.

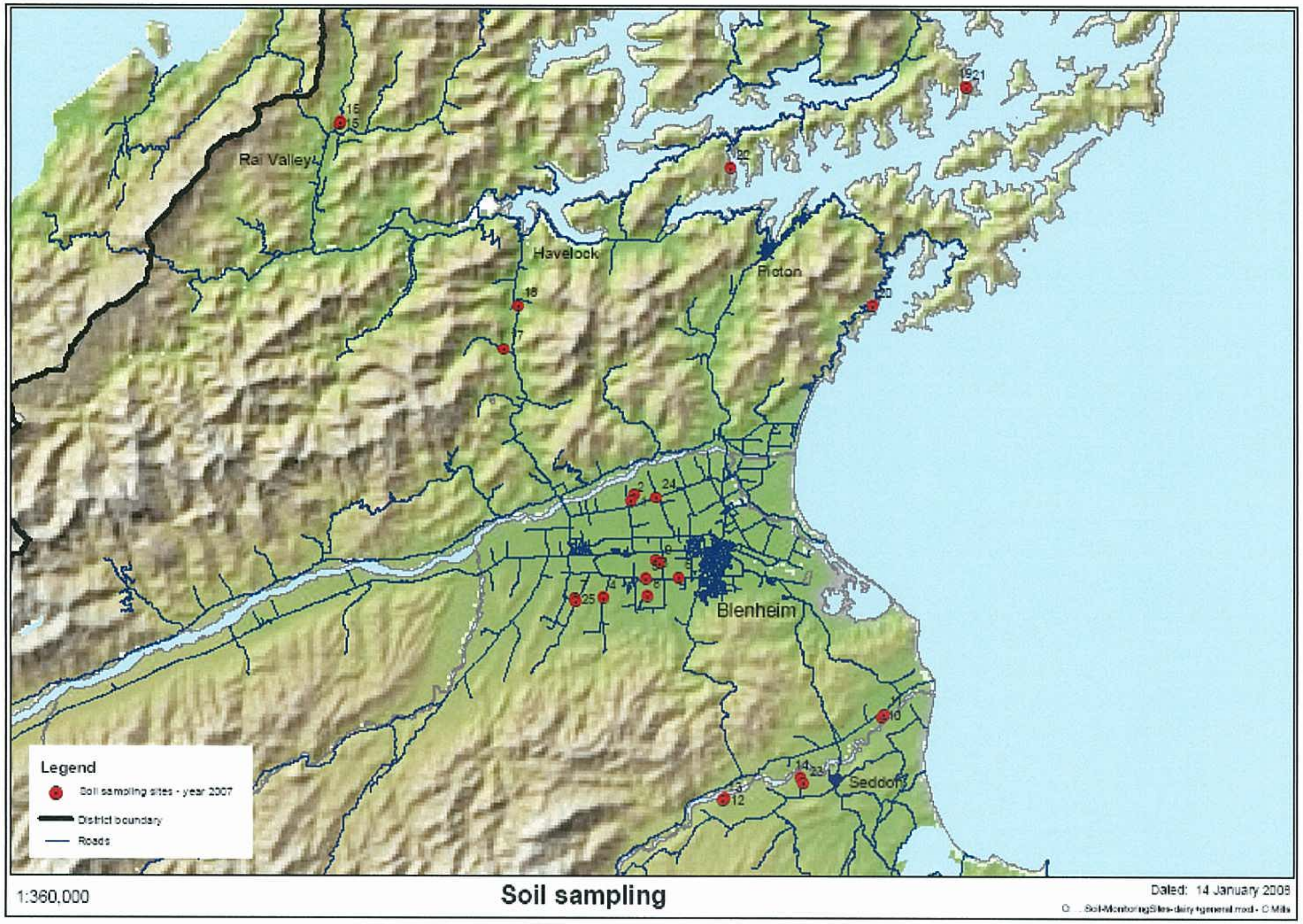


**Figure 1** Location of soil quality sampling sites in Marlborough

**Table 2** Indicators used for soil quality assessment

| Indicators | Soil Quality Information | Method |
|---|---|---|
| **Chemical properties** | | |
| Total carbon content | Organic matter status | Dry combustion, CNS analyser |
| Total nitrogen content | Organic N reserves | Dry combustion, CNS analyser |
| Soil pH | Acidity or alkalinity | Glass electrode pH meter, |
| Olsen P | Plant available phosphate | Bicarbonate extraction, molybdenum blue method |
| **Biological properties** | | |
| Anaerobically mineralisable N | Readily mineralisable nitrogen reserves | Waterlogged incubation at 40 °C for 7 days |
| **Physical properties** | | |
| Dry bulk density | Compaction, volumetric conversions | Soil cores |
| Particle density | Used to calculate porosity and available water | Specific gravity |
| Total porosity, air capacity and macroporosity | Soil compaction, aeration, drainage | Pressure plates |

## 2.4 Soil Analyses

### 2.4.1 Chemical

Total carbon and nitrogen were determined by dry combustion of air-dry soil using a LECO 2000 CNS analyser (Blakemore et al., 1987). Soil pH was measured in water using glass electrodes and a 2.5:1 water to soil ratio (Blackmore et al., 1987). Olsen P was determined by extracting soils for 30 min with 0.5 M $NaHCO_3$ at pH 8.5 (Olsen, 1954) and measuring the phosphate concentration by the molybdenum blue method. Trace element concentrations in soils i.e. total recoverable copper, chromium, cadmium, arsenic, lead, nickel and zinc were determined by digesting soils in nitric/hydrochloric acid and analysing trace elements in the digest by inductively coupled plasma mass spectrometry (US EPA 200.2).

### 2.4.2 Biological

Anaerobically mineralisable nitrogen (AMN) was estimated by the anaerobic incubation method. The increase in $NH_4$-N concentration was measured after incubation for 7 days at 40 °C and extraction in 2 M KCl (Keeney and Bremner, 1966).

