Soil Quality in the Marlborough Region in 2009

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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 undertake 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 16 new soil quality monitoring sites. The sites included four different land use activities including drystock pasture (9), exotic forestry (4), viticulture (2) and cropping (1) and represent 10 different soil types from 2 soil orders.

Monitoring results indicate that 9 out of 16 sites meet all their soil quality targets and 7 others have one indicator out of the target range. Monitoring has highlighted that there are some soil quality issues under some land use activities in Marlborough.

Several sites showed signs of soil compaction i.e. low macroporosity and a number of others i.e. drystock pasture sites had macroporosity at the lower end of the optimal target range. These results put soils at risk of poor aeration and poor drainage, and may result in reduced pasture growth.

One of the cropping sites has depleted soil carbon along with a high bulk density value. This result puts this cropping soil at risk of structural degradation, poor aeration and poor drainage and possibly may result in reduced crop growth.

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 fluorine on pasture farm sites to determine changes over time.

It is recommended 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 (≈ 3 - 5 years) to determine trends over time.

It is also recommended that the number of sites currently being monitored should be expanded to include new sites that are under-represented in the current monitoring programme.

Contents

1. Introduction

Regional councils (and Unitary Councils) have a responsibility for promoting the management of the natural and physical resources of their region. One of the physical resources that we have a duty under the Resource Management Act (1991) to monitor is the "life supporting capacity of soil" and determine whether current practices will meet the "foreseeable needs of future generations". Detailed soil monitoring information is therefore vital because it provides information on what effect current land use activities are having on soil quality and whether we need to change or prioritise the way we manage the land environment. This is becoming increasingly important as land use activities are intensifying and putting pressure on our soils, some of which are fragile and if not carefully managed are at risk of degradation.

To help determine what effect land use practices are having on soil quality, the Marlborough District Council (MDC) began a monitoring program in 2000. The monitoring program involved collecting soil samples from a network of sites that represented the main land use activities and soil types within the 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.

Up until 2008, 44 soil quality sites had been established, sampled and results reported. However, to provide a more complete picture of soil quality in the Marlborough region, further sampling of soil is still required from more sites. This report present the results for 16 new soil quality monitoring sites that were sampled and analysed for a suite of soil physical, biological and chemical properties to determine if they meet their target ranges for soil quality.

2. Materials and Methods

2.1. Sampling Sites

Soils were sampled from 16 sites that included four different land use activities including drystock pasture (9), exotic forestry (4), viticulture (2) and cropping (1) and represent 10 different soil types from 2 soil orders (Table 1).

At each site a soil pit was dug to about 1 m depth and a detailed soil profile description was undertaken to confirm the soil type and to note any salient soil features that may affect soil management i.e. rooting depth, mottling, hardpans etc. In addition, details of the site were recorded such as current landuse, present vegetation, slope, elevation, landform, parent material and soil drainage class. This information in presented in Appendix A.

Table 1 Soil type, soil classification and land use management of sites sampled in Marlborough

Site Code	Soil Type	New Zealand Soil Order	Land use; management
MDC45	Dashwood	Pallic	Pasture; Grapes 2003
MDC46	Sedgemere	Pallic	Pasture; Grapes planted - 2001
MDC47	Sedgemere	Pallic	Pasture; barley; peas rotation
MDC48	Sedgemere	Pallic	Pasture - sheep
MDC49	Hororata	Brown	1st generation pines - planted 1988
MDC50	Hororata	Brown	Pasture - Sheep/beef
MDC51	Kaituna	Brown	Pasture - Sheep/beef
MDC52	Tuamarina Hill	Brown	Pasture - Sheep/beef
MDC53	Tuamarina Hill	Brown	2nd Generation pines; 1990
MDC54	Weld Steepland	Pallic	Pasture - Sheep/beef
MDC55	Weld Steepland	Pallic	Pines, 1st rotation, planted 1994
MDC56	Warwick	Pallic	Pasture - Sheep/beef
MDC57	Wither Hill	Pallic	Pasture - Sheep/beef
MDC58	Haldon Steepland	Pallic	Pasture - Sheep/beef
MDC59	Waihopai Steepland	Pallic	Pines, 1st rotation, planted 1996
MDC60	Waihopai Steepland	Pallic	Pasture - Sheep

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.

2.3. Soil Quality Measurements

A number of different soil properties were measured to assess soil quality. Soil chemical characteristics were assessed by soil pH, total carbon, total nitrogen, carbon:nitrogen ratio, Olsen P and trace elements concentration. 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 (Table 2).

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
Trace elements	Deficiency or toxicity of trace elements in soil	Acid digestion
Biological properties		
Anaerobically mineralisable N	Readily mineralisable nitrogen reserves	Waterlogged incubation at 40 ºC 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). Total Fluoride was measured by alkaline fusion of samples with fluoride measured by an ion selective electrode.

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 ºC 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

Where appropriate, data were expressed on a weight/volume or volume/volume basis to allow comparison between soils with differing bulk density.

