2023 Soil quality monitoring – Dairying

Contents

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Overview

Greater Wellington (GW) monitors soil quality as part of its State of the Environment programme, to meet the requirements of section 35 of the Resource Management Act (1991) and to provide information to measure Regional Plan policy effectiveness.

The soil quality monitoring programme consists of approximately 100 monitoring sites on a range of soils across the region under different land uses. The frequency of sampling is dependent on the intensity of the land use; dairying, cropping and market garden sites are sampled every 3-4 years, dry stock, horticulture and exotic forestry sites are sampled every 5-7 years, while indigenous vegetation sites are sampled every 10 years. This years' report summarises monitoring results for dairying sites.

Monitoring objectives

1. Provide information on the physical, chemical and biological properties of soils;
2. Provide an early-warning system to identify the effects of primary land uses on long-term soil productivity and the environment;
3. Track specific, identified issues relating to the effects of land use on long- term soil productivity;
4. Assist in the detection of spatial and temporal changes in soil quality; and
5. Provide information required to determine the effectiveness of regional policies and plans.

Monitoring indicators

Monitoring indicators are used to assess soil chemistry and fertility, and to understand soil physical condition. The indicators used are as follows:

- Soil chemistry and fertility - total carbon (C), total nitrogen (N), anaerobic mineralisable nitrogen, soil pH, Olsen phosphorus (P), and total recoverable trace elements.
- Physical condition - bulk density and macroporosity.

Measured indicator values at each monitoring site are benchmarked against relevant guidelines for monitoring soil health. See the methods page for more information.

Monitoring sites and indicator breaches

Each monitoring site is shown by the map circles below, with the total number of indicators breached during the 2023 monitoring season displayed by colour of the circle.

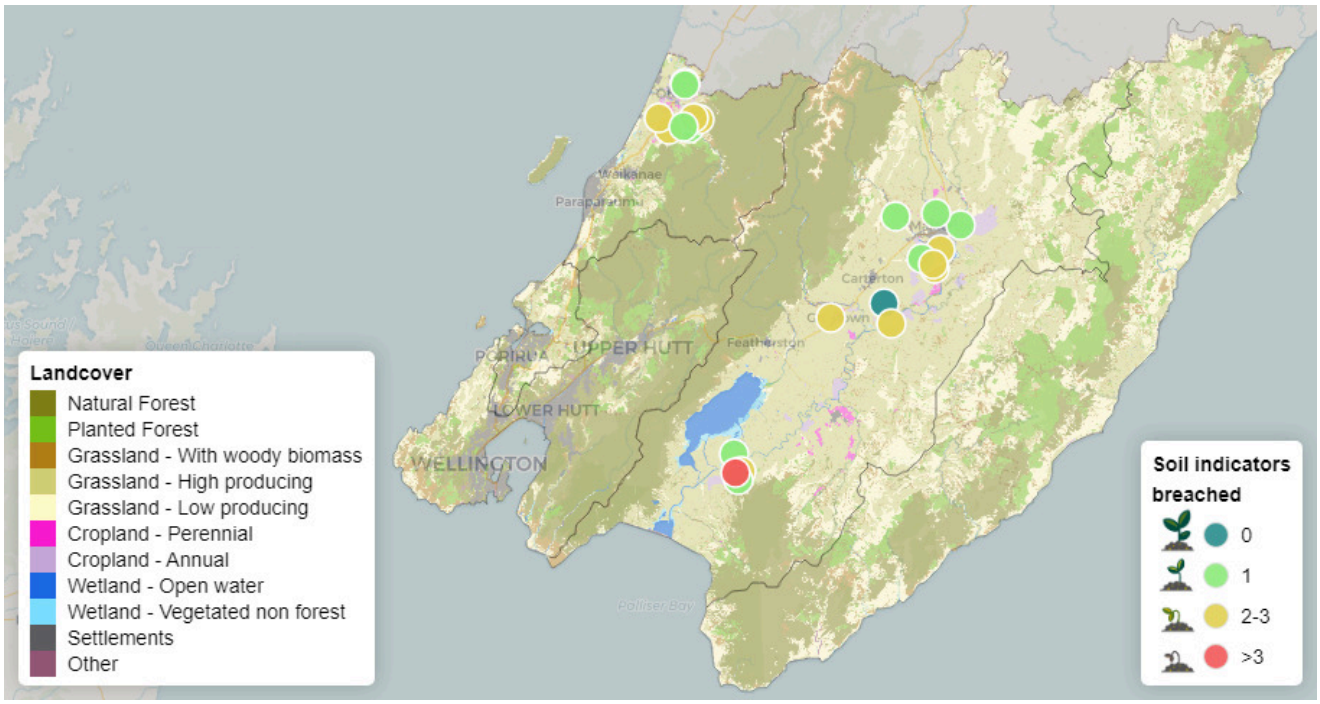

Figure 1: Soil quality monitoring sites rated by the total number of soil quality indicators breached. See the results sections for which indicators were breached, and LUCAS 16 landcover for more information on the classifications shown. Whaitua (main river catchments) are outlined by thin grey lines.

Note that site coordinates have been moved slightly throughout the report for visualisation and confidentiality purposes.

Proportion of total sites that breached indicators

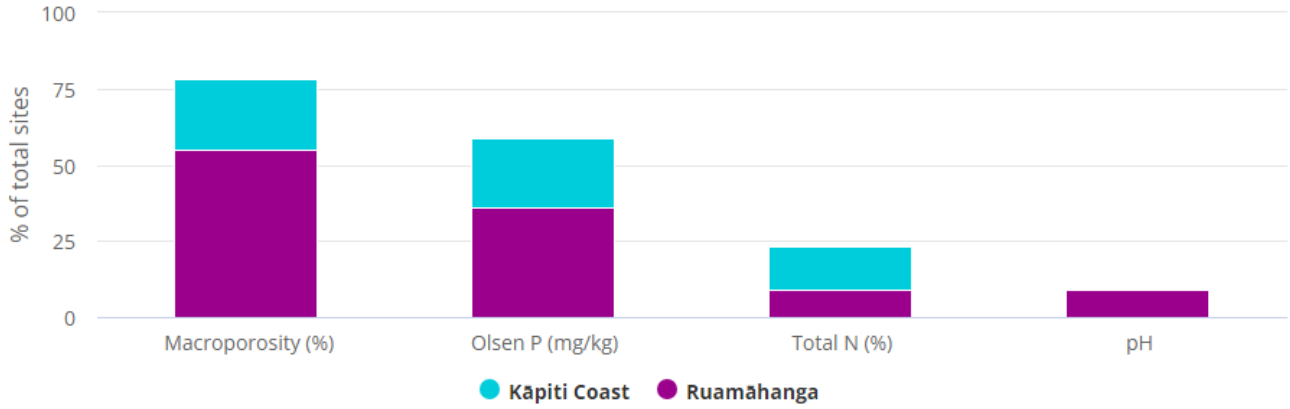

Figure 2: Percentage of total soil quality monitoring sites that breached each soil quality indicator, coloured by Whaitua. Note from the earlier map that in 2023 all sites were located in the Kāpiti Coast and Ruamāhanga whaitua.

Methods

Analytical methods

Analyses of the soil chemistry and soil physics indicators were completed at the Landcare Research laboratory. Trace element analyses were undertaken at Hill Laboratories in Hamilton. Where necessary, samples were stored at 4°C until analysis.

Soil macroporosity was determined at the Landcare Research soil physics laboratory in Hamilton. The Land Monitoring Forum specifies that macroporosity should be measured at a matric potential of -10 kPa. Macroporosity is the percentage of pores > 30 microns in diameter, when measured at -10 kPa. Ambiguity may arise with other terms (e.g. air-filled porosity) or macroporosity measured at other matric potentials (Drewry et al. 2008; 2015).

Olsen P measurements analysed at Landcare Research were undertaken using a gravimetric (weight) method to avoid the influence of soil bulk density. In New Zealand several large commercial laboratories measure soil received in the laboratory by volume prior to Olsen P chemical extraction. The fertiliser industry guidelines for Olsen P measurement are based on a volumetric method. Further information and explanation is available from Drewry et al. (2013; 2015).

Indicator	Method
Bulk density	Measured on a sub-sampled core dried at 105°C.
Total-C content	Dry combustion method. Using air-dried, finely ground soils using a Leco 2000 CNS analyser.
Total-N content	Dry combustion method. Using air-dried, finely ground soils using a Leco 2000 CNS analyser.
Mineralisable-N	Waterlogged incubation method. Increase in NH_4^+ concentration was measured after incubation for 7 days at 40°C and extraction in 2M KCl.
Soil pH	Measured in water using glass electrodes and a 2.5:1 water-to-soil ratio.
Olsen P	Bicarbonate extraction method. Extracting <2mm air dried soils for 30 minutes with 0.5M $NaHCO_3$ at pH 8.5 and measuring the PO_4^{3-} concentration by the molybdenum blue method.
Trace elements	Total recoverable digestion. Nitric/hydrochloric acid digestion, USEPA 2002.

Benchmarking

Green shaded columns indicate **soil quality target ranges**, follow the referenced links for more information.

Bulk density (t/m^3)

Table 1: Target range is 'Loose' to 'Compact' (Hill and Sparling, 2009).

Soil order	Very loose	Loose	Adequate	Compact	Very compact
Semi-arid, pallic and recent	≤0.40	>0.40 to ≤0.90	>0.90 to ≤1.25	>1.25 to ≤1.40	>1.40
Allophanic	≤0.30	>0.30 to ≤0.60	>0.60 to ≤0.90	>0.90 to ≤1.30	>1.30
Organic	≤0.20	>0.20 to ≤0.40	>0.40 to ≤0.60	>0.60 to ≤1.00	>1.00
All other	≤0.70	>0.70 to ≤0.80	>0.80 to ≤1.20	>1.20 to ≤1.40	>1.40

Macroporosity (% v/v at -10kPa)

Table 2: Target range is 'Adequate' (Hill and Sparling, 2009).

Land use	Very low	Low	Adequate	High
Pastures, cropping and horticulture	≤6	>6 to ≤10	>10 to ≤30	>30
Forestry	≤8	>8 to ≤10	>10 to ≤30	>30

Total Carbon (% w/w)

Table 3: Target range is 'Depleted' to 'Ample' (modified from Hill and Sparling, 2009 to have no upper bound on the ample category). *Organic soils excluded as by definition these soils have ample total carbon content.