### 2.4.3 Physical

Dry bulk density was measured on soil samples extruded from cores and dried in an oven at 105°C until the weight remained constant and the sample was then weighed (Gradwell and Birrell, 1979). Macroporosity (-5 kPa), air capacity (-10 kpa) and total porosity were calculated as described by Klute (1986). Particle density was measured by the pipette method.

2.5 Statistics and Data Display

All data were expressed on a weight/volume or volume/volume basis to allow comparison between soils with differing bulk density. Values from the current samples were compared against archive data sampled in 2000, to calculate the extent of changes in soil properties.

2.6 Targets and Ranges

Target ranges for individual soil characteristics were assessed using 'SINDI'. This is a web-based tool designed by Landcare Research to help interpret the quality of a soil that has been sampled. SINDI allows us to i) compare soil data with information for similar soils stored in the National Soil Database ii) see how our soil measures up against the current understanding of optimal environmental target values and iii) learn about the effect each indicator has on soil quality and some general management practices that could be implemented to improve the soil.

## 3.0 Results and Discussion

3.1 Comparison of Target Ranges

The results of soil chemical/biological and physical analyses from soils sampled at each site are given in Tables 3 and 4 respectively.

Figure 2 shows the proportion of sites not meeting targets for specific indicators in 2007. In general Olsen P was the soil quality indicator most often outside the desired target range followed by macroporosity. These results are similar to what has been found nationally.

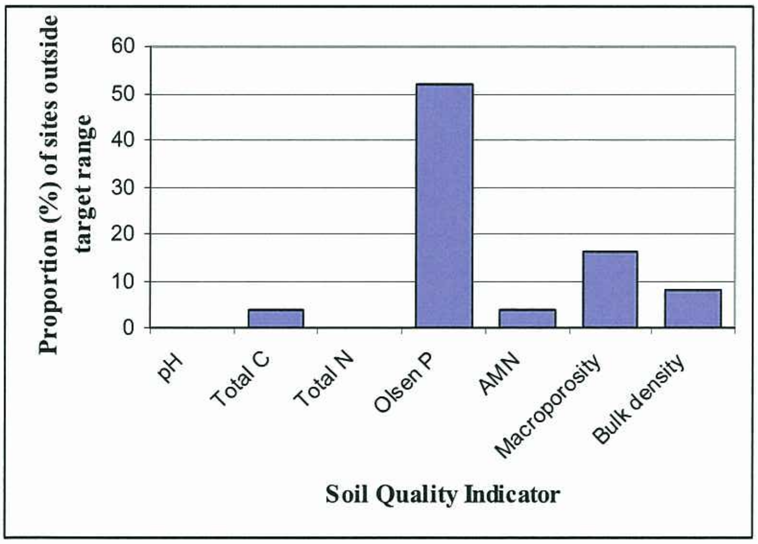


**Figure 2** Proportion of sites not meeting target ranges for indicators in 2007

**Table 3** Chemical and biological characteristic of soils sampled in the Marlborough Region 2007

| Site | Land use | Soil Type | Soil pH | Olsen P (µg cm$^{-3}$) | Total C (mg cm$^{-3}$) | Total N (mg cm$^{-3}$) | C:N ratio | AMN (µg cm$^{-3}$) |
|---|---|---|---|---|---|---|---|---|
| Site 1 | Vineyard | Wairau silt loam | 6.5 | 10 | 44 | 4.13 | 10.6 | 120 |
| Site 2 | Cropping | Wairau silt loam | 6.2 | 52 | 33 | 3.45 | 9.6 | 89 |
| Site 3 | Dairy | Wairau fine sandy loam | 6.4 | 42 | 51 | 5.11 | 10.0 | 131 |
| Site 4 | Vineyard | Renwick shallow silt loam | 6.6 | 39 | 40 | 3.37 | 11.8 | 93 |
| Site 5 | Cropping | Renwick silt loam | 5.9 | 29 | 31 | 3.11 | 10.0 | 55 |
| Site 6 | Pasture | Renwick shallow silt loam | 6.0 | 44 | 45 | 4.58 | 9.7 | 97 |
| Site 7 | Vineyard | Paynter clay loam | 6.1 | 11 | 41 | 4.24 | 9.7 | 87 |
| Site 8 | Cropping | Paynter heavy silt loam | 6.2 | 53 | 41 | 4.79 | 8.5 | 65 |
| Site 9 | Dairy | Paynter heavy silt loam | 6.3 | 127 | 60 | 6.29 | 9.5 | 299 |
| Site 10 | Vineyard | Omaka fine sandy loam | 6.2 | 16 | 43 | 4.07 | 10.6 | 101 |
| Site 11 | Vineyard | Omaka fine sandy loam | 6.8 | 13 | 40 | 4.36 | 9.1 | 105 |
| Site 12 | Vineyard | Seddon fine sandy loam | 6.6 | 12 | 39 | 3.86 | 10.0 | 85 |
| Site 13 | Vineyard | Seddon fine sandy loam | 6.3 | 15 | 41 | 4.00 | 10.3 | 110 |
| Site 14 | Pasture | Seddon silt loam | 5.9 | 13 | 48 | 4.57 | 10.5 | 134 |
| Site 15 | Bush | Ronga silt Loam | 5.3 | 12 | 51 | 4.64 | 10.9 | 124 |
| Site 16 | Dairy | Ronga silt Loam | 5.7 | 21 | 45 | 4.97 | 9.1 | 238 |
| Site 17 | Bush | Kaituna silt loam | 5.4 | 34 | 56 | 4.56 | 12.3 | 134 |
| Site 18 | Dairy | Kaituna silt loam | 6.2 | 35 | 65 | 6.26 | 10.3 | 204 |
| Site 19 | Bush | Kenepuru steepland | 6.0 | 7 | 73 | 4.63 | 15.8 | 213 |
| Site 20 | Exotic Forest | Kenepuru steepland | 5.1 | 7 | 57 | 2.62 | 21.7 | 37 |
| Site 21 | Exotic Forest | Kenepuru steepland | 5.0 | 11 | 60 | 3.16 | 18.9 | 83 |
| Site 22 | Pasture | Kenepuru steepland | 5.3 | 13 | 52 | 4.11 | 12.6 | 138 |
| Site 23 | Cropping | Seddon silt loam | 6.3 | 50 | 25 | 2.63 | 9.5 | 59 |
| Site 24 | Pasture | Wairau fine sandy loam | 5.9 | 15 | 48 | 4.49 | 10.7 | 118 |
| Site 25 | Vineyard | Renwick silt loam | 6.4 | 81 | 47 | 4.33 | 10.9 | 78 |