2.6. Targets and Ranges

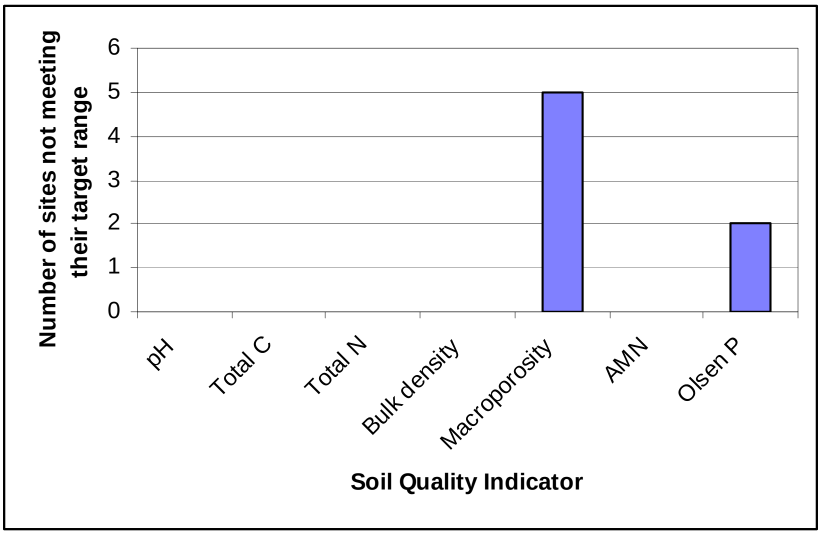
Target ranges for individual soil characteristics were assessed using 'SINDI'. This is a web-based tool designed by Landcare Research to help interpret the quality of a soil that has been sampled. SINDI allows us to i) compare soil data with information for similar soils stored in the National Soil Database 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. Results and Discussion

3.1. Comparison of Target Ranges

Figure 1 shows the number of sites not meeting their target ranges for a specific soil quality indicator. Macroporosity was the soil indicator most often not meeting its target range (i.e. 5 sites) while Olsen P did not meet its target at two sites. In contrast, soil pH, total C, total N, bulk density and AMN targets were met at all sites. The significant number of sites not meeting their target for macroporosity is similar to what has been previously found at soil quality monitoring sites (Marlborough District Council, 2007a and 2008) and is what has been found nationally where soil compaction i.e. low macroporosity is recognised as a key soil quality issue.

Figure 1 The number of sites not meeting their target range for a specific soil quality indicator.



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

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.

As indicated in Figure 1, all sites had soil pH values within their acceptable target ranges for their respective land use. However, at seven of the drystock pasture sites, soil pH values were at the lower end of their target range (Table 3). The ideal pH range for pasture soils (excluding peat soils) is 5.8 – 6.0 (Morton et al., 2004) which maximises nutrient availability. An increase in soil pH can be readily remediated by the application of a lime product.

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.

All sites had total carbon contents within acceptable target ranges for their respective land use activity (Figure 1). However, at the cropping site i.e. MDC47, the total soil carbon content was at the lower boundary of its target range (Table 3). This result put this soil at risk of structural degradation, poor aeration and impeded drainage if soil carbon contents decrease further over time. In comparison, the same soil under permanent pasture adjacent to the cropping site i.e. MDC48 has significantly higher total carbon content and illustrates the benefits of a pasture phase in the cropping rotation. Interestingly this site does have a pasture phase in the rotation and may indicate that it could be beneficial to extend its duration to help increase the total soil carbon content.

Table 3 Chemical and biological characteristic of soils sampled in the Marlborough Region 2009

Site Code	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})
MDC45	Vineyard – inter-row	Dashwood	6.9	28	51.4	5.3	9.6	174
MDC46	Vineyard – inter-row	Sedgemere	7.0	23	39.1	3.9	10.0	152
MDC47	Cropping – process peas	Sedgemere	5.6	31	33.3	3.7	8.9	155
MDC48	Drystock Pasture – sheep/beef	Sedgemere	5.6	19	41.1	4.2	9.7	187
MDC49	Exotic forest - *pinus radiata*	Hororata	4.9	13	58.8	4.2	14.0	70
MDC50	Drystock Pasture – sheep/beef	Hororata	5.1	32	73.7	6.5	11.3	152
MDC51	Drystock Pasture – sheep/beef	Kaituna	6.0	13	38.9	4.1	9.4	172
MDC52	Drystock Pasture – sheep/beef	Tuamarina Hill	5.4	18	38.4	3.1	12.4	74
MDC53	Exotic forest - *pinus radiata*	Tuamarina Hill	5.2	10	46.2	3.3	14.0	92
MDC54	Drystock Pasture – sheep/beef	Weld Steepland	5.2	31	44.8	4.7	9.5	177
MDC55	Exotic forest - *pinus radiata*	Weld Steepland	6.0	18	35.9	3.5	10.4	77
MDC56	Drystock Pasture – sheep/beef	Warwick	5.9	38	43.1	4.9	8.7	261
MDC57	Drystock Pasture – sheep/beef	Wither Hill	5.3	21	48.9	4.9	10.0	218
MDC58	Drystock Pasture – sheep/beef	Haldon Steepland	5.6	16	58.9	5.7	10.4	245
MDC59	Exotic forest - *pinus radiata*	Waihopai Steepland	5.4	23	41.6	3.5	11.8	111
MDC60	Drystock Pasture – sheep/beef	Waihopai Steepland	5.3	16	47.4	4.3	11.0	199

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.

Like for total carbon, all sites had total nitrogen contents within acceptable target ranges for their respective land use activity (Table 3).

3.5. Carbon:Nitrogen 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.

All sites had C:N ratios within acceptable target ranges for their respective land use activity (Table 3).

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 4-fold between sites with the lowest value found at one of the exotic forestry sites i.e. MDC53 and highest value at one of the drystock pasture sites i.e. MDC56 (Table 3). As indicated in Figure 1, two sites had Olsen P values out of the desired target range. Both sites i.e. MDC51 and MDC58 had Olsen P concentrations below their target range. Phosphorous concentrations in soils can be increased relatively easily by the application of phosphate fertilisers to soil hence these low values are not of any major concern.

3.7. Anaerobically Mineralisable Nitrogen

Anaerobically mineralisable nitrogen (AMN) 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.

Anaerobically Mineralisable Nitrogen concentrations varied 4-fold between sites with the lowest values typically found on the exotic forestry sites with the highest values on the drystock pasture sites (Table 3). All values were within their target range for their respective land use activity. An AMN values above the target range is regarded as important as it can potentially lead to water quality issues if nitrogen is lost from soil as nitrate, primarily by leaching.