Soil order	Very depleted	Depleted	Normal	Ample
Semi-arid, pallic and recent	≤2.0	>2.0 to ≤3.0	>3.0 to ≤5.0	>5.0
Allophanic	≤3.0	>3.0 to ≤4.0	>4.0 to ≤9.0	>9.0
Organic*				
All other	≤2.5	>2.5 to ≤3.5	>3.5 to ≤7.0	>7.0

Total nitrogen (% w/w)

Table 4: Target range is 'Depleted' to 'Ample', (Hill and Sparling, 2009). *Cropping and horticulture excluded as ranges would depend on specific crops grown.

Land use	Very depleted	Depleted	Normal	Ample	High
Pasture	≤0.25	>0.25 to ≤0.35	>0.35 to ≤0.65	>0.65 to ≤0.70	>0.70
Forestry	≤0.10	>0.10 to ≤0.20	>0.20 to ≤0.60	>0.60 to ≤0.70	>0.70

Mineralisable nitrogen (mg/kg)

Table 5: Target range is 'Low' to 'High' (Hill and Sparling 2009).

Land use	Very low	Low	Adequate	Ample	High	Excessive
Pasture	≤50	>50 to ≤100	>100 to ≤200	>200 to ≤200	>200 to ≤250	>250
Cropping and horticulture	≤20	>20 to ≤100	>100 to ≤150	>150 to ≤150	>150 to ≤200	>200
Forestry	≤20	>20 to ≤40	>40 to ≤120	>120 to ≤150	>150 to ≤175	>175

Soil pH

Table 6: Target range is 'Slighly-acidic' to 'Optimal' (Hill and Sparling, 2009). Note that we refer to their 'Sub-optimal' rating as 'Slightly alkaline' throughout this report. Also note that soil pH classifications differ from usual liquid pH classifications; liquid acidity and alkalinity are usually classified with respect to a neutral pH of 7, whereas soil acidity and alkalinity are classified relative the optimal range for that land use and soil order.

Land use & soil order	Very acidic	Slightly acidic	Optimal	Slightly alkaline	Very alkaline
Pastures on all except Organic	>4.0 to ≤5.0	>5.0 to ≤5.5	>5.5 to ≤6.3	>6.3 to ≤6.6	>6.6 to ≤8.5
Pastures on Organic	>4.0 to ≤4.5	>4.5 to ≤5.0	>5.0 to ≤6.0	>6.0 to ≤7.0	>7.0
Cropping & horticulture on all except Organic	>4.0 to ≤5.0	>5.0 to ≤5.5	>5.5 to ≤7.2	>7.2 to ≤7.6	>7.6 to ≤8.5
Cropping & horticulture on Organic	>4.0 to ≤4.5	>4.5 to ≤5.0	>5.0 to ≤7.0	>7.0 to ≤7.6	>7.6
Forestry on all except Organic	≤3.5	>3.5 to ≤4.0	>4.0 to ≤7.0	>7.0 to ≤7.6	>7.6
Forestry on organic soils*					

**Forestry on organic soils are excluded as this combination is unlikely in real life due to windthrow.*

Olsen P (mg/kg)

Table 7: Target ranges are set for different land use and soil orders (see the revised targets of McKay et al 2013). Note that 'Market gardening' refers to the cropping of Celery, Leeks, Winter Lettuce, Onions, Early Potatoes, and Winter Spinach. Note also that lifestyle blocks are included in 'Pastures, [other] cropping, and horticulture'.

Land use	Soil order	Range
Forestry	All Soils	>5 to ≤50
Indigenous	All Soils	>0 to ≤50
Market gardening	Recent and Pallic Soils	>45 to ≤55
Market gardening	Brown, Gley, Melanic, Organic, Pumice, Semi arid and Ultic Soils	>55 to ≤75
Market gardening	Allophanic, Granular and Oxidic Soils	>75 to ≤90
Pasture, cropping and horticulture	Andisols	>35 to ≤60
Pasture, cropping and horticulture	Pumice Soils	>35 to ≤60
Pasture, cropping and horticulture	Organic Soils	>35 to ≤50
Pasture, cropping and horticulture	Recent Soils and Podzols	>20 to ≤50
Pasture, cropping and horticulture	Raw Soils	>10 to ≤25
Pasture, cropping and horticulture	Other Soils	>25 to ≤50

Trace elements - draft eco-soil guidelines (mg/kg)

Table 8: Target range is less than the soil guideline value (Cavanagh, 2019). Note: Other values may apply for non-agricultural land uses, soils and circumstances.

Trace element	Guideline (mg/kg)	Soil orders rated
Arsenic (mg/kg)	<20	All soil
Cadmium (mg/kg)	<1.5	All soil
Chromium (mg/kg)	<300	All soil
Copper (mg/kg)	<150	Sensitive soil
Copper (mg/kg)	<340	Tolerant soil
Copper (mg/kg)	<220	Typical soil
Lead (mg/kg)	<530	All soil
Nickel (Ni)	Not determined	
Zinc (mg/kg)	<130	Sensitive soil
Zinc (mg/kg)	<265	Tolerant soil
Zinc (mg/kg)	<190	Typical soil

Trace elements - adapted from NZWWA (mg/kg)

Table 9: Target range is less the the soil limit value (NZWWA, 2003). Note: the suggested values by Alloway (2008) suggested for copper deficiency (≤ 5 mg/kg) and zinc deficiency (≤ 10 mg/kg) may be of interest depending on circumstances and type of farm production.

Trace element	Soil limit (mg/kg)
Arsenic (mg/kg)	<20
Cadmium (mg/kg)	<1
Chromium (mg/kg)	<600
Copper (mg/kg)	<100
Lead (mg/kg)	<300
Nickel (mg/kg)	<60
Zinc (mg/kg)	<300

Cadmium - Tiered Fertiliser Management System (mg/kg)

Table 10: Target ranges depend on the choice and rate of phosphate fertiliser application, see the Fertiliser Association Tiered Fertiliser Management System for Soil Cadmium for more detail.

Tier	Concentration (mg/kg)
0	>0.0 to ≤0.6
1	>0.6 to ≤1.0
2	>1.0 to ≤1.4
3	>1.4 to ≤1.8
4	>1.8

Soil chemistry & fertility results

The following sections present maps of soil quality monitoring results benchmarked against relevant indicator guidelines, see Appendix 2: Data tables for tabulated results.

Organic resources

Total carbon (C)

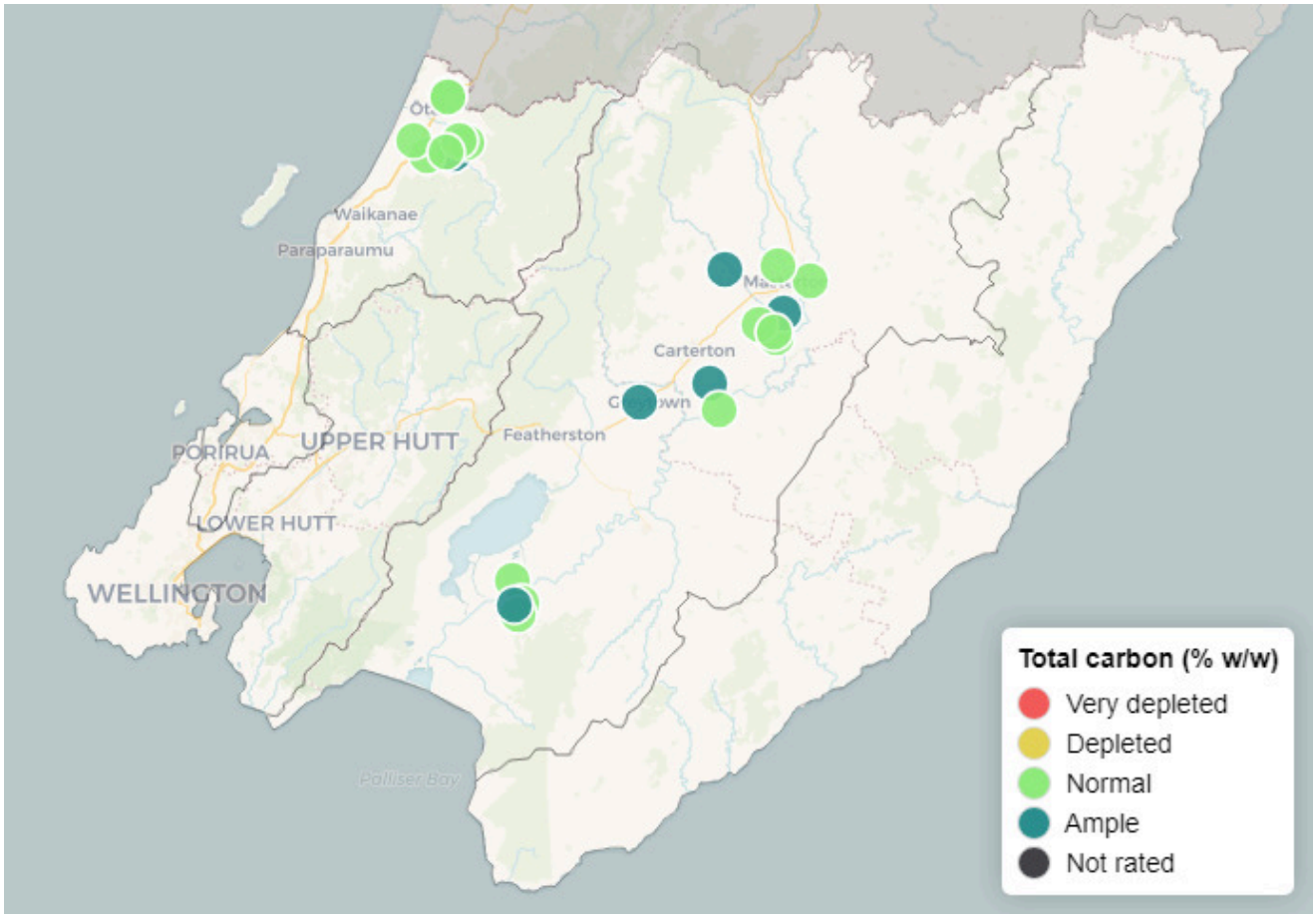

Figure 3: Total carbon is an estimate of the amount of organic matter. Organic matter helps soils retain moisture and nutrients, and gives good soil structure for water movement and root growth. It can be used to address the issue of organic matter depletion and carbon loss from the soil. The target range is **'Depleted' to 'Ample'**, see benchmarking for more information.