**Table 4** Physical characteristic of soils sampled in the Marlborough Region 2007

| Site | Land use | Soil Type | Bulk density (Mg m$^{-3}$) | Particle density (Mg m$^{-3}$) | Total porosity (% v/v) | Macro-porosity (%v/v) | Air-filled porosity (%v/v) |
|---|---|---|---|---|---|---|---|
| Site 1 | Vineyard | Wairau silt loam | 1.18 | 2.62 | 54.9 | 14.4 | 16.83 |
| Site 2 | Cropping | Wairau silt loam | 1.50 | 2.65 | 43.7 | 6.9 | 3.97 |
| Site 3 | Dairy | Wairau fine sandy loam | 1.28 | 2.58 | 50.5 | 8.9 | 11.20 |
| Site 4 | Vineyard | Renwick shallow silt loam | 1.21 | 2.57 | 53.1 | 16.3 | 18.67 |
| Site 5 | Cropping | Renwick silt loam | 1.35 | 2.62 | 48.4 | 11.8 | 14.33 |
| Site 6 | Pasture | Renwick shallow silt loam | 1.31 | 2.60 | 49.7 | 13.1 | 16.60 |
| Site 7 | Vineyard | Paynter clay loam | 1.21 | 2.57 | 52.8 | 7.3 | 10.83 |
| Site 8 | Cropping | Paynter heavy silt loam | 1.41 | 2.61 | 46.0 | 5.4 | 6.77 |
| Site 9 | Dairy | Paynter heavy silt loam | 1.07 | 2.52 | 57.7 | 5.4 | 6.97 |
| Site 10 | Vineyard | Omaka fine sandy loam | 1.23 | 2.62 | 53.0 | 16.5 | 19.23 |
| Site 11 | Vineyard | Omaka fine sandy loam | 1.28 | 2.63 | 51.2 | 8.9 | 15.47 |
| Site 12 | Vineyard | Seddon fine sandy loam | 1.33 | 2.64 | 49.6 | 9.8 | 12.40 |
| Site 13 | Vineyard | Seddon fine sandy loam | 1.21 | 2.64 | 54.2 | 11.4 | 15.73 |
| Site 14 | Pasture | Seddon silt loam | 1.17 | 2.59 | 54.9 | 13.9 | 16.97 |
| Site 15 | Bush | Ronga silt Loam | 0.84 | 2.56 | 67.0 | 15.3 | 18.43 |
| Site 16 | Dairy | Ronga silt Loam | 0.94 | 2.57 | 63.5 | 5.4 | 7.30 |
| Site 17 | Bush | Kaituna silt loam | 1.06 | 2.61 | 59.2 | 13.4 | 15.00 |
| Site 18 | Dairy | Kaituna silt loam | 1.01 | 2.54 | 60.2 | 3.9 | 6.13 |
| Site 19 | Bush | Kenepuru steepland | 1.22 | 2.65 | 54.4 | 14.1 | 16.13 |
| Site 20 | Exotic Forest | Kenepuru steepland | 1.09 | 2.62 | 58.2 | 26.7 | 28.17 |
| Site 21 | Exotic Forest | Kenepuru steepland | 1.17 | 2.58 | 54.7 | 23.0 | 23.23 |
| Site 22 | Pasture | Kenepuru steepland | 0.96 | 2.58 | 63.0 | 17.9 | 19.67 |
| Site 23 | Cropping | Seddon silt loam | 1.32 | 2.67 | 50.8 | 18.0 | 20.70 |
| Site 24 | Pasture | Wairau fine sandy loam | 1.10 | 2.57 | 57.4 | 14.1 | 16.17 |
| Site 25 | Vineyard | Renwick silt loam | 1.27 | 2.60 | 51.1 | 11.9 | 13.37 |

The differences in results between samples taken in 2000 and 2007 for specific indicators are discussed and presented as a series of bar graphs (Figures 3 – 10). A negative bar on the graph indicates that the soil characteristic has declined since the earlier sampling. Note that a decline is not necessarily a bad thing. For example a decline in a high fertility level would be viewed as a positive trend. However a decline in total C would generally be viewed as a negative trend.

3.2 Soil pH

Soil pH is a measure of the acidity and alkalinity in soil. It is an important soil indicator because it affects nutrient and contaminant availability in plants and the functioning of beneficial soil macro- and micro-organisms. Most plants and soil organisms will have an optimum pH range for growth, and the pH of the soil affects which species will grow best. For example, most forest soils in New Zealand are acidic and indigenous forest species are generally tolerant of acid conditions. In contrast, introduced exotic pasture and crop species require more alkaline conditions.

The range of pH values measured from the different land uses are typical of those found elsewhere, with indigenous and exotic forest soils generally being slightly more acidic than those found under cropping, pastoral and viticulture land uses (Table 3). Soil pH showed both positive and negative changes depending on the site between 2000 and 2007 (Figure 3). Overall, the average soil pH increased marginally by $0.09 \pm 0.36$ but was highly variable. All sites had values that were within acceptable target ranges for their respective land use.