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.

All sites had bulk density values that were within their respective target ranges (Table 3), although three sites i.e. MDC46, MDC47 and MDC55 were approaching their upper limits.

3.9. Macroporosity

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

Five sites did not meet their target for macroporosity (Figure 1). These included three of the drystock pasture sites i.e. MDC48, MDC52 and MDC54, the cropping site i.e. MDC47 and one vineyard site i.e. MDC46 (Table 4).

The low macroporosity values on the drystock pasture sites are likely related to heavy grazing or grazing under moist soil conditions. Interestingly all the other drystock pasture sites sampled had macroporosity values less than 10%. Research has shown that soil macroporosity values below this threshold may adversely affect pasture production. Furthermore, low macroporosity may result in poor water infiltration which may increase overland flow and the potential for nutrient losses such as phosphorous from soils and also increase the opportunity for sheetwash erosion. The results in this study are in line with what has been found nationally where about of a third of drystock sites had compacted soils (Ministry for the Environment, 2010).

Another interesting observation and one that was made in previous sampling on dairy sites Marlborough District Council (2008) is that low macroporosity values were not necessarily associated with high bulk density values. One possible explanation is that compaction has reduced the volume of macropores in the soils but there is adequate total organic carbon in these soils which helps resist overall compaction. The net result is presumably a change in the pore-size distribution, with a decrease in the macropore volume and an increase in the volume of the smaller pore sizes.

At the cropping site, the low macroporosity value is likely related to the depleted organic carbon in this soil and the use of machinery. Interestingly this soil also had a high bulk density. So in contrast to what was observed for the drystock pasture soils, for the cropping soil there isn't sufficient soil carbon to minimise soil compaction. The low macroporosity values at the vineyard site is likely related to machinery movement to undertake activities such as mowing, spraying, harvesting and pruning and best practice would suggest minimising vehicle movements and avoiding activities during wet soil conditions which exacerbate soil compaction.

Table 4 Physical characteristic of soils sampled in the Marlborough Region 2009

Site Code	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)
MDC45	Vineyard – inter-row	Dashwood	1.07	2.56	58.1	12.5	16.8
MDC46	Vineyard – inter-row	Sedgemere	1.35	2.58	47.8	1.6	3.3
MDC47	Cropping – process peas	Sedgemere	1.33	2.59	48.6	4.4	5.6
MDC48	Drystock Pasture – sheep/beef	Sedgemere	1.14	2.55	55.1	2.7	5.6
MDC49	Exotic forest - *pinus radiata*	Hororata	0.79	2.46	67.7	24.7	29.4
MDC50	Drystock Pasture – sheep/beef	Hororata	0.96	2.45	60.9	9.6	15.5
MDC51	Drystock Pasture – sheep/beef	Kaituna	1.15	2.58	55.7	6.1	8.0
MDC52	Drystock Pasture – sheep/beef	Tuamarina Hill	1.24	2.57	51.7	3.2	5.1
MDC53	Exotic forest - *pinus radiata*	Tuamarina Hill	1.10	2.60	57.6	19.1	20.8
MDC54	Drystock Pasture – sheep/beef	Weld Steepland	1.15	2.52	54.5	5.9	12.9
MDC55	Exotic forest - *pinus radiata*	Weld Steepland	1.38	2.65	48.0	17.1	19.2
MDC56	Drystock Pasture – sheep/beef	Warwick	1.27	2.57	50.7	6.2	8.4
MDC57	Drystock Pasture – sheep/beef	Wither Hill	1.17	2.54	54.1	8.6	12.1
MDC58	Drystock Pasture – sheep/beef	Haldon Steepland	1.18	2.53	53.4	8.0	12.1
MDC59	Exotic forest - *pinus radiata*	Waihopai Steepland	1.04	2.61	60.0	19.9	26.1
MDC60	Drystock Pasture – sheep/beef	Waihopai Steepland	1.08	2.59	58.5	8.9	14.0

3.10. Trace Elements

Trace elements accumulate in soils either naturally through weathering of minerals contained in the soil parent material or from anthropogenic sources. While many trace elements are essential for healthy plant and animal growth, i.e. copper and zinc, at high concentrations in soils these can have a negative impact on soil fertility and plant and animal health. Furthermore, some trace elements, i.e. cadmium and arsenic are not required in soils and their accumulation can also have a negative impact on soil, plant and animal health, and in some cases there is potential for them to accumulate in the human food chain.

Table 5 summarises trace element concentrations in soils from the 16 monitoring sites. On average concentrations were 4 mg kg^{-1} for arsenic, 0.12 mg kg^{-1} for cadmium, 15 mg kg^{-1} for chromium, 9 mg kg^{-1} for copper, 10 mg kg^{-1} for nickel, 12 mg kg^{-1} for lead, 55 mg kg^{-1} for zinc and 187 mg kg^{-1} for fluorine. These concentrations are similar to those found in soils at other monitoring sites in Marlborough (Marlborough District Council, 2007a, 2007b, 2008) and in other regions of New Zealand (Auckland Regional Council, 1999; Greater Wellington Regional Council, 2005; Canterbury Regional Council, 2006). With the exception of fluorine, concentrations are similar to typical background concentrations found in New Zealand soils and well within suggested upper limits for trace elements in soils as suggested by the New Zealand Water and Waste Association (NZWWA, 2003). Whereby the NZWWA suggest upper soil limits of 20 mg kg^{-1} for arsenic; 1 mg kg^{-1} for cadmium; 600 mg kg^{-1} for chromium; 100 mg kg^{-1} for copper; 60 mg kg^{-1} for nickel; 300 mg kg^{-1} for lead and 300 mg kg^{-1} zinc.