Total nitrogen (N)

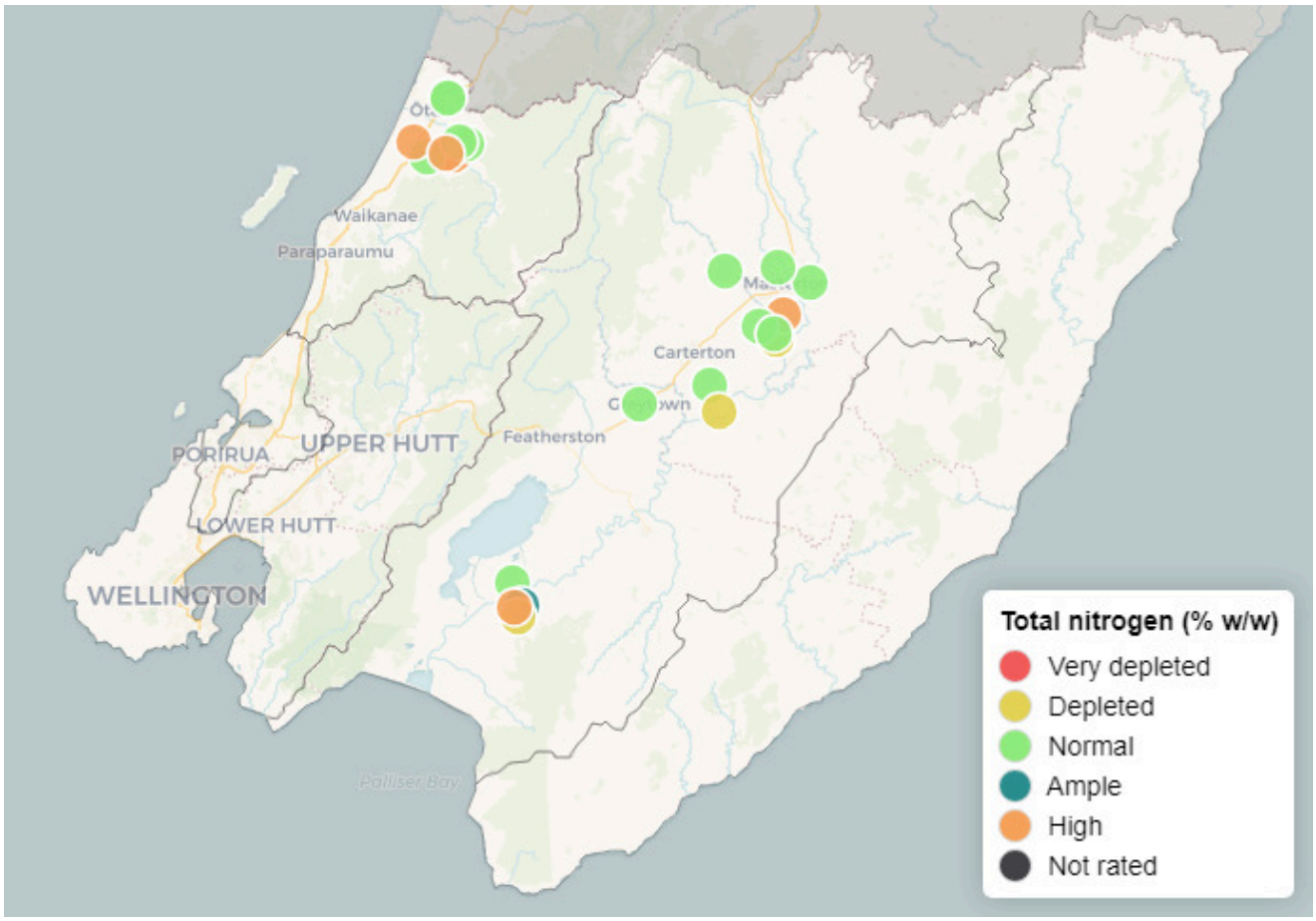

Figure 4: Most nitrogen in soil is present within the organic matter fraction, and total nitrogen gives a measure of those reserves. It also provides an indication for the potential of nitrogen to leach into underlying groundwater. The target range is **'Depleted' to 'Ample'**, see benchmarking for more information.

Mineralisable nitrogen (N)

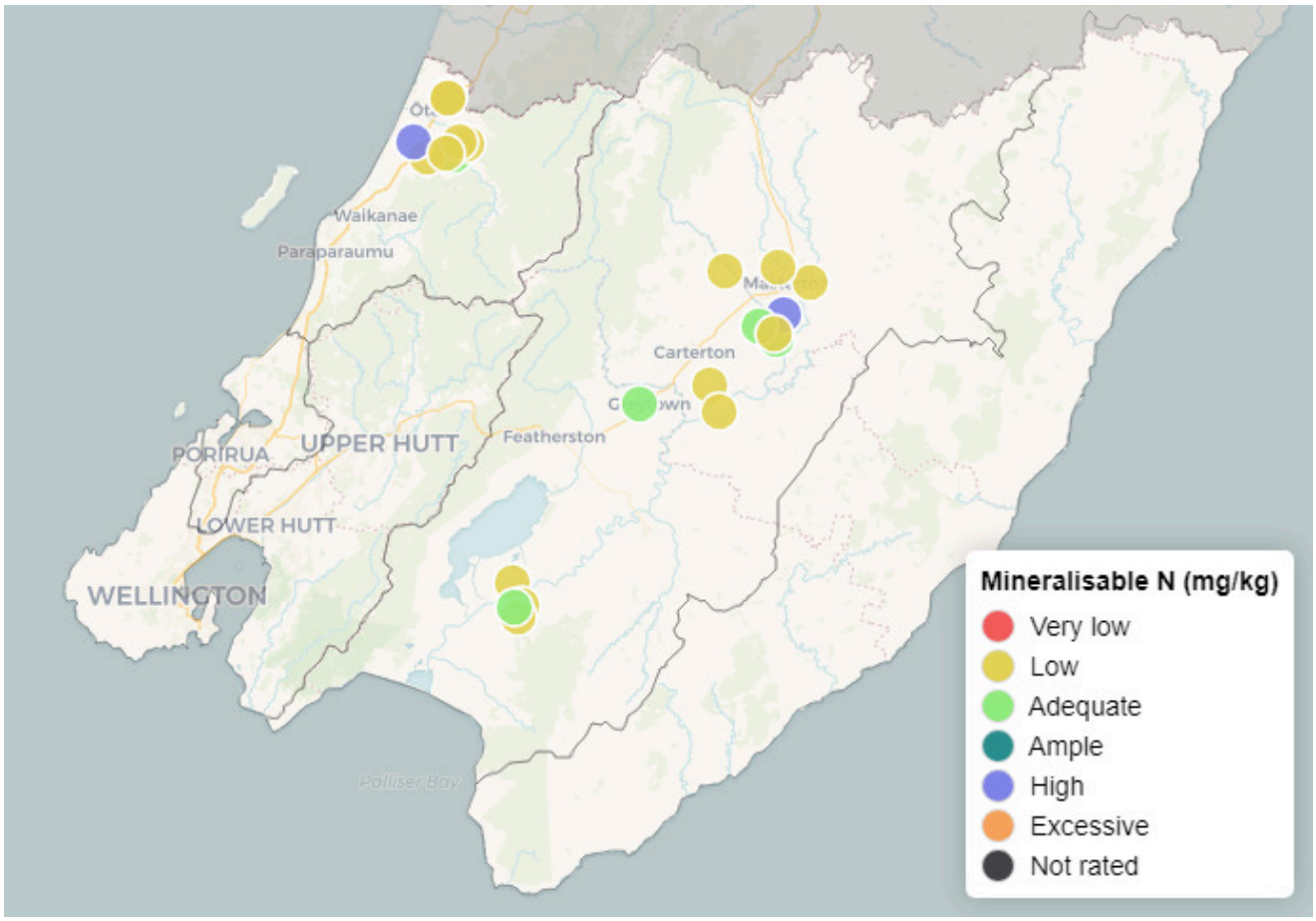

Figure 5: Not all nitrogen can be used by plants; soil organisms change nitrogen to forms that plants can use. Mineralisable N gives a measure of how much organic nitrogen is available to plants, and the potential for nitrogen leaching at times of low plant demand. Mineralisable nitrogen is also used as a surrogate measure of the microbial biomass. The target range is **'Low' to 'High'**, see benchmarking for more information.