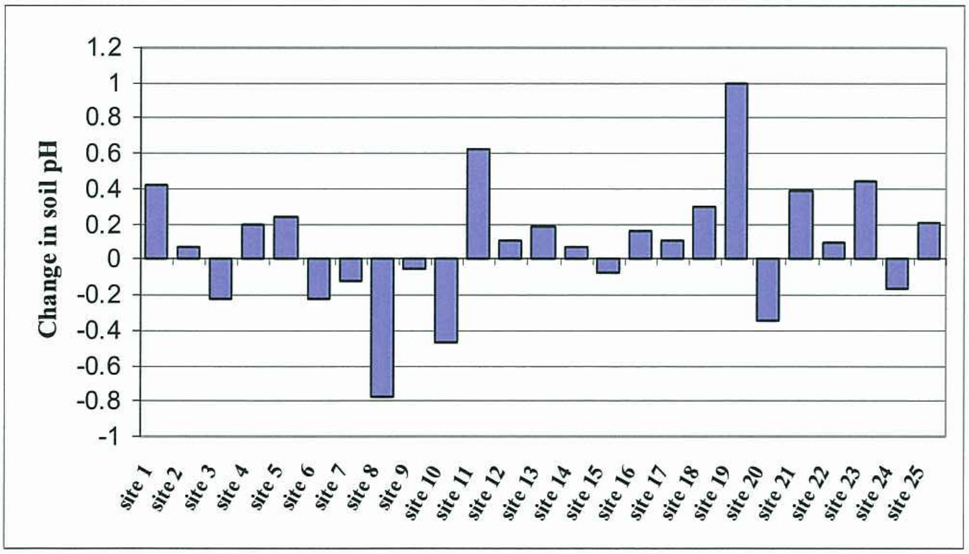


**Figure 3** Change in soil pH in soils sampled in 2000 and 2007

3.3 Total Soil Carbon

Total carbon is the total amount of carbon in soil which includes carbonates and soil organic matter carbon. Typically New Zealand soils contain only small amounts of carbonate; hence total carbon is generally considered a good measure of organic matter carbon in soil. Organic matter is important for soil quality because it helps soil retain moisture and nutrients, it contributes to a stable soil structure and it provides a source of energy for soil microbes.

Total soil carbon concentrations were generally lowest in cropping soils, while pasture and indigenous forest soils showed the widest range (from 45 to 73 mg cm$^{-3}$; Table 3). There was an overall small increase in the total soil carbon content of 5.32 ± 8.15 mg cm$^{-3}$ in soils sampled in 2007, but there was a wide scatter of values (Figure 4). With the exception of site 23 (a continuously cropped site) that had a total carbon content below the target range, all values were within acceptable target ranges for their respective land use activity. However, the other three cropping sites sampled i.e. 2, 5 and 8 had soil carbon contents at the lower boundary of the target range. These results may put cropping soils at risk of poor aeration, poor drainage and soil structural degradation. In contrast the highest soil carbon value was found at one of the indigenous sites i.e. 19. This was principally due to the peaty loam present in the top 2 cm of this soil.

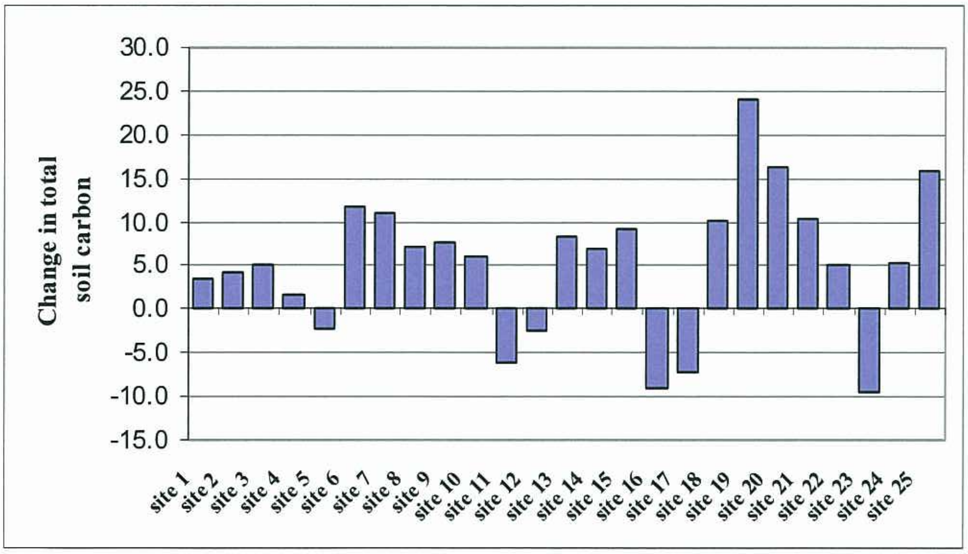


**Figure 4** Change in total soil carbon (mg cm$^{-3}$) in soils sampled in 2000 and 2007

3.4 Total Soil Nitrogen

Nitrogen is an essential major nutrient for plants and animals, and the store of organic matter nitrogen is an important measure of soil fertility. Typically in topsoils, organic matter nitrogen comprises more than 90% of the total nitrogen. However organic matter nitrogen needs to be mineralised to inorganic forms (i.e. ammonium and nitrate) by soil microbes before it can be utilised by plants.

Total soil nitrogen concentrations were generally highest at the dairy sites and lowest in exotic forest sites (Table 3). Like for total carbon, there was an overall increase of 0.92 ± 0.63 mg $cm^{-3}$ in total N in 2007 (Figure 5). All sites were within acceptable target ranges for their respective land use, however three sites i.e. 2, 6 and 23 had total nitrogen contents at the lower boundary of the target range. For most of the sites sampled, any increase (or decrease) in total nitrogen matched the increase or decrease in total soil carbon. This indicates that most of the soil nitrogen was associated with soil organic matter as expected.