Total soil fluorine concentrations ranged from 100 to 300 mg kg^{-1} with an average concentration of 187 mg kg^{-1}. Natural soil fluorine concentrations depend on the soil parent material. In New Zealand, Allophanic Soils formed from volcanic ash have been found to have concentrations ranging between 175- 200 mg kg^{-1}, whilst soils derived from sedimentary parents, such as those found in much of Marlborough, have been found to have lower concentrations ranging between 43- 116 mg kg^{-1} (Loganathan et al., 2003). Therefore the results in this study indicate that the soils have likely received varying amounts of anthropogenic inputs of fluorine, probably from regular application of phosphate fertiliser in which fluorine is an incidental impurity.

Based on the results of this study, at normal soil ingestion rates (which is the main risk pathway), soils with the range of soil fluorine concentrations found in this study are unlikely to result in fluorine toxicity to grazing animals (which is the main risk of elevated fluorine in pasture soils). However if soil fluorine concentrations continue to increase in the future, management options to reduce the risk could include maintaining adequate pasture cover, reducing stocking rates, especially during winter, and withholding stock from recently fertilised pastures.

Table 5 Trace element concentrations in soils sampled in the Marlborough Region 2009

Site Code	Land use	Soil Type	As (mg kg^{-1})	Cd (mg kg^{-1})	Cr (mg kg^{-1})	Cu (mg kg^{-1})	Ni (mg kg^{-1})	Pb (mg kg^{-1})	Zn (mg kg^{-1})	F (mg kg^{-1})
MDC45	Vineyard – inter-row	Dashwood	4	0.12	21	12	13	13	88	300
MDC46	Vineyard – inter-row	Sedgemere	2	0.16	13	5	9	8	56	180
MDC47	Cropping – process peas	Sedgemere	3	0.11	13	5	8	8	48	160
MDC48	Drystock Pasture – sheep/beef	Sedgemere	3	0.10	16	7	8	9	54	160
MDC49	Exotic forest - *pinus radiata*	Hororata	3	0.10	19	5	11	15	53	120
MDC50	Drystock Pasture – sheep/beef	Hororata	3	0.10	20	7	11	14	50	180
MDC51	Drystock Pasture – sheep/beef	Kaituna	4	0.21	20	11	10	11	50	220
MDC52	Drystock Pasture – sheep/beef	Tuamarina	2	0.10	8	4	4	7	18	100
MDC53	Exotic forest - *pinus radiata*	Tuamarina	6	0.10	8	14	9	14	45	230
MDC54	Drystock Pasture – sheep/beef	Weld	5	0.10	11	12	8	15	67	210
MDC55	Exotic forest - *pinus radiata*	Haldon	5	0.10	14	15	14	18	75	250
MDC56	Drystock Pasture – sheep/beef	Warwick	3	0.21	15	13	12	12	79	210
MDC57	Drystock Pasture – sheep/beef	Wither Hill	4	0.10	11	6	6	9	31	160
MDC58	Drystock Pasture – sheep/beef	Haldon	5	0.11	16	16	11	14	70	240
MDC59	Exotic forest - *pinus radiata*	Waihopai Steepland	2	0.10	16	9	11	11	46	140
MDC60	Drystock Pasture – sheep/beef	Waihopai Steepland	2	0.12	13	9	10	9	43	130

4. Summary

Monitoring results indicate that 9 out of 16 sites meet all their soil quality targets and 7 others have one indicator out of the target range. Monitoring has highlighted that there are several soil quality issues under some land use activities.

- Several sites showed signs of soil compaction i.e. low macroporosity and a number of other sites, mainly drystock pasture sites had macroporosity at the lower end of the desired taken range. These results put soils at risk of poor aeration and poor drainage, and may result in reduced pasture growth.

- Furthermore one of the cropping sites has depleted soil carbon along with a high bulk density value. This result puts this cropping soil at risk of structural degradation, poor aeration and poor drainage and possibly may result in reduced crop growth.

- 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 fluorine on pasture farm sites to determine changes over time.

- It is recommended that the number of sites currently being monitored should be expanded to include new sites that are under-represented in the current monitoring programme.

It is also recommended that repeat monitoring of these risk sites be conducted in the medium-term (≈ 3-5 years) to determine the rate of change over time.

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Appendix A

Sample name: MDC45
Soil Name: Dashwood
Location: Awatere Valley, approx 6 km NE of Seddon and 650m SE of Toi Downs
GPS Coordinates: E2602354 N5953970
Land use: Vineyard – inter-row
Topography: Terrace
Elevation: 40m
Slope: 0º
Soil material: Late Pleistocene gravelly alluvium
Soil drainage: Well
Date sampled: 6/10/09

Horizon	Thickness (cm)	Soil description
A	0 - 16	very dark greyish brown (10YR 3/2) silt loam; moderately developed fine polyhedral structure; 15% medium to very coarse stones; weak soil strength; friable; many fine and medium roots
AB	16 - 22	very dark greyish brown and dark yellowish brown (10YR 3/2+10YR 4/4) silt loam; moderately developed fine polyhedral structure; 20% medium to very coarse stones; weak soil strength; friable; few fine and few medium roots
Bw	22 - 52	dark yellowish brown (10YR 4/4) sandy silt loam; weakly developed medium blocky structure breaking to fine polyhedral structure; 35% medium to very coarse stones; friable; few fine and few coarse roots
BC	52 - 75	dark yellowish brown (10YR 4/4) coarse sand; 50% medium to very coarse stones; loose; few fine roots

Sample name: MDC46
Soil Name: Sedgemere
Location: Approximately 2 km N of Ward, west of Highway 1 and 150m S of Kaka Road
GPS Coordinates: E2604320 N5932223
Land use: Vineyard – inter-row
Topography: Terrace
Elevation: 47m
Slope: 0º
Soil material: Weathered loess
Soil drainage: Imperfect
Date sampled: 20/10/09