Acidity - soil pH

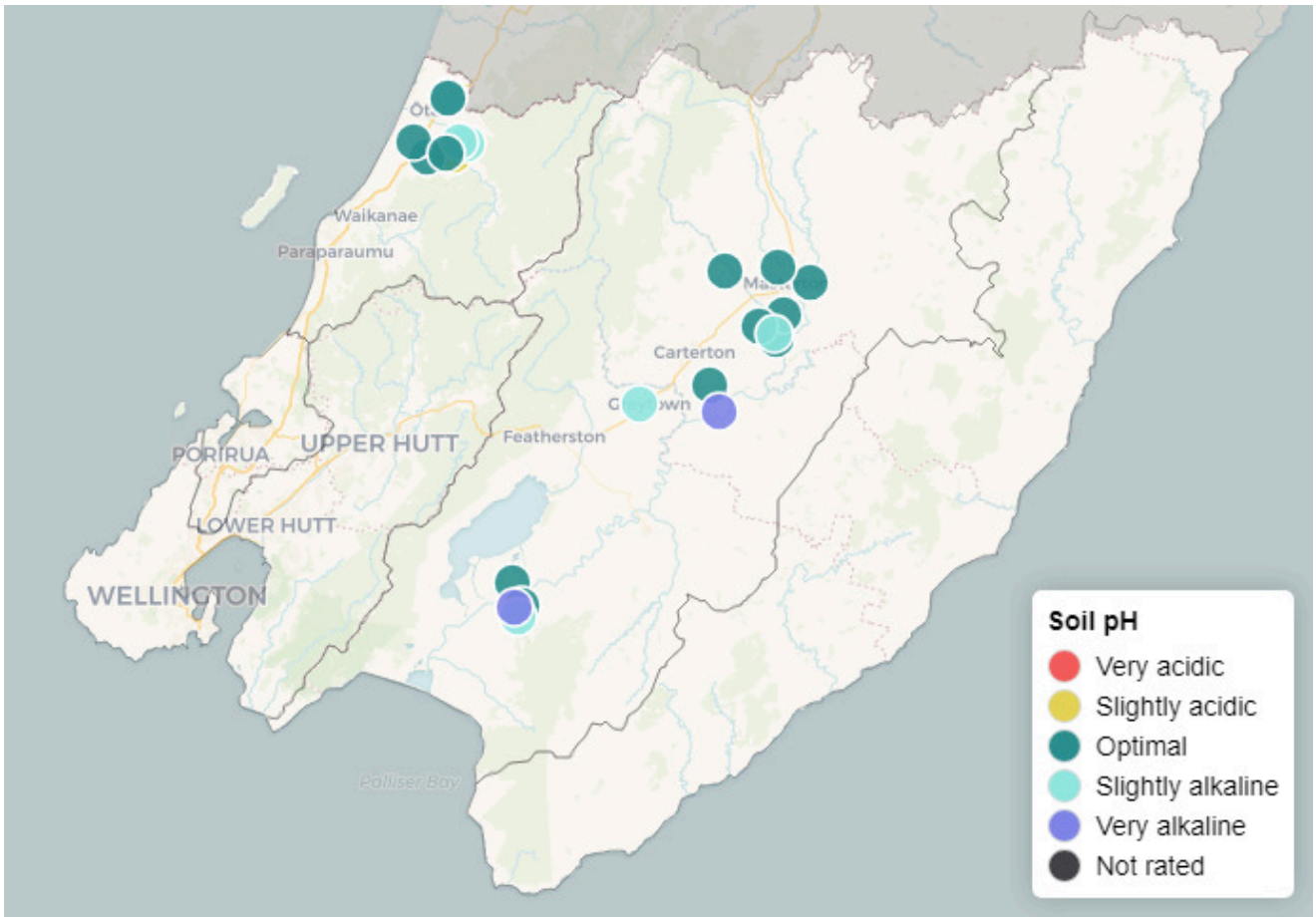

Figure 6: Most plants have an optimal pH range for growth. The pH of a soil influences the availability of many nutrients to plants and the solubility of some trace elements. Soil pH is influenced by the application of lime and some fertilisers. The target range is **'Slightly-acidic' to 'Optimal'**, see benchmarking for more information.

Fertility - Olsen P

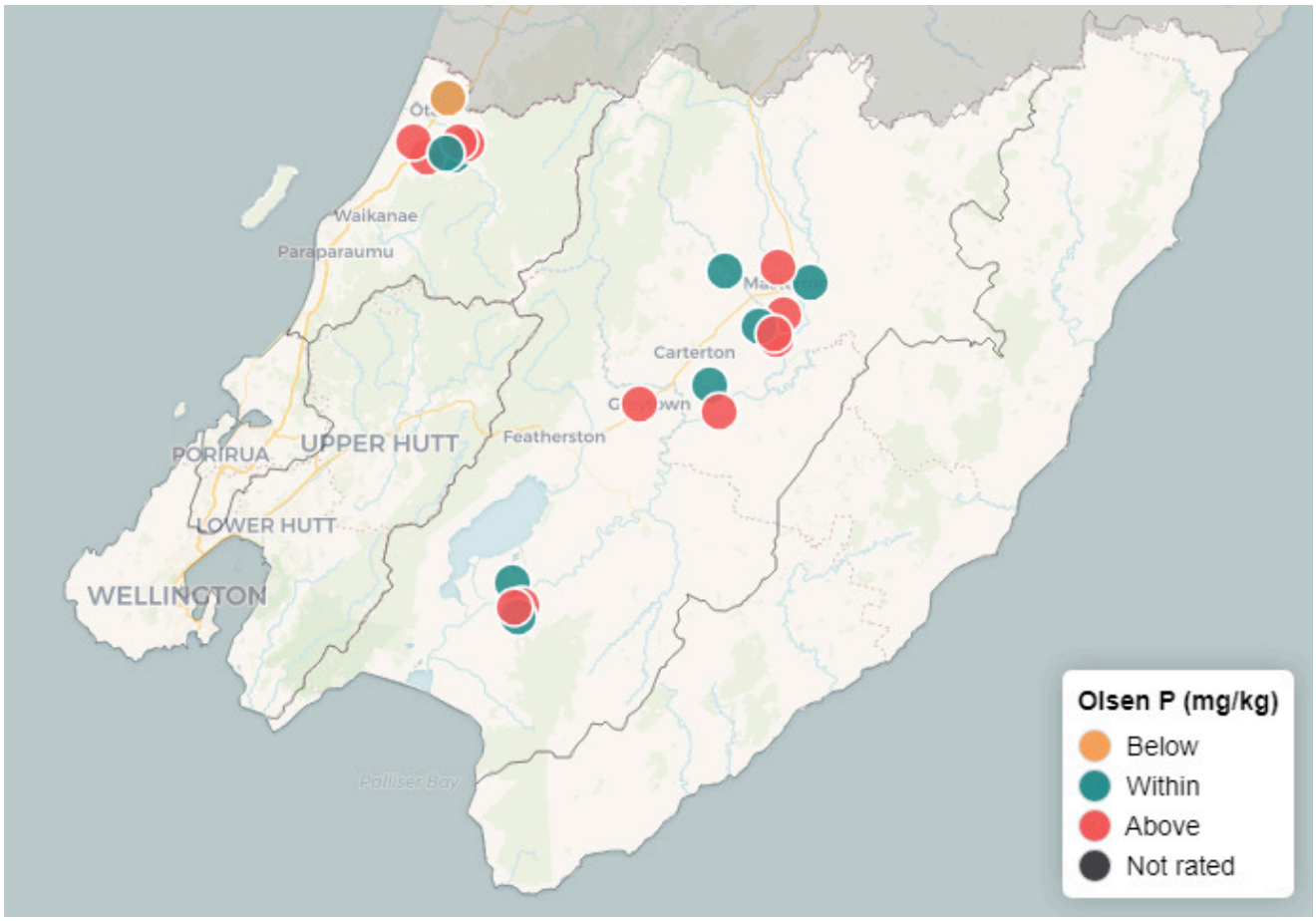

Figure 7: Phosphorus (P) is an essential nutrient for plants and animals. Olsen P is a measure of the amount of phosphorus that is available to plants. Levels of P greater than agronomic requirements can increase P losses to waterways, and therefore contribute to eutrophication (nutrient enrichment). The target ranges for pastural sites vary, see benchmarking for more information.

Trace elements

Some trace elements are essential micro-nutrients for plants and animals. Both essential and non-essential trace elements can become toxic at high concentrations. Trace elements can accumulate in the soil from various common agricultural and horticultural land use practices.

Arsenic (As)

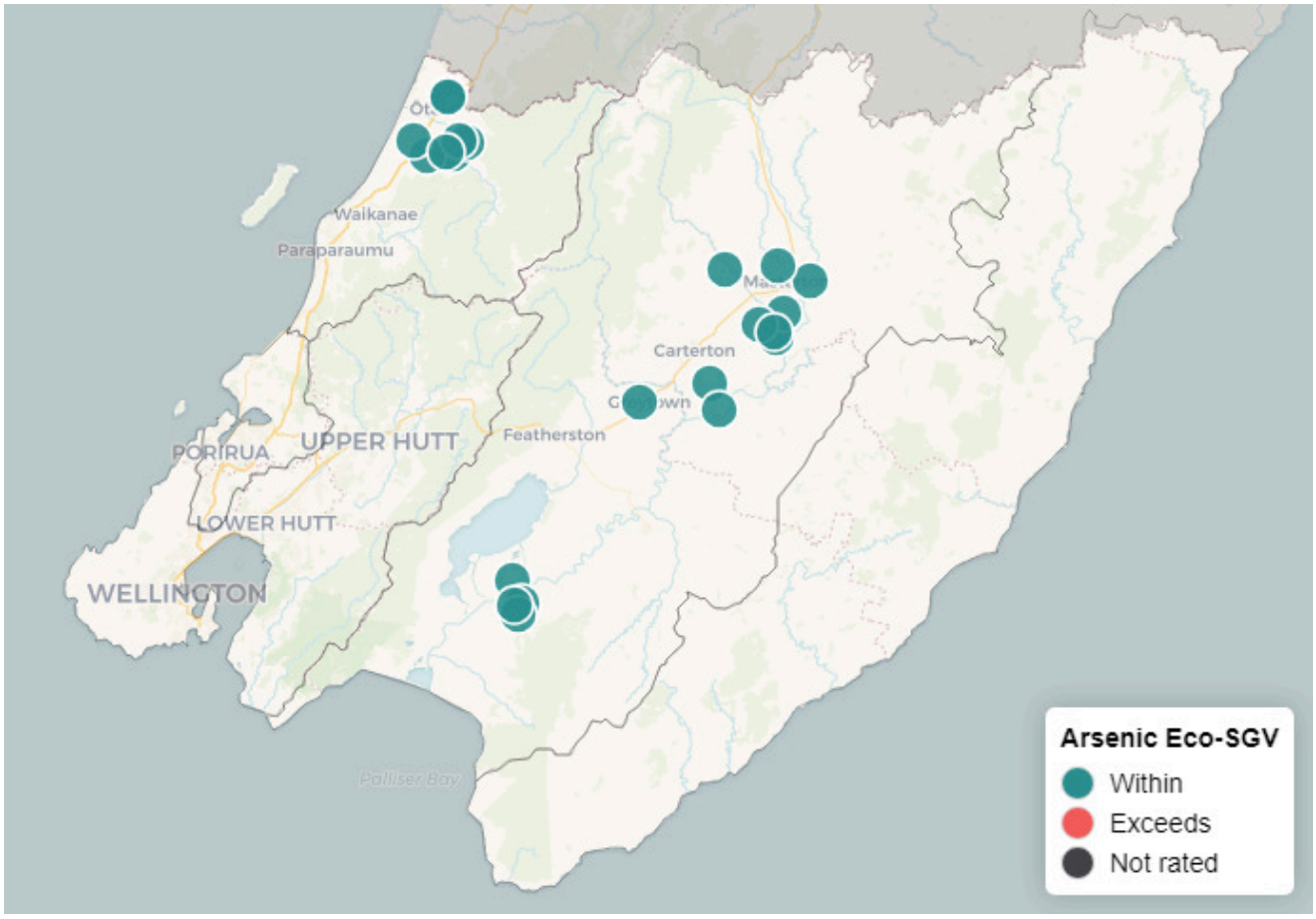

Figure 8: Arsenic results are compared against draft eco-soil guideline values (Eco-SGVs), see benchmarking for more information.