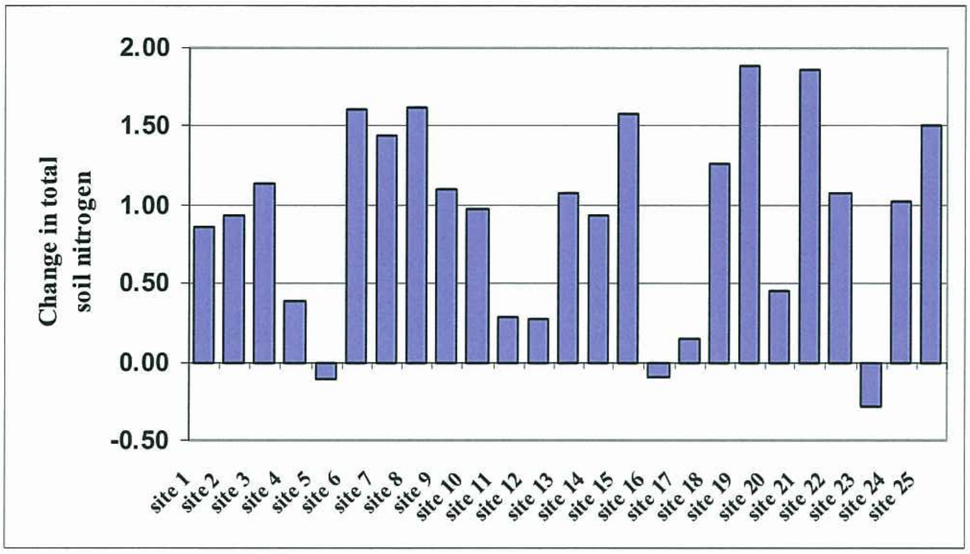


**Figure 5** Change in total soil nitrogen (mg $cm^{-3}$) in soils sampled in 2000 and 2007

3.5 C:N Ratio

The balance of the amount of carbon:nitrogen in soil is called the carbon-nitrogen ratio (C:N). This ratio is important as a guide to the state of decomposition or likely ease of decomposition and mineralization of nutrients from organic residues in soils and is a measure of organic matter quality.

Most sites had acceptable C:N ratios, apart from the two exotic forest sites i.e. 20 and 21 where ratios of 22:1 and 19:1 were measured that may lead to limited nitrogen availability (Table 3). These sites also had comparatively low concentrations of total nitrogen and AMN (Table 3). There was an overall decrease in the C:N ratio of 2.02 ± 3.78 (Figure 6) in 2007, although this was largely influenced by the unexpected large decrease in the C:N ratio for site 21. Further sampling at this site would be required to confirm this trend.

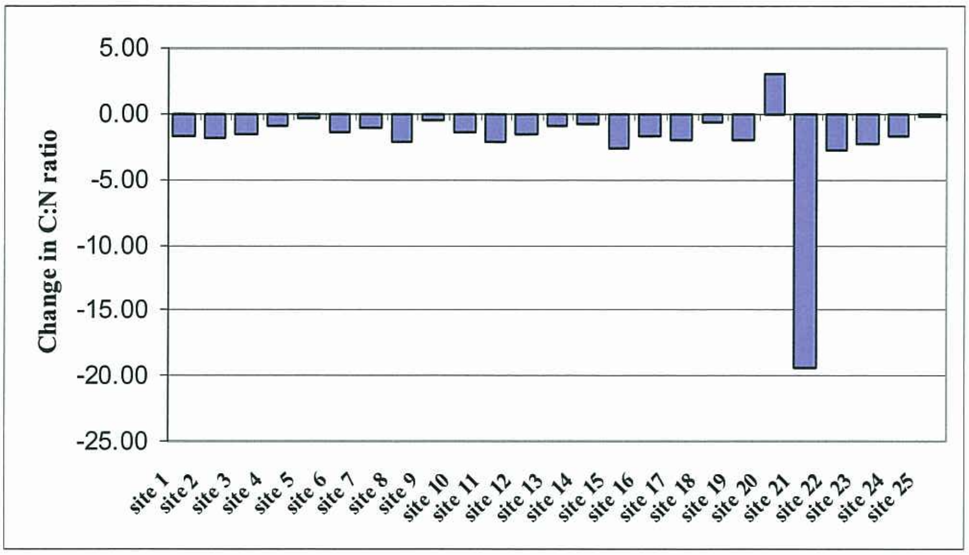


**Figure 6** Change in C:N ratio in soils sampled in 2000 and 2007

3.6 Olsen P

Phosphorus is an essential nutrient for both plants and animals. Only a small amount of the total phosphorus in soil is in forms able to be taken up by plants (plant-available P). The Olsen P method is a chemical extractant that provides a reasonable estimate of the amount of plant-available phosphorus by measuring phosphate from soil solution and exchange surfaces. A high Olsen P value in soil may result in phosphorus losses from soil which potentially can have a negative impact on water quality.

Olsen P concentrations varied greatly between sites with values in general lower at the indigenous and exotic forestry sites and higher on the cropping and dairy sites (Table 3). There was an overall small increase in Olsen P concentrations of $1.12 \pm 18.44$ µg $cm^{-3}$ in soils sampled in 2007, but values had a very wide scatter (Figure 7).

Olsen P concentrations in soils were generally low, with 12 of the 25 sites having concentrations below their target range for the particular land use. In contrast, at one of the dairy sites i.e. site 9 the Olsen P value was higher than the target range. Olsen P concentrations in soils can be increased relatively easily by the application of phosphate fertilisers to soil, hence the large number of low values are not of major concern. An Olsen P concentration above the target range is regarded as more important as it can lead to water quality issues if phosphorous is lost from soil by leaching or overland flow.