Horizon	Thickness (cm)	Soil description
A	0-15	dark greyish brown (10YR 4/2) heavy silt loam; moderately developed fine polyhedral structure; weak soil strength; friable; many fine and few medium roots
AB	15-20	dark greyish brown and light yellowish brown (10YR 4/2 +2.5Y 6/4) clay loam; moderately developed fine polyhedral structure; slightly firm soil strength; many fine roots
Bw1	20-27	light yellowish brown (2.5Y 6/4) clay loam; moderately developed medium blocky and polyhedral structure; 20% yellowish brown (10YR 5/6) fine distinct mottles; slightly firm soil strength; brittle very few fine roots
Bw(g)	27-45	yellowish brown (10YR 5/8) clay; strongly developed coarse blocky structure; 35% olive (5Y 5/3) medium distinct mottles; slightly firm soil strength; semi-deformable; very few fine roots
Bwg1	45-85	yellowish brown (10YR 5/8) clay; strongly developed coarse blocky structure; 50% light olive grey (2.5Y 5/2) coarse prominent mottles on ped faces; firm soil strength; semi-deformable; very few fine roots
Bwg2	85-90	yellowish brown (10YR 5/8) clay; strongly developed coarse blocky structure; 70% light olive grey (2.5Y 5/2) coarse prominent mottles on ped faces; firm soil strength; semi- deformable
Bx	90-95+	yellowish brown (10YR 5/8) silt loam; strongly developed prismatic structure; light olive grey (2.5Y 5/2) vein fillings very firm soil strength; brittle

Sample name: MDC47
Soil Name: Sedgemere
Location: Approximately 1.9 km N of Ward, west of Highway 1 and 300m S of Kaka Road
GPS Coordinates: E2604305 N5932096
Land use: Cropping - Process peas
Topography: Terrace
Elevation: 52m
Slope: 0º
Soil material: Weathered loess
Soil drainage: Imperfect
Date sampled: 20/10/09

Horizon	Thickness (cm)	Soil description
A	0-17	very dark greyish brown (10YR 3/2) silt loam; weakly developed fine polyhedral and blocky structure; weak soil strength; friable; few medium roots
AB	17-25	very dark greyish brown and light yellowish brown (10YR 3/2 +2.5Y 6/4) clay loam; moderately developed fine and medium polyhedral blocky structure; slightly firm soil strength; brittle very few fine roots
Bw1	25-35	light yellowish brown (2.5Y 6/4) clay; moderately developed coarse blocky structure; 15% light olive grey (5Y 6/2) and15% yellowish brown and strong brown (10YR 5/8 + 7.5YR 5/8) fine distinct mottles; some firm small concretions; slightly firm soil strength
Bwg1	35-43	light yellowish brown to light brownish grey (2.5Y 6/4-6/2) clay; moderately developed coarse blocky structure; 30% brownish yellow(10YR 6/6) medium prominent mottles; firm soil strength; semi deformable;
Bwg2	43-80	yellowish brown (10YR 5/6) clay; moderately to strongly developed coarse blocky and medium prismatic structure; 10% dark yellowish brown (10YR 4/6) and 55% greyish brown to light brownish grey10YR 5/2-6/2) coarse mottles with grey colours prominent on ped faces; firm soil strength; semi deformable
Bx	80-90+	dark yellowish brown (10YR 4/6) silt loam; strongly developed coarse prismatic structure; light brownish grey (2.5Y 6/2) distinct veins; very firm soil strength; brittle

Sample name: MDC48
Soil Name: Sedgemere
Location: Approximately 2 km N of Ward, west of Highway 1 and 300m S of Kaka Road
GPS Coordinates: E2604191 N5932146
Land use: Drystock pasture - sheep
Topography: Terrace
Elevation: 52m
Slope: 0º
Soil material: Weathered loess
Soil drainage: Imperfect
Date sampled: 20/10/09

Horizon	Thickness (cm)	Soil description
A	0-17	very dark greyish brown (10YR 3/2) heavy silt loam; strongly developed fine polyhedral structure; weak soil strength; friable many fine roots
AB	17-23	very dark greyish brown and light yellowish brown (10YR 3/2 2.5Y 6/4) clay loam; moderately developed fine polyhedral and blocky structure; slightly firm soil strength; friable; many fine roots
Bw	23-31	light yellowish brown (2.5Y 6/4) clay; moderately developed medium blocky structure; 10% fine distinct light brownish grey (2.5Y 6/2) mottles; firm soil strength; brittle; few fine roots
Bw(g)1	31-48	yellowish brown (10YR 5/8) clay; strongly developed coarse blocky structure; 40% light brownish grey (2.5Y 6/2) medium prominent mottles in cracks and ped faces; firm soil strength; semi deformable; few fine roots
Bwg1	48-78	brownish yellow (10YR 6/8) clay; strongly developed coarse blocky structure; 55% light brownish grey (2.5Y 6/2) coarse prominent mottles in cracks and on ped faces; firm soil strength; semi-deformable; very few fine roots
Bx	78-85+	dark yellowish brown (10YR 4/4) silt loam; strongly developed extremely coarse prismatic structure; 15% yellowish brown (10YR 5/4) coarse mottles in veins; hard soil strength; brittle

Sample name: MDC49
Soil Name: Hororata
Location: Approx 14 km WSW of Hillersden, N of Birch Hill station and 550m N of State Highway 63
GPS Coordinates: E2533283 N5950988
Land use: Exotic forest - *pinus radiata*
Topography: Plain
Elevation: 293
Slope: 0º
Soil material: Late Quaternary/early Holocene unconsolidated glacial outwash alluvium
Soil drainage: Well
Date sampled: 7/10/09