Cadmium (Cd)

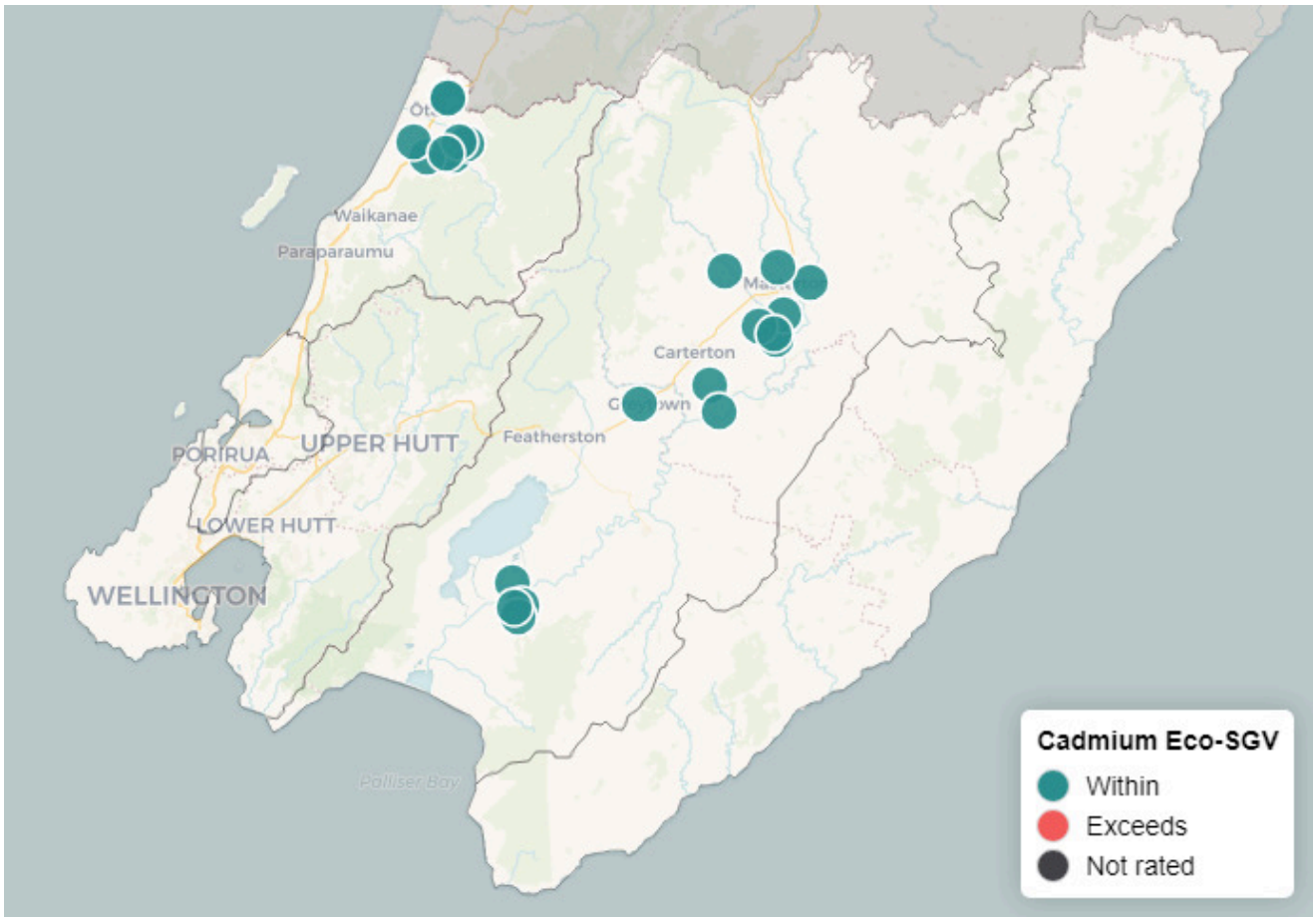

Figure 9: Cadmium results are compared against draft eco-soil guideline values (Eco-SGVs) on the map and trigger values from the tiered fertiliser management system (TFMS) also in the table, see benchmarking for more information.

Chromium (Cr)

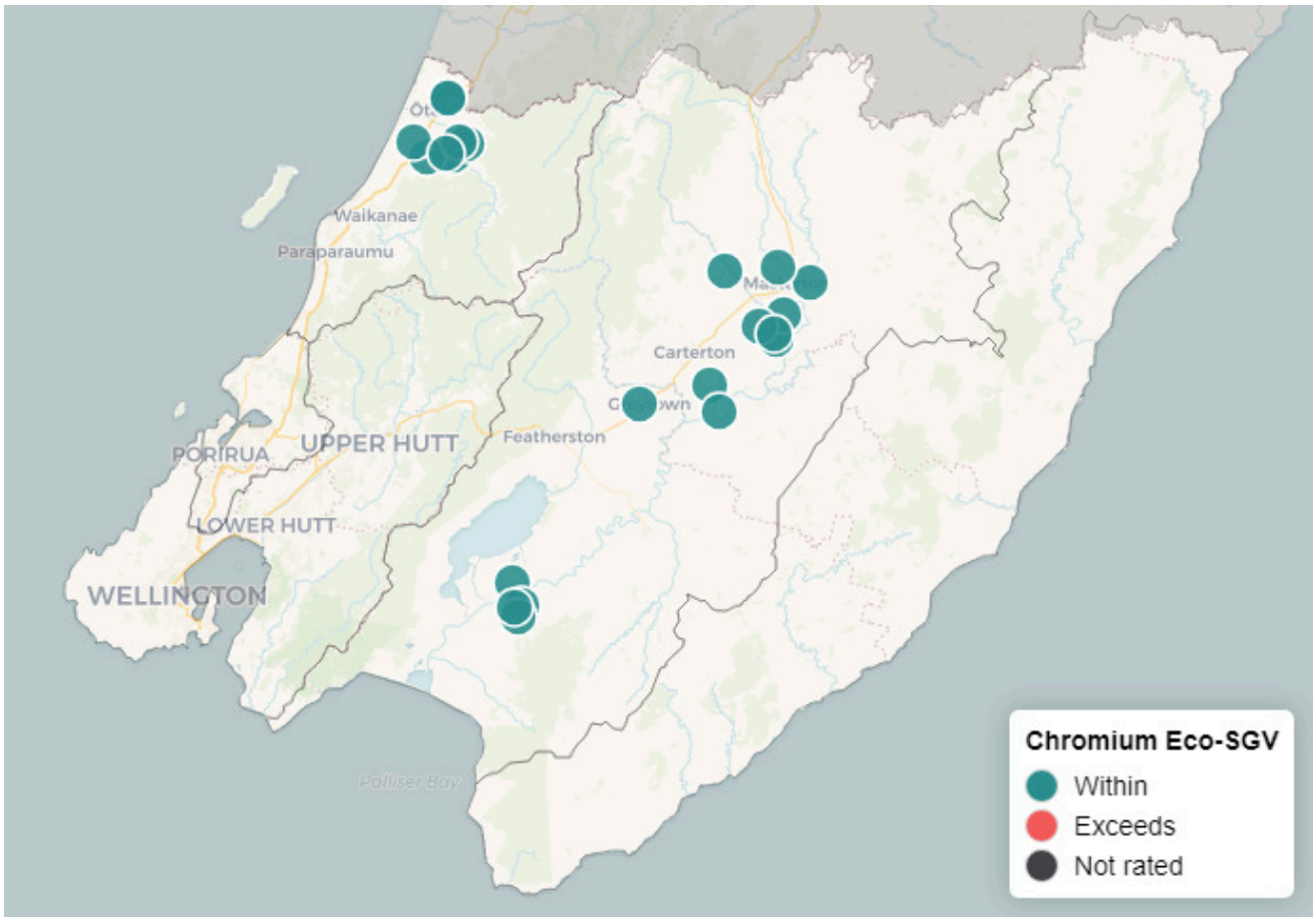

Figure 10: Chromium results are compared against draft eco-soil guideline values (Eco-SGVs), see benchmarking for more information.

Copper (Cu)

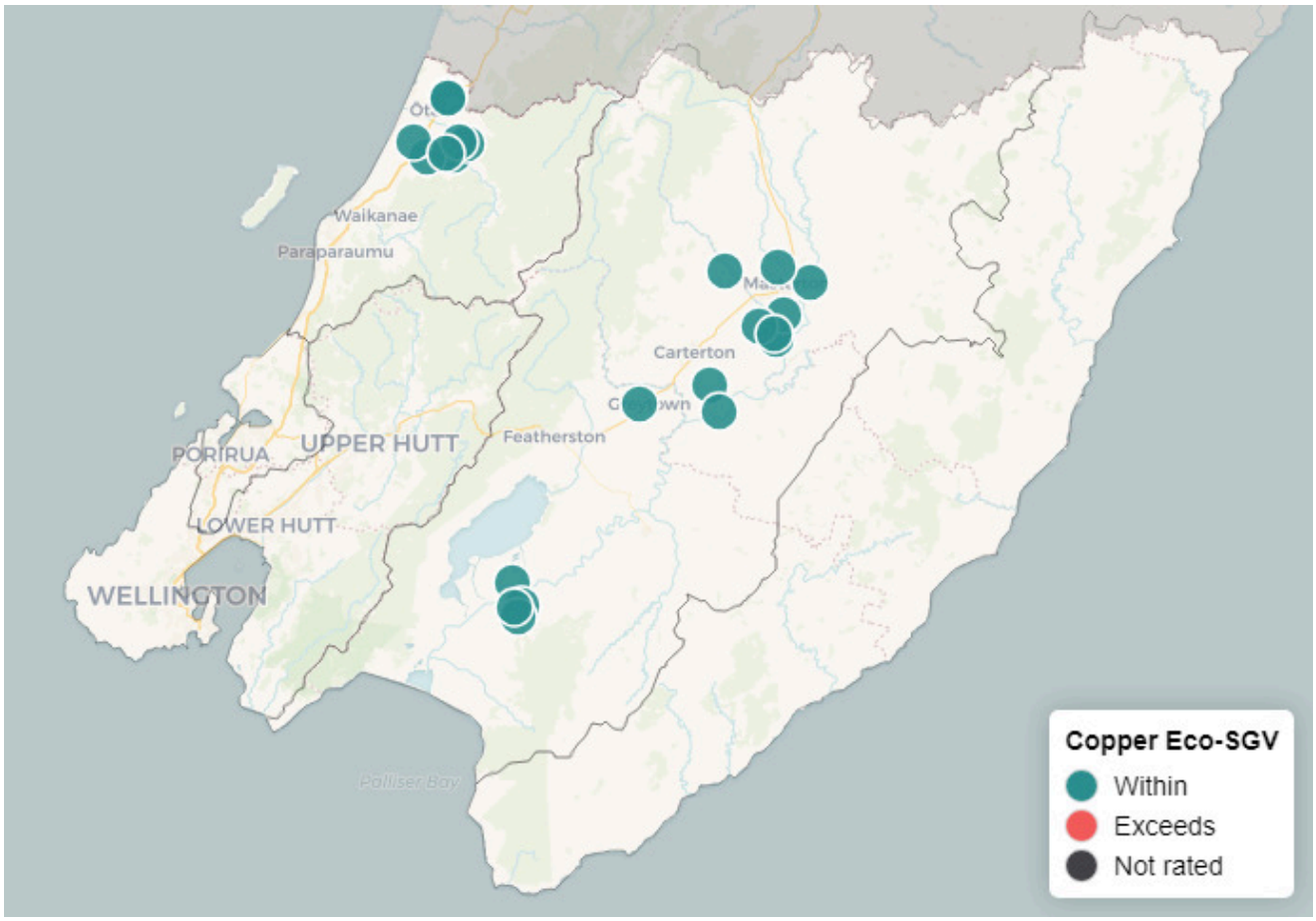

Figure 11: Copper results are compared against draft eco-soil guideline values (Eco-SGVs), see benchmarking for more information.