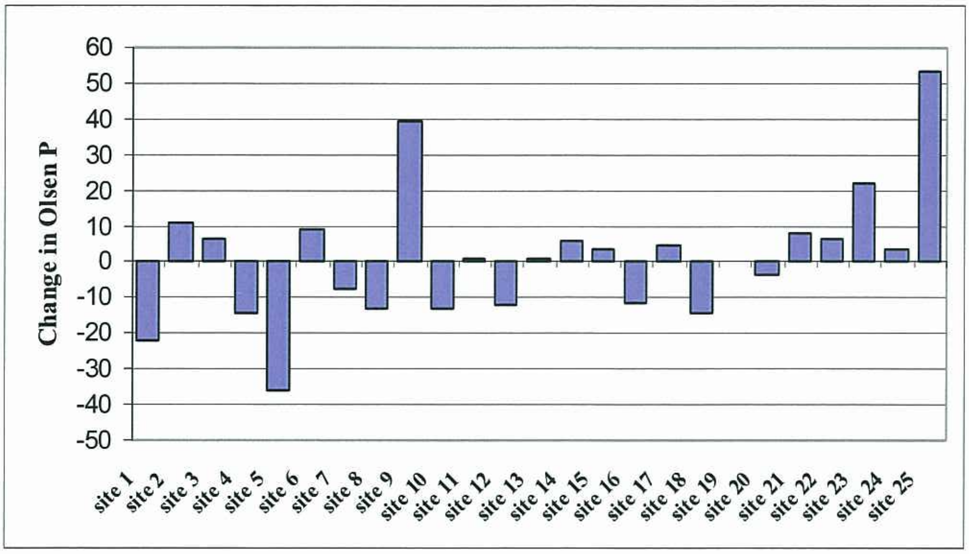


**Figure 7** Change in Olsen P (μg cm$^{-3}$) in soils sampled in 2000 and 2007

3.7 Anaerobically Mineralisable Nitrogen

Anaerobically mineralisable nitrogen is a measure of the amount of nitrogen that can be supplied to plants through the decomposition of soil organic matter by soil microbes. It is a useful measure of the soil organic matter quality in terms of its ability to store nitrogen. However, the amount of AMN has also been found to correspond with the amount of soil microbial biomass – hence it is also a useful indictor of microbial activity in soils.

There were some large changes in anaerobically mineralisable nitrogen at some sites i.e. 9 and 19 had large increases and site 5 and 20 had large decreases (Figure 8). Averaged across all sites there was a slight increase in AMN of 11.31 ± 45.53 μg cm$^{-3}$. The large changes on the forest and bush sites could reflect the inherent difficulties of sampling these types of soils where there is a significant organic layer overlying the mineral soil. The decrease and increase in sites 5 and 9 probably reflect the changes in total soil C at these two sites which also decreased and increased respectively.

With the exception of site 9 which had an excessive AMN concentration, all values were within the target range for their respective land use activity. However for 13 of 25 sites sampled, AMN values in soils were at the lower end of the target range, and at the higher end of the target for two additional sites (Table 3). Anaerobically mineralisable nitrogen values in soils can be increased by the application of nitrogen fertilisers to soil or raised by increasing the proportion of legumes in the pastures by liming, fertilising and oversowing of pastures, by ploughing in green manures to cropped soils, or by direct additions of organic matter (e.g. composted wastes) to the soil, hence the large number low values are not of concern. An AMN value above the target range is regarded as more important as it can lead to water quality issues if nitrogen is lost from soil by leaching or overland flow.

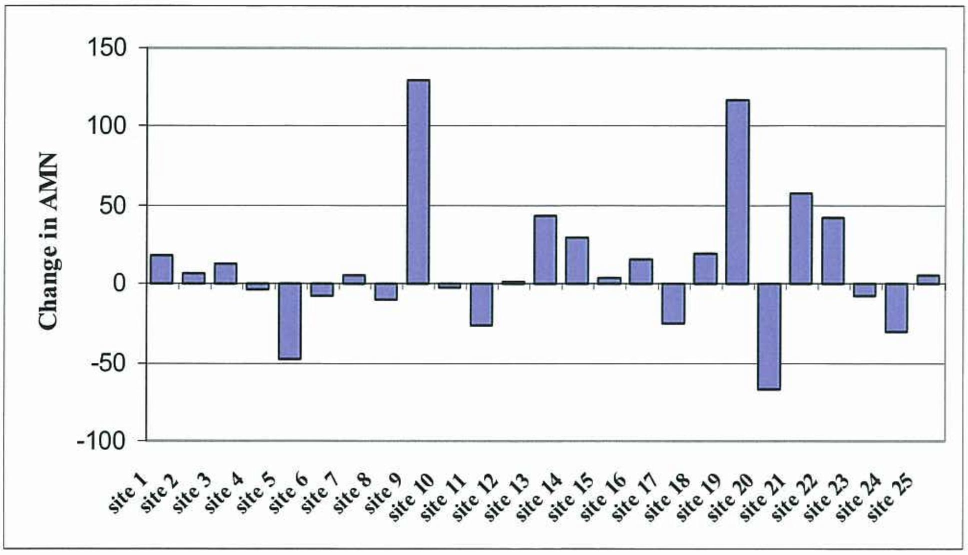


**Figure 8** Change in anaerobically mineraliseable nitrogen (µg cm$^3$) in soils sampled in 2000 and 2007

3.8 Bulk Density

Bulk density is the weight of soil in a specified volume and provides a measure of how loose or compacted a soil is. Loose soils may be subject to increased risk of erosion, dry out quickly, and plant roots find it difficult to get purchase and absorb water and nutrients. In contrast, compacted soils have poor aeration and are slow draining. The consequences of compacted soil may include reduced supply of air to plant roots, increased resistance to penetration that may limit root extension and germination, and reduced capacity of the soil to store water that is available to plants. Further, reduced water entry into the soil may increase water runoff over the soil surface.

Bulk density values for the cropping land uses were all above 1.30 Mg m$^{-3}$, possibly due to surface compaction from wheel traffic and/or structural collapse (Table 4). However, for any given land use it appears that within site variation was greater than between site variation.

Results for 2007 indicate there was an overall small decrease in soil bulk density of 0.02 ± 0.13 Mg m$^{-3}$ (Figure 9).