Horizon	Thickness (cm)	Soil description
L	3-0	dark yellowish brown (10YR 4/4) partly decomposed litter; very friable
A	0-18	dark brown (7.5YR 3/2) sandy loam; moderately developed fine polyhedral structure; 5% medium stones; weak soil strength; very friable; few fine and many medium and coarse roots
AB	18-23	dark brown (5YR 3/2) and dark yellowish brown (10YR 4/6) sandy loam; moderately developed fine polyhedral structure; 5% medium stones; weak soil strength; very friable; many medium and few coarse roots
Bw	23-45	dark yellowish brown (10YR4/6) sandy loam; moderately developed medium blocky structure; 15% medium to coarse stones; weak soil strength; friable; many medium roots
BC	45-60	dark yellowish brown (10YR 4/4) loamy sand; weakly developed medium blocky structure; 40% medium stones and boulders; very friable; few medium roots
C	60-70	olive brown (2.5Y 4/4) sand; loose; 50% medium stones and boulders

Sample name: MDC50
Soil Name: Hororata
Location: Approx 14 km WSW of Hillersden, N of Birch Hill station and 550m N of State Highway 63
GPS Coordinates: E2533174 N5951016
Land use: Drystock pasture - sheep/cattle
Topography: Plain
Elevation: 283
Slope: 0º
Soil material: Late Quaternary/early Holocene unconsolidated glacial outwash alluvium
Soil drainage: Well
Date sampled: 7/10/09

Horizon	Thickness (cm)	Soil description
A	0 - 17	dark yellowish brown (10YR 3/4) sandy loam; moderately developed fine polyhedral structure; 15% medium to very coarse stones; weak soil strength; very friable; many fine and few medium roots
AB	17 - 21	dark yellowish brown (10YR 3/4 + 10YR 4/6) sandy loam; moderately developed fine polyhedral structure; 15% medium to very coarse stones; weak soil strength; very friable; many fine roots
Bw	21 - 45	dark yellowish brown (10YR 4/6) sandy loam; moderately developed medium blocky structure; 25% medium to very coarse stones; weak soil strength; few fine roots
BC	45 - 55	olive brown (2.5Y 4/4) to yellowish brown (10YR 4/4) sand; weakly developed fine polyhedral structure; 35% medium stones and boulders; friable; few fine roots
	55-70+	olive (5Y 4/4) coarse sand; single grain structure; 70% medium to coarse stones and boulders; very few fine roots

Sample name: MDC51
Soil Name: Kaituna
Location: Nth side of Wairau River, approximately 1 km N of Northbank Road and 50m E off Fabians road
GPS Coordinates: E2558779 N5965992
Land use: Drystock pasture - sheep/cattle
Topography: Lowland valley
Elevation: 135m
Slope: 0º
Soil material: Weakly weathered schist alluvium
Soil drainage: Well
Date sampled: 21/10/09

Horizon	Thickness (cm)	Soil description
A	0-17	dark brown (10YR 3/3) silt loam; moderately developed fine polyhedral structure; 2% fine stones; weak soil strength; friable; many fine roots;
AB	17-22	dark brown and yellowish brown (10YR 3/3 + 10YR 5/6) silt loam; moderately developed fine polyhedral structure; 2% fine stones; slightly firm soil strength; friable; few fine roots
Bw1	22-38	yellowish brown (10YR 5/6) heavy silt loam; moderately developed medium polyhedral structure; 5% fine to coarse stones; slightly firm soil strength; friable; few fine roots
Bw2	38-70	yellowish brown (10YR 5/6) heavy silt loam to clay loam ; moderately developed coarse blocky and fine polyhedral structure; 2% fine stones; slightly firm soil strength; brittle; very few fine roots
BC	70-95+	yellowish brown to light olive brown (10YR 5/6-2.5Y 5/6) silt loam; weakly developed coarse blocky structure; 10% fine to medium stones; slightly firm soil strength; brittle

Sample name: MDC52
Soil Name: Tuamarina hill soil
Location: Nth side of Wairau River, approximately 1.2 km N of Northbank Road and 1.2 km W off Fabians road
GPS Coordinates: E2557393 N5965507
Land use: Drystock pasture - sheep/cattle
Topography: Hill country
Elevation: 188m
Slope: 22º
Soil material: Loess with some schist slope deposits
Soil drainage: Moderately
Date sampled: 21/10/09

Horizon	Thickness (cm)	Soil description
A	0-17	very dark greyish brown (10YR 3/2) silt loam; moderately developed fine polyhedral structure; 2% fine stones; weak soil strength; many fine roots
AB	17-26	very dark greyish brown and brownish yellow (10YR 3/2+10YR 6/6) silt loam; moderately developed fine polyhedral structure; 2% fine stones; slightly firm soil strength; friable; many fine roots
Bw1	26-40	brownish yellow (10YR 6/6) silt loam; strongly developed coarse blocky structure; slightly firm soil strength; brittle; few fine roots
Bw2	40-60	yellowish brown (10YR 5/6) clay loam; strongly developed coarse blocky structure; 2% fine stones; 15% light yellowish brown(2.5Y 6/4) clay loam; strongly developed coarse blocky structure; 2% fine stones; 15% light yellowish brown (2.5Y 6/4) medium distinct vein mottles on ped faces; slightly firm soil strength; few fine roots
Bw3	60-95+	yellowish brown (10YR 5/8) clay loam; strongly developed coarse blocky structure; 5% fine and medium stones; 20% light yellowish brown (2.5Y 6/4) coarse prominent vein mottles; slightly firm soil strength; brittle; very few fine roots

Sample name: MDC53
Soil Name: Tuamarina hill soil
Location: Nth side of Wairau River, approximately 1.2 km N of Northbank Road and 1.2 km W off Fabians road
GPS Coordinates: E2557312 N5965601
Land use: Exotic forest – *pinus radiata*
Topography: Hill country
Elevation: 205m
Slope: 24º
Soil material: Weathered schist slope detritus plus some loess
Soil drainage: Well
Date sampled: 21/10/09