Lead (Pb)

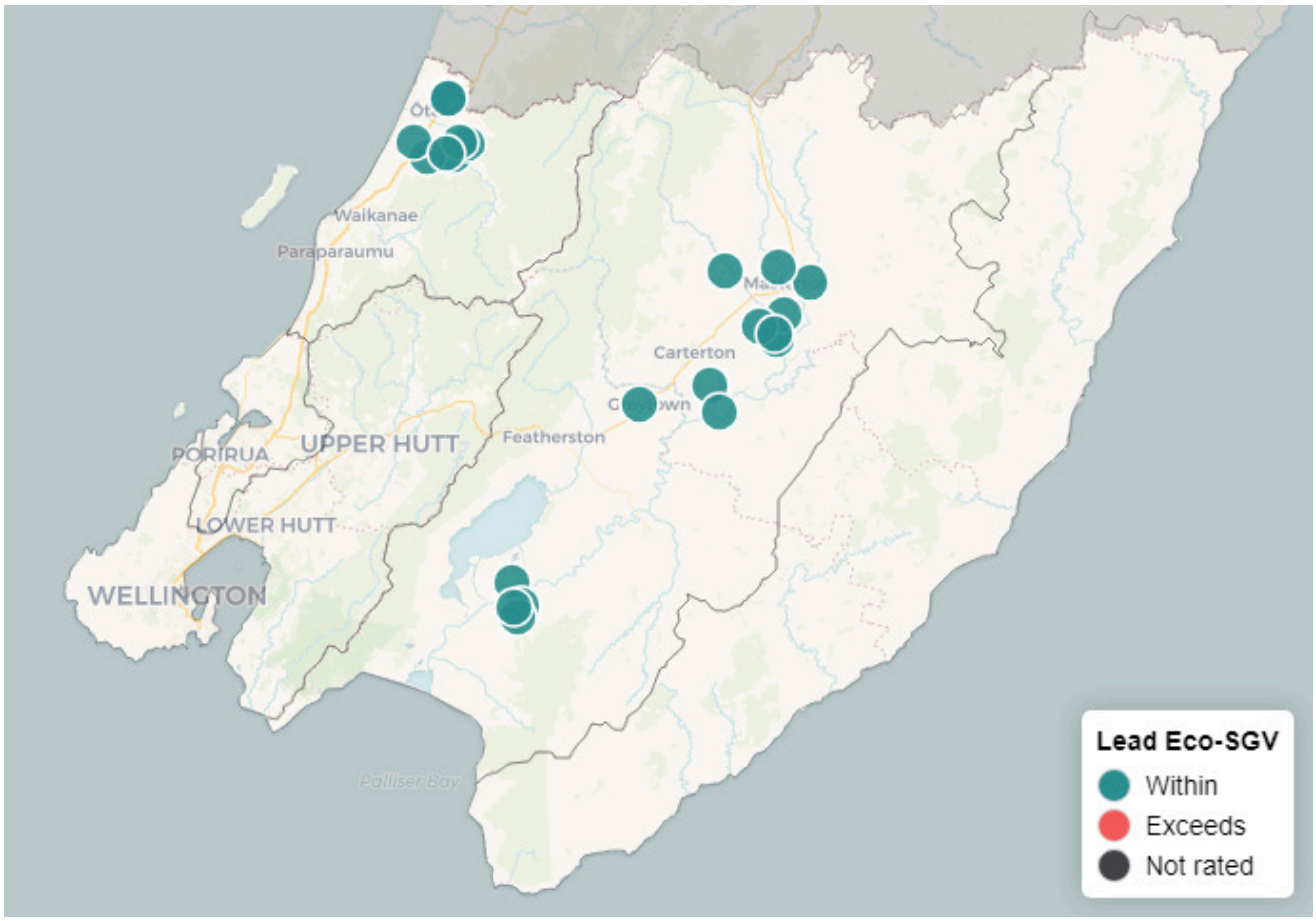

Figure 12: Lead results are compared against draft eco-soil guideline values (Eco-SGVs), see benchmarking for more information.

Nickel (Ni)

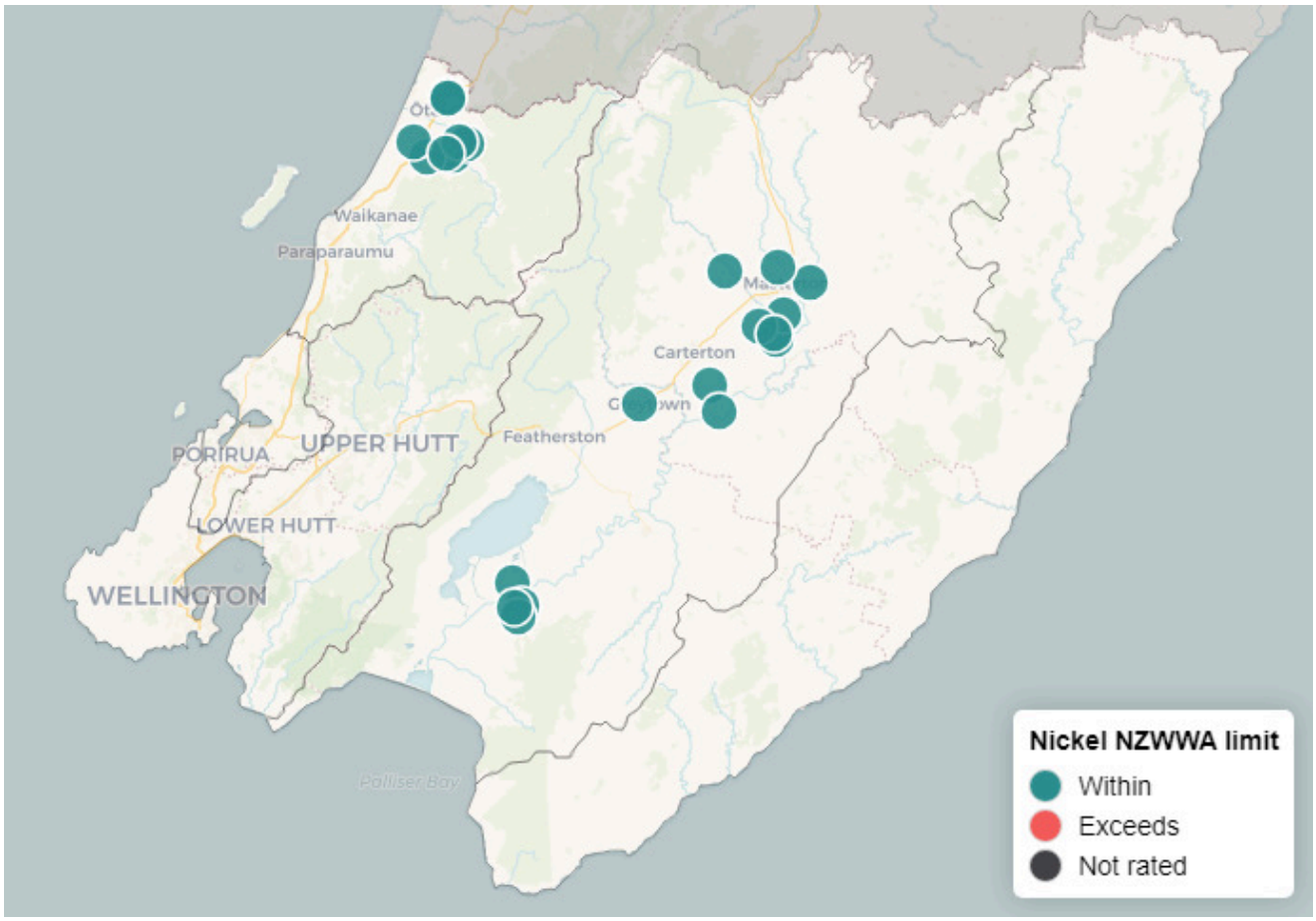

Figure 13: Nickel results are compared against New Zealand Water and Wastes Association (NZWWA) limits, see benchmarking for more information.