Two sites i.e. 2 and 8 both cropping sites had very compacted bulk densities outside the target range. Further, two other sites i.e. 5 a cropping site and site 12 a vineyard site had bulk density values at the upper end of the target range. The high bulk density values could be associated with the relatively low organic matter contents in the cropping soils which is an integral component of stable structure in soils, coupled with the use of heavy machinery. Whilst the low value at the vineyard site could also be related to heavy machinery use because soils at the vineyard sites were sampled in the inter-rows. Conversely one site had a loose bulk density i.e. site 15 which is a bush site and was the same result as was found in 2000.

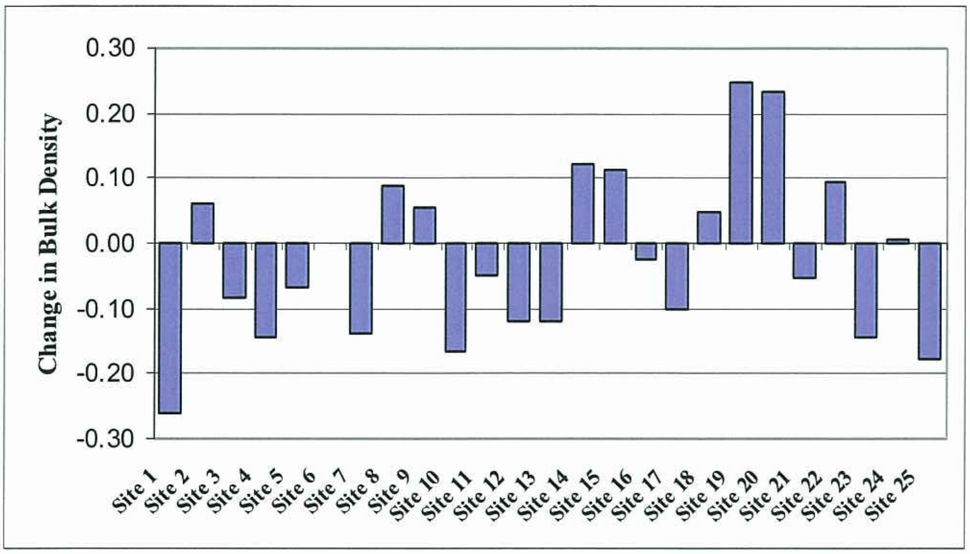


**Figure 9** Change in bulk density (Mg $m^{-3}$) in soils sampled in 2000 and 2007

3.9 Macroporosity

Macroporosity is a measure of the proportion of large pores (about 60 microns in diameter) in the soil. Macropores are important for air penetration into soil, extension of roots into the soil and drainage of water. Typically macropores and are the first to be lost when the soil is compacted.

Macroporosity increased between the two sampling times (Figure 10) with an average across all sites of $3.7 \pm 4.0$ % v/v. Four sites did not meet their target for macroporosity. These included three dairy sites sampled i.e. 9, 16 and 18 and one of the cropping sites i.e. 8. Low values on the dairy sites could be due to heavy grazing or grazing under wet conditions where animal treading can lead to pugging of soil. This has been shown to reduce soil aeration and drainage and potentially reduce pasture production. On the cropping site, the low macroporosity may be related to machinery use.

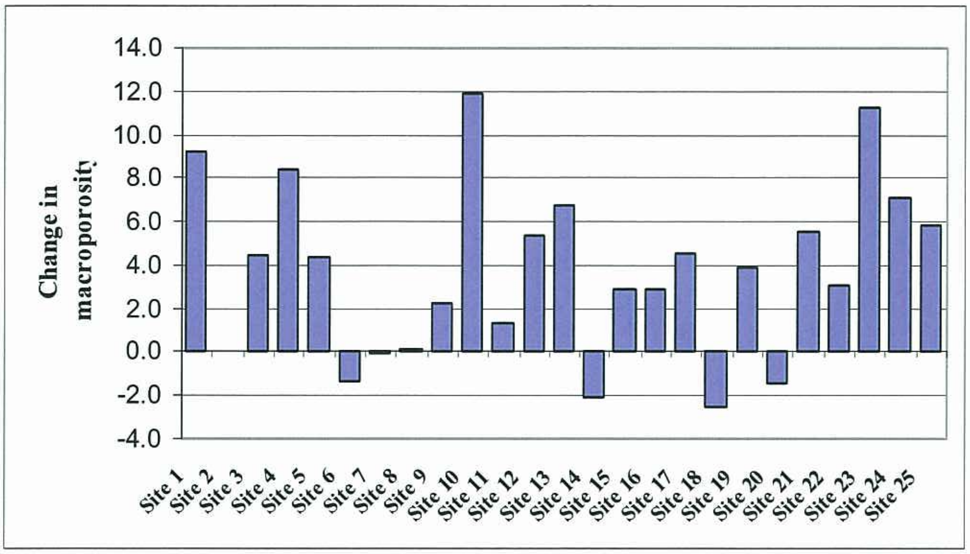


**Figure 10** Change in macroporosity (% v/v) in soils sampled in 2000 and 2007

## 3.10 Trace Elements

Trace elements can accumulate in soils from a range of different sources. At elevated concentrations these have the potential to have an adverse effect on soil and plant fertility, animal health and in some cases accumulate in the human food chain. It is therefore important we have information on the concentrations of key trace element in soils. For that reason trace element concentrations were incorporated into the soil quality monitoring program for 2007.

Table 5 summarises trace element concentrations in soils from the 25 sites. On average concentrations were 5 $\mu g\ cm^{-3}$ for arsenic, 0.18 $\mu g\ cm^{-3}$ for cadmium, 26 $\mu g\ cm^{-3}$ for chromium, 21 $\mu g\ cm^{-3}$ for copper, 20 $\mu g\ cm^{-3}$ for nickel, 16 $\mu g\ cm^{-3}$ for lead and 88 $\mu g\ cm^{-3}$ for zinc. These concentrations are low and are similar to concentrations found in other parts of New Zealand. Furthermore, concentrations are similar to typical background concentrations found in New Zealand soils.