Horizon	Thickness (cm)	Soil description
L	0-3	dusky red (2.5Y 3/2) partly decomposed litter; very friable
A	3-25	very dark greyish brown (10YR 3/2) silt loam; moderately developed fine polyhedral structure; 5% medium stones; weak soil strength; friable; many coarse roots
AB	25-33	very dark greyish brown and yellowish brown (10YR 5/4) silt loam; moderately developed fine polyhedral structure; 15% medium to coarse stones; weak soil strength; friable; few fine and many coarse roots
Bw1	33-48	yellowish brown (10YR 5/4) silt loam; strongly developed medium blocky structure; 15% medium to coarse stones; weak soil strength; friable; few coarse roots
Bw2	48-87	yellowish brown (10YR 5/6) silt loam; strongly developed fine blocky and polyhedral structure; 25% medium to coarse stones; weak soil strength; brittle; few medium roots
Bw3	87-98+	yellowish brown (10YR 5/6) heavy silt loam; strongly developed medium blocky and polyhedral structure; 15% medium and coarse stones; weak soil strength; brittle; few fine roots

Sample name: MDC54
Soil Name: Weld Steepland Soil
Location: Approx 12 km S of Blenheim and 3.5 km N of Taylor Pass, about 750m NE of Taylor Pass Road
GPS Coordinates: E2591800 N5955314
Land use: Drystock pasture sheep & cattle
Topography: Hill country
Elevation: 231m
Slope: 28º
Soil material: Weathered greywacke
Soil drainage: Well
Date sampled: 7/10/09

Horizon	Thickness (cm)	Soil description
A	0-18	very dark greyish brown (10YR 3/2) silt loam; moderately developed fine polyhedral structure; 2% fine stones; weak soil strength; friable; many fine roots
AB	18-26	very dark greyish brown (10YR 3/2) and light olive brown (2.5Y 5/4) silt loam; moderately developed fine polyhedral structure; 2% fine stones; weak soil strength; friable; many fine roots
Bw1	26-46	light olive brown (2.5Y 5/4) sandy silt loam; moderately developed fine polyhedral structure; 15% fine to medium stones; weakly developed fine blocky structure; friable; few fine roots
Bw2	46-60	light olive brown (2.5Y 5/4) to yellowish brown (10YR 5/4) sandy silt loam; weakly developed fine blocky structure; 35% fine to coarse stones; friable; few fine roots
BC	60-75+	light olive brown (2.5Y 5/4) to yellowish brown (10YR 5/4) sandy silt loam; 80% coarse to very coarse stones; very few fine roots

Sample name: MDC55
Soil Name: Weld Steepland Soil
Location: Taylor Pass Road
GPS Coordinates: E2590569 N5954223
Land use: Exotic forest – *pinus radiata*
Topography: Hill country
Elevation: 197m
Slope: 27º
Soil material: Weathered greywacke
Soil drainage: Well
Date sampled: 19/10/09

Horizon	Thickness (cm)	Soil description
A	0-13	very dark greyish brown (10YR 3/2) silt loam; weakly-moderately developed fine polyhedral structure; weak soil strength; friable; few fine roots
AB	13-20	brown (10YR 4/3) silt loam; moderately developed fine polyhedral structure; weak soil strength; friable; few fine roots
Bw1	20-36	brown (10YR 4/3) sandy silt loam; weakly developed fine polyhedral structure; weakly developed fine blocky structure; friable; few fine roots
Bw2	36-55	yellowish brown (10YR 5/6) sandy silt loam; weakly developed fine blocky structure; 35% fine to coarse stones; friable; few fine roots
B/C	55-75+	light olive brown (2.5Y 5/4) to yellowish brown (10YR 5/4) sandy silt loam; 60% coarse to very coarse stones

Sample name: MDC56
Soil Name: Warwick
Location: Mt Adde Station, 5 km WNW of Seddon and 0.6km N of Awatere valley Highway
GPS Coordinates: E2596243 N5949941
Land use: Drystock pasture – sheep/cattle
Topography: Lowland terrace
Elevation: 110m
Slope: 0º
Soil material: Weakly weathered gravelly alluvial outwash
Soil drainage: Well
Date sampled: 8/10/09

Horizon	Thickness (cm)	Soil description
A	0-17	brown to dark yellowish brown (10YR 4/3-4/4) silt loam; strongly developed fine polyhedral structure; weak soil strength; friable; many fine roots
AB	17-27	brown and dark yellowish brown (10YR 4/3 and 10YR 4/6) silt loam; strongly developed fine polyhedral structure; weak soil strength; friable; many fine roots
Bw1	27-45	dark yellowish brown (10YR 4/6) silt loam; moderately medium and fine blocky and polyhedral structure; slightly firm soil strength; brittle few fine roots
Bw2	45-54	dark yellowish brown (10YR 4/6) heavy silt loam; moderately developed medium polyhedral structure; 20% fine to coarse stones; slightly firm soil strength; brittle; few fine roots
BC	54-70	light olive brown (2.5Y 5/6) sandy silt loam; weakly developed fine polyhedral structure; 30% fine to coarse stones; friable few fine roots
C	70-90+	olive brown (2.5Y 4/4) sand; loose; 20% fine and medium stones; very few fine roots

Sample name: MDC57
Soil Name: Wither Hill soil
Location: Mt Adde Station, 6.5 km WNW of Seddon a 3 km NE of junction of Taylor Pass & Awatere Valley roads
GPS Coordinates: E2594161 N5950730
Land use: Drystock pasture – sheep/cattle
Topography: Hill country
Elevation: 212m
Slope: 18º
Soil material: Loess over greywacke
Soil drainage: Well
Date sampled: 8/10/09

Horizon	Thickness (cm)	Soil description
A	0-17	dark brown (10YR 3/3) silt loam; moderately developed fine polyhedral structure; weak soil strength; friable; many fine roots
AB	17-26	dark brown (10YR 3/3) and light olive brown (2.5Y 5/6) silt loam; moderately developed fine polyhedral structure; weak soil strength; friable; many fine roots
Bw1	26-38	light olive brown (2.5Y 5/6) clay loam; moderately developed medium blocky structure; slightly firm soil strength; brittle; few fine roots
Bw2	38-53	light olive brown to light yellowish brown (2.5Y 5/6-10YR 6/4) clay loam; 5% yellowish brown (10YR 5/8) medium distinct mottles; strongly developed medium blocky structure slightly firm soil strength; brittle; few fine roots
Bw3	53-70	yellowish brown (10YR 5/6) clay loam to clay; 10% brown7.5YR 5/4) coarse prominent mottles and 5% light brownish grey (2.5Y 6/2) fine distinct mottles; strongly developed medium blocky and polyhedral structure; slightly firm soil strength; brittle; very few fine roots
Bx	70-80+	brownish yellow (10YR 6/8) silt loam; 15% brown(10YR 5/4) coarse distinct mottles; strongly developed medium prismatic structure; very firm soil strength; brittle

Sample name: MDC58
Soil Name: Haldon steepland soil
Location: Mt Adde Station, 6.5 km WNW of Seddon a 3 km NE of junction of Taylor Pass & Awatere Valley roads
GPS Coordinates: E2593460 N5950302
Land use: Drystock pasture – sheep/cattle
Topography: Steepland hill country
Elevation: 256m
Slope: 29º
Soil material: Partly weathered greywacke – slope detritus
Soil drainage: Well
Date sampled: 8/10/09

Horizon	Thickness (cm)	Soil description
A	0-19	very dark greyish brown (10YR 3/2) sandy silt loam; strongly developed polyhedral structure; 5% fine stones; weak soil strength; friable; many fine roots
AB	19-25	very dark greyish brown and yellowish brown (10YR 3/2 +10YR 5/4) sandy silt loam; moderately developed fine polyhedral structure 10% fine to medium stones; weak soil strength; many fine roots
Bw1	25-40	yellowish brown (10YR 5/4) sandy silt loam; moderately developed fine blocky and polyhedral structure; 10% fine to medium stones; weak soil strength; friable; few fine roots
Bw2	40-68	yellowish brown (10YR 5/4) sandy silt loam; moderately developed fine blocky and polyhedral structure; 15% fine stones; weak soil strength; friable; few fine roots
BC	68-80+	light yellowish brown (10YR 6/4) sandy silt loam; weakly developed fine polyhedral structure; 20% fine to medium stones; weak slightly firm; brittle; very few fine roots

Sample name: MDC59
Soil Name: Waihopai steepland soil
Location: Wairau Valley, approx 3 km SE of Wairau Village on a slope on E side of Brothers Stream
GPS Coordinates: E2557120 N5958630
Land use: Exotic forest – *pinus radiata*
Topography: Hill country valley
Elevation: 275 m
Slope: 28º
Soil material: Partly weathered greywacke conglomerate gravels
Soil drainage: Well
Date sampled: 6/10/09

Horizon	Thickness (cm)	Soil description
A	0 - 18	very dark greyish brown to black (10YR 2/2-2/1) silt loam; moderately developed fine polyhedral structure; 10% medium to coarse stones; weak soil strength; friable; many fine and few medium root
AB	18 - 26	very dark greyish brown (10YR 2/2) and dark yellowish brown (10YR 4/4) sandy silt loam; moderately developed fine polyhedral structure; 15% medium to coarse stones; weak soil strength; many fine and few medium roots
Bw	26 - 57	dark yellowish brown (10YR 4/4) silty sand; 35% medium and coarse stones; friable; many fine and few coarse roots
BC	57 - 70	olive brown to dark yellowish brown (2.5Y 4/4-10YR 4/4) coarse sand; weakly developed fine polyhedral structure; 50% medium to very coarse stones; few fine roots

Sample name: MDC60
Soil Name: Waihopai steepland soil
Location: Wairau Valley, approx 3 km SE of Wairau Village on a slope on E side of Brothers Stream
GPS Coordinates: E2557116 N5958668
Land use: Drystock pasture – sheep/beef
Topography: Hill country
Elevation: 267 m
Slope: 20º
Soil material: Partly weathered greywacke conglomerate gravels
Soil drainage: Well
Date sampled: 6/10/09

Horizon	Thickness (cm)	Soil description
A	0 - 15	very dark greyish brown to black (10YR 3/2-2/1) silt loam; moderately developed fine polyhedral structure; 10% medium and coarse stones; weak soil strength; friable; many fine and few roots
AB	15 - 22	yellowish brown (10YR 5/6) and light olive brown (2.5Y 5/6) sandy loam; moderately developed fine polyhedral structure; 10% medium and coarse stones; weak soil strength; friable; many fine roots
Bw1	22 - 37	yellowish brown (10YR 5/6) to light olive brown (2.5Y 5/6) silt loam; weakly developed medium blocky structure; 15% medium and coarse stones; weak soil strength; friable; few fine roots,
Bw2	37 - 55	light olive brown (2.5Y 5/6) to light yellowish brown (10YR 5/6) sandy silt loam; weakly developed medium polyhedral structure; 20% medium and coarse stones; friable; few fine roots,
Bw3	55 – 90 +	light olive brown (2.5Y 5/6) coarse sandy loam; weakly developed medium polyhedral structure; 20% medium and coarse stones; friable; few fine roots
on		stony regolith