Zinc (Zn)

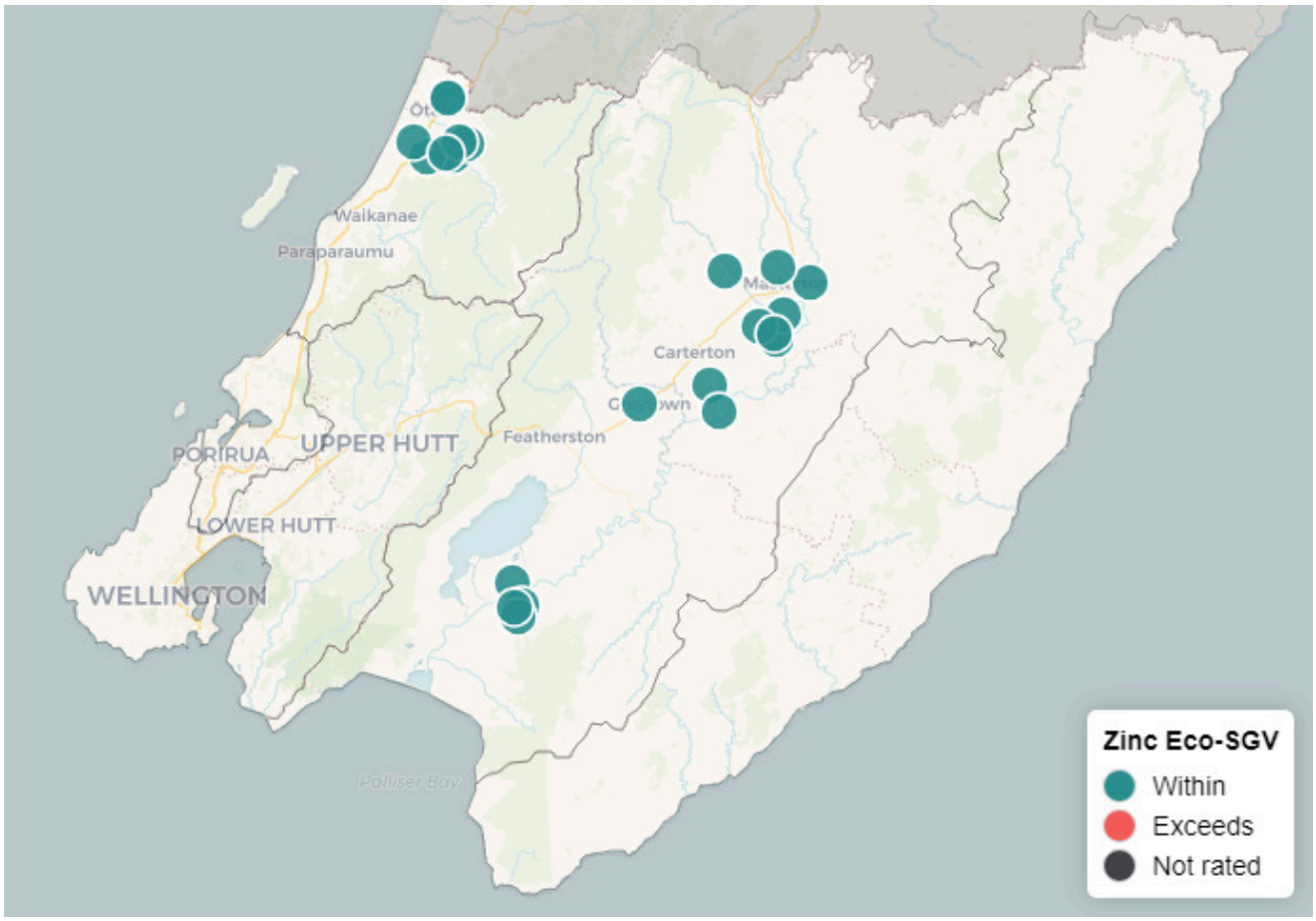

Figure 14: Zinc results are compared against draft eco-soil guideline values (Eco-SGVs), see benchmarking for more information.

Physical condition results

The following sections present maps of soil quality monitoring results benchmarked against relevant indicator guidelines, see Appendix 2: Data tables for tabulated results.

Bulk density

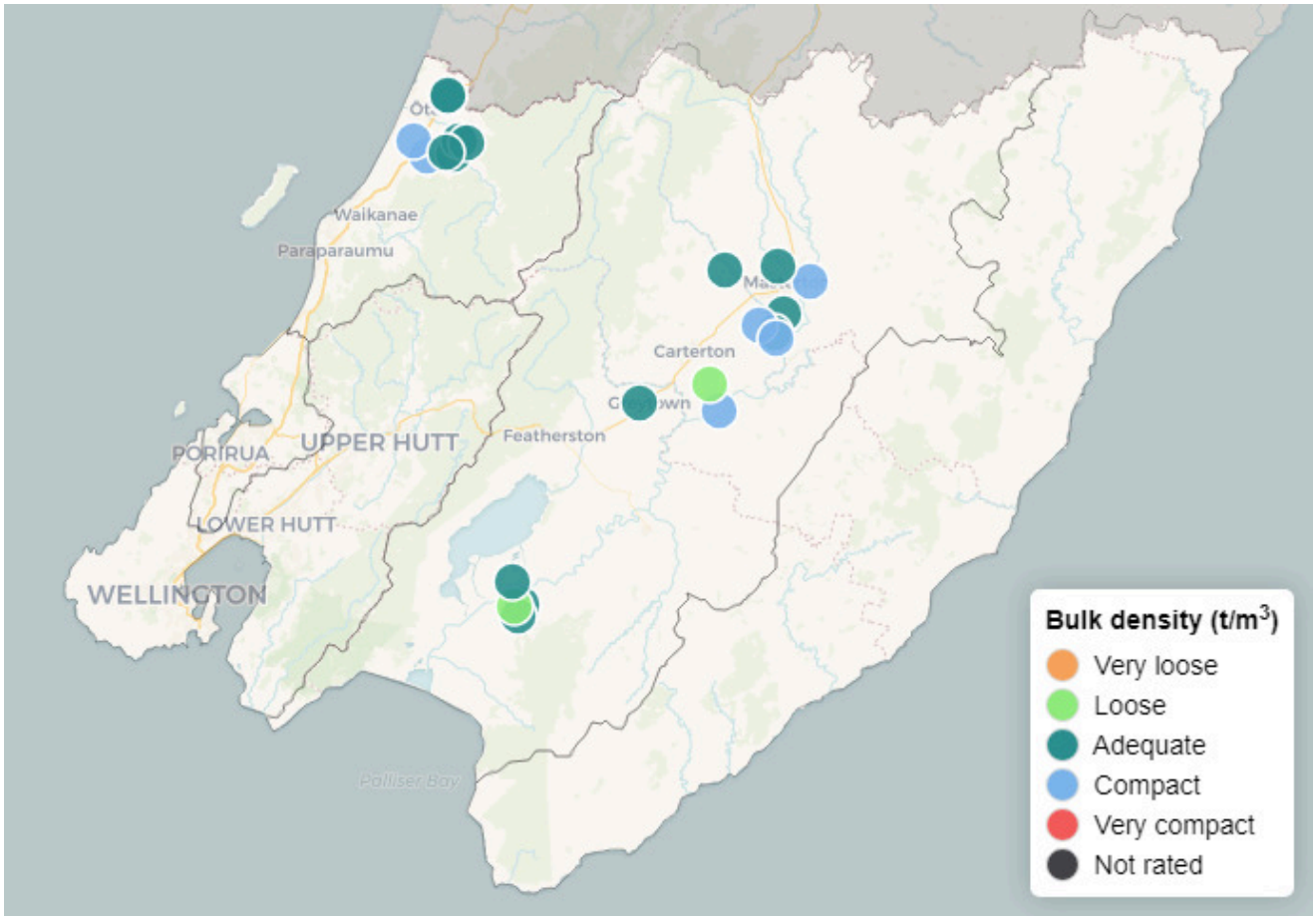

Figure 15: Bulk density is a measure of soil density. A high bulk density indicates a compacted or dense soil. Movement of water and air through soil pores is reduced in compacted soils. High soil bulk density can restrict root growth and adversely affect plant growth. There is also potential for increased run-off and nutrient loss to surface waters in compacted soils. The target range is 'Loose' to 'Compact', see benchmarking for more information.

Macroporosity

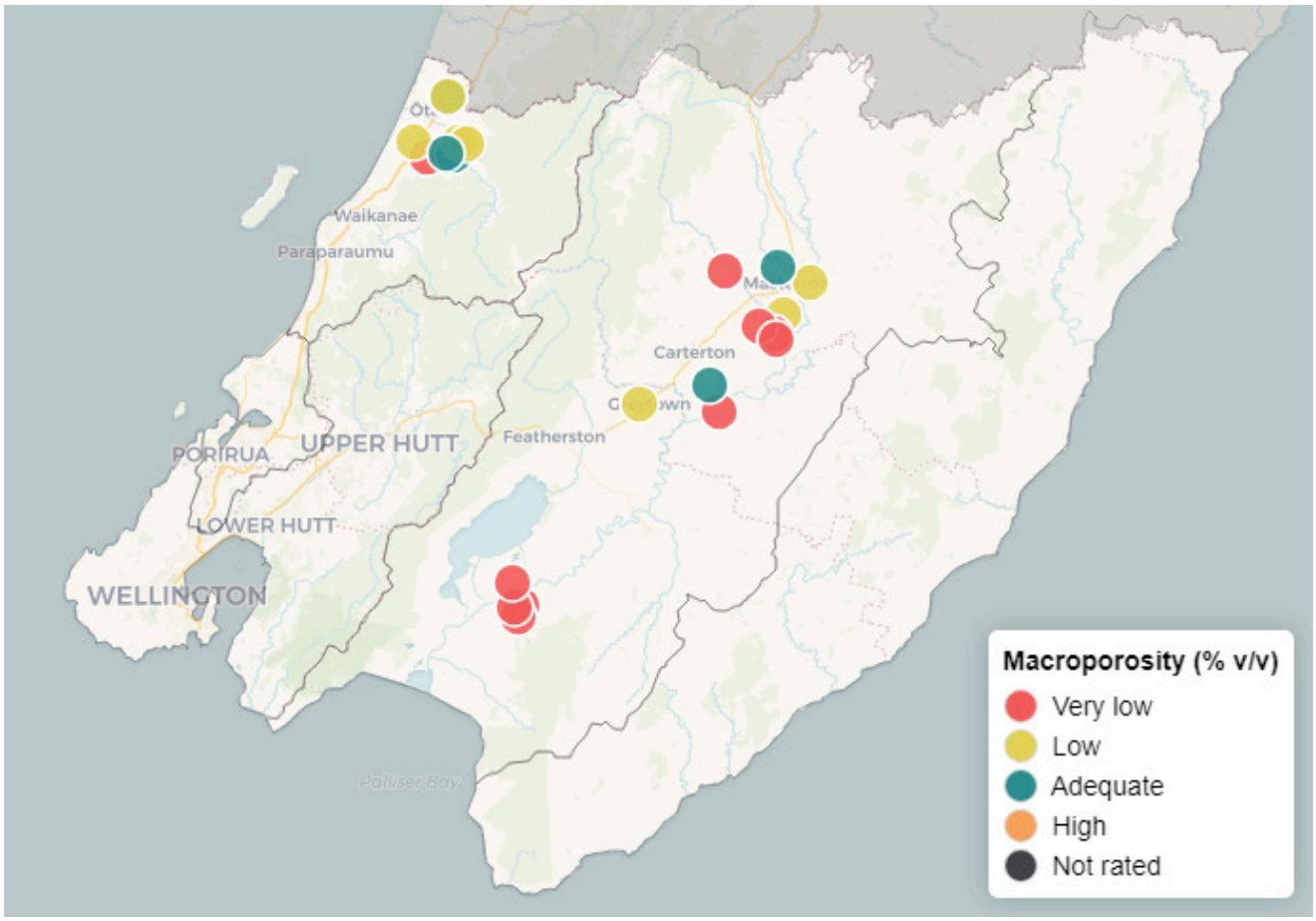

Figure 16: Macropores are important for soil air movement and drainage. Large soil pores are the most susceptible to collapse when soil is compacted. Low macroporosity adversely affects plant growth due to poor root environment, restricted air movement and N-fixation by clover roots. It also infers poor drainage and infiltration. The target is 'Adequate', see benchmarking for more information.

Resources

Useful links for managing soil quality

- Reducing the impacts of winter grazing on soil and water quality
- Soil compaction and pugging on farms
- Limiting Pugging and Compaction Damage
- Soil Fertility for Pasture
- Nitrogen Fertiliser
- Nutrient Management
- Beef and Lamb - Successful soil and fertiliser management
- Managing our soils
- New Zealand Landcare Trust
- Soil Quality Indicators - A web-based tool designed to help you interpret the quality or health of a soil you have sampled

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Appendix 1: Monitoring site information

Table A1.1: 2023 dairying monitoring sites with LUCAS 16 landcover classifications.

Whaitua	Site code	Land use	Soil order	Soil subgroup	Soil type	Landcover
Kāpiti Coast	GW005	Dairy	Brown	Acidic Allophanic Brown	Kawhatau stony silt loam	Grassland - High producing
Kāpiti Coast	GW006	Dairy	Brown	Mottled Orthic Brown	Te Horo silt loam	Grassland - High producing
Kāpiti Coast	GW010	Dairy	Recent	Acidic-weathered Fluvial Recent	Manawatu fine sandy loam	Grassland - High producing
Ruamāhanga	GW013	Dairy	Gley	Typic Recent Gley	Ahikouka silt loam	Grassland - High producing
Ruamāhanga	GW015	Dairy	Gley	Typic Recent Gley	Ahikouka silty clay	Grassland - High producing
Ruamāhanga	GW019	Dairy	Pallic	Argillic Perch-gley Pallic	Kokotau silt loam	Grassland - High producing
Ruamāhanga	GW023	Dairy	Recent	Acidic-weathered Fluvial Recent	Greytown silt loam	Grassland - High producing
Ruamāhanga	GW032	Dairy	Pallic	Typic Perch-gley Pallic	Bideford silt loam	Grassland - High producing
Ruamāhanga	GW036	Dairy	Pallic	Typic Perch-gley Pallic	Moroa silt loam	Grassland - High producing
Ruamāhanga	GW038	Dairy	Pallic	Typic Argillic Pallic	Tauherenikau silt loam	Grassland - High producing
Ruamāhanga	GW042	Dairy	Pallic	Typic Immature Pallic	Moroa silt loam	Grassland - High producing
Kāpiti Coast	GW046	Dairy	Gley	Acidic Orthic Gley	Rahui silt loam.	Grassland - High producing
Kāpiti Coast	GW048	Dairy	Recent	Acidic Fluvial Recent	Otaki gravelly silt loam	Grassland - High producing
Ruamāhanga	GW076	Dairy	Pallic	Mottled Immature Pallic	Tauherenikau silt loam	Grassland - Low producing
Ruamāhanga	GW078	Dairy	Recent	Weathered Fluvial Recent	Greytown silt loam	Grassland - High producing
Ruamāhanga	GW096	Dairy	Recent	Weathered Fluvial Recent	Greytown silt loam	Grassland - High producing
Ruamāhanga	GW098	Dairy	Pallic	Typic Perch-gley Pallic	Moroa silt loam	Cropland - Annual
Ruamāhanga	GW100	Dairy	Pallic	Mottled Argillic Pallic	Kokotau silt loam	Settlements
Ruamāhanga	GW105	Dairy	Pallic	Mottled Argillic Pallic	Kokotau silt loam	Grassland - High producing
Kāpiti Coast	GW109	Dairy	Brown	Typic Orthic Brown	Ashhurst stony silt loam	Grassland - High producing
Kāpiti Coast	GW115	Dairy	Brown	Typic Orthic Brown	Te Horo silt loam	Grassland - High producing
Kāpiti Coast	GW116	Dairy	Brown	Acid Orthic Brown	Hautere stony silt loam	Grassland - High producing

Appendix 2: Data tables

Total carbon (C)

Table A2.1: Total carbon results benchmarked against the target range of **'Depleted' to 'Ample'**, see benchmarking for more information.

Whaitua	Site code	Land use	Soil order	Rating	Total carbon (%)
Kāpiti Coast	GW005	Dairy	Allophanic	Ample	12.10
Kāpiti Coast	GW006	Dairy	Allophanic	Normal	4.60
Kāpiti Coast	GW010	Dairy	Semi-arid, pallic and recent	Normal	4.90
Ruamāhanga	GW013	Dairy	All other	Normal	6.50
Ruamāhanga	GW015	Dairy	All other	Normal	6.40
Ruamāhanga	GW019	Dairy	Semi-arid, pallic and recent	Normal	3.90
Ruamāhanga	GW023	Dairy	Semi-arid, pallic and recent	Ample	6.90
Ruamāhanga	GW032	Dairy	Semi-arid, pallic and recent	Normal	3.20
Ruamāhanga	GW036	Dairy	Semi-arid, pallic and recent	Ample	5.30
Ruamāhanga	GW038	Dairy	Semi-arid, pallic and recent	Ample	6.20
Ruamāhanga	GW042	Dairy	Semi-arid, pallic and recent	Ample	8.70
Kāpiti Coast	GW046	Dairy	All other	Normal	5.20
Kāpiti Coast	GW048	Dairy	Semi-arid, pallic and recent	Normal	4.20
Ruamāhanga	GW076	Dairy	Semi-arid, pallic and recent	Normal	4.30
Ruamāhanga	GW078	Dairy	Semi-arid, pallic and recent	Normal	3.20
Ruamāhanga	GW096	Dairy	Semi-arid, pallic and recent	Normal	3.70
Ruamāhanga	GW098	Dairy	Semi-arid, pallic and recent	Normal	3.70
Ruamāhanga	GW105	Dairy	Semi-arid, pallic and recent	Ample	6.90
Kāpiti Coast	GW109	Dairy	Allophanic	Normal	8.80
Ruamāhanga	GW100	Dairy	Semi-arid, pallic and recent	Normal	5.00
Kāpiti Coast	GW115	Dairy	Allophanic	Normal	4.60
Kāpiti Coast	GW116	Dairy	Allophanic	Normal	8.30

Mineralisable nitrogen (N)

Table A2.2: Mineralisable nitrogen results benchmarked against the target range of **'Low' to 'High'**, see benchmarking for more information.

Whaitua	Site code	Land use	Rating land use	Rating	Mineralisable N (mg/kg)
Kāpiti Coast	GW005	Dairy	Pasture	Adequate	112.5
Kāpiti Coast	GW006	Dairy	Pasture	Low	97.9
Kāpiti Coast	GW010	Dairy	Pasture	Low	76.9
Ruamāhanga	GW013	Dairy	Pasture	Low	54.2
Ruamāhanga	GW015	Dairy	Pasture	Low	93.9
Ruamāhanga	GW019	Dairy	Pasture	Adequate	118.9
Ruamāhanga	GW023	Dairy	Pasture	Adequate	101.9
Ruamāhanga	GW032	Dairy	Pasture	Low	54.4
Ruamāhanga	GW036	Dairy	Pasture	Low	95.8
Ruamāhanga	GW038	Dairy	Pasture	Low	84.3
Ruamāhanga	GW042	Dairy	Pasture	High	225.4
Kāpiti Coast	GW046	Dairy	Pasture	Low	94.1
Kāpiti Coast	GW048	Dairy	Pasture	Low	90.8
Ruamāhanga	GW076	Dairy	Pasture	Low	65.9
Ruamāhanga	GW078	Dairy	Pasture	Low	61.0
Ruamāhanga	GW096	Dairy	Pasture	Low	63.0
Ruamāhanga	GW098	Dairy	Pasture	Adequate	120.3
Ruamāhanga	GW100	Dairy	Pasture	Low	87.6
Ruamāhanga	GW105	Dairy	Pasture	Adequate	105.3
Kāpiti Coast	GW109	Dairy	Pasture	High	203.5
Kāpiti Coast	GW115	Dairy	Pasture	Low	88.9
Kāpiti Coast	GW116	Dairy	Pasture	Low	89.2

Acidity - soil pH

Table A2.3: Soil pH results benchmarked against the target range of **'Slightly-acidic' to 'Optimal'**, see benchmarking for more information.

Whaitua	Site code	Land use	Land use & soil order	Rating	Soil pH
Kāpiti Coast	GW005	Dairy	Pastures on all except Organic	Slightly acidic	5.41
Kāpiti Coast	GW006	Dairy	Pastures on all except Organic	Optimal	6.26
Kāpiti Coast	GW010	Dairy	Pastures on all except Organic	Slightly alkaline	6.35
Ruamāhanga	GW013	Dairy	Pastures on all except Organic	Optimal	5.64
Ruamāhanga	GW015	Dairy	Pastures on all except Organic	Optimal	6.10
Ruamāhanga	GW019	Dairy	Pastures on all except Organic	Optimal	6.11
Ruamāhanga	GW023	Dairy	Pastures on all except Organic	Slightly alkaline	6.40
Ruamāhanga	GW032	Dairy	Pastures on all except Organic	Slightly alkaline	6.37
Ruamāhanga	GW036	Dairy	Pastures on all except Organic	Optimal	5.82
Ruamāhanga	GW038	Dairy	Pastures on all except Organic	Optimal	6.13
Ruamāhanga	GW042	Dairy	Pastures on all except Organic	Optimal	6.03
Kāpiti Coast	GW046	Dairy	Pastures on all except Organic	Slightly alkaline	6.45
Kāpiti Coast	GW048	Dairy	Pastures on all except Organic	Slightly alkaline	6.37
Ruamāhanga	GW076	Dairy	Pastures on all except Organic	Optimal	5.68
Ruamāhanga	GW078	Dairy	Pastures on all except Organic	Very alkaline	6.92
Ruamāhanga	GW096	Dairy	Pastures on all except Organic	Optimal	5.93
Ruamāhanga	GW098	Dairy	Pastures on all except Organic