With the exception of cadmium, there didn't appear to be any difference in trace element concentrations between land use activities. For cadmium it was found that there were higher concentrations on dairy sites; most likely related to higher inputs of phosphate fertiliser which has been shown to contain cadmium as an incidental impurity.

**Table 5** Trace element (μg $cm^{-3}$) concentrations for soils sites sampled in the Marlborough Region in 2007

| Code | Land use | Soil Type | As (μg $cm^{-3}$) | Cd (μg $cm^{-3}$) | Cr (μg $cm^{-3}$) | Cu (μg $cm^{-3}$) | Ni (μg $cm^{-3}$) | Pb (μg $cm^{-3}$) | Zn (μg $cm^{-3}$) |
|---|---|---|---|---|---|---|---|---|---|
| Site 1 | Vineyard | Wairau silt loam | 5 | 0.2 | 24 | 28 | 34 | 17 | 86 |
| Site 2 | Cropping | Wairau silt loam | 8 | 0.3 | 36 | 32 | 50 | 25 | 128 |
| Site 3 | Dairy | Wairau fine sandy loam | 5 | 0.3 | 18 | 22 | 13 | 31 | 106 |
| Site 4 | Vineyard | Renwick shallow silt loam | 4 | 0.1 | 17 | 46 | 14 | 13 | 87 |
| Site 5 | Cropping | Renwick silt loam | 5 | 0.1 | 23 | 19 | 16 | 18 | 101 |
| Site 6 | Pasture | Renwick shallow silt loam | 4 | 0.1 | 25 | 14 | 20 | 15 | 103 |
| Site 7 | Vineyard | Paynter clay loam | 2 | 0.1 | 16 | 25 | 12 | 12 | 89 |
| Site 8 | Cropping | Paynter heavy silt loam | 6 | 0.1 | 24 | 18 | 16 | 20 | 118 |
| Site 9 | Dairy | Paynter heavy silt loam | 6 | 0.3 | 22 | 26 | 15 | 17 | 100 |
| Site 10 | Vineyard | Omaka fine sandy loam | 5 | 0.1 | 31 | 31 | 23 | 16 | 100 |
| Site 11 | Vineyard | Omaka fine sandy loam | 6 | 0.1 | 33 | 18 | 26 | 16 | 91 |
| Site 12 | Vineyard | Seddon fine sandy loam | 7 | 0.1 | 33 | 27 | 27 | 17 | 110 |
| Site 13 | Vineyard | Seddon fine sandy loam | 6 | 0.1 | 30 | 22 | 22 | 14 | 93 |
| Site 14 | Pasture | Seddon silt loam | 5 | 0.1 | 29 | 18 | 21 | 14 | 96 |
| Site 15 | Bush | Ronga silt Loam | 4 | 0.2 | 45 | 18 | 27 | 13 | 71 |
| Site 16 | Dairy | Ronga silt Loam | 6 | 0.4 | 50 | 23 | 30 | 14 | 83 |
| Site 17 | Bush | Kaituna silt loam | 4 | 0.1 | 23 | 16 | 13 | 20 | 83 |
| Site 18 | Dairy | Kaituna silt loam | 4 | 0.4 | 22 | 20 | 11 | 14 | 69 |
| Site 19 | Bush | Kenepuru steepland | 4 | 0.1 | 10 | 12 | 6 | 9 | 45 |
| Site 20 | Exotic Forest | Kenepuru steepland | 3 | 0.1 | 10 | 13 | 7 | 10 | 38 |
| Site 21 | Exotic Forest | Kenepuru steepland | 2 | 0.1 | 9 | 6 | 5 | 7 | 26 |
| Site 22 | Pasture | Kenepuru steepland | 3 | 0.1 | 10 | 13 | 5 | 8 | 44 |
| Site 23 | Cropping | Seddon silt loam | 5 | 0.1 | 37 | 17 | 22 | 15 | 99 |
| Site 24 | Pasture | Wairau fine sandy loam | 4 | 0.1 | 22 | 14 | 33 | 31 | 87 |
| Site 25 | Vineyard | Renwick silt loam | 4 | 0.3 | 45 | 37 | 32 | 18 | 158 |

**4.0 Summary**

In general, soil quality in Marlborough was pretty good with 7 out of 25 sites meeting all their soil quality targets and 16 others only having one indicator out of the target range. However, monitoring has highlighted that there are some soil quality issues under some land use activities in the Marlborough region.

- Cropping sites all had low total carbon concentrations and suffered from surface compaction and at one site low macroporosity. These results may put cropping soils at risk of poor aeration, poor drainage and soil structural degradation. It is possible that this was due to intensive cultivation and/or insufficient pasture rotations within the mixed cropping rotation.
- One of the dairy pasture sites had an AMN concentration above the suggested upper limit of 250 $\mu g$ nitrogen $cm^{-3}$. There is an associated risk of nitrogen loss via nitrate leaching from soils with appreciable levels of AMN. One of these sites also contained Olsen P concentrations greater than the suggested maximum of 100 $\mu g$ phosphorous $cm^{-3}$. This may lead to phosphorus leaching if the volume of irrigation applied is greater than the water-holding capacity of this soil.
- The two exotic forestry sites had high C:N ratios which may limit nitrogen availability for a balanced ecosystem.
- Trace element concentrations in Marlborough agricultural soils were generally low and were similar to concentrations found in other parts of New Zealand. However there should be long-term monitoring of cadmium on dairy farm sites to determine changes over time.
- It is recommended that repeat monitoring of these at-risk sites be conducted in the medium-term ($\approx$5 years) to determine the rate of change over time.
- It is also recommended that the number of sites currently being monitored should be expanded to include sites on soil types that are not currently part of the monitoring program and to include more vineyards sites in light of the expansion of viticulture in Marlborough.

**5.0 References**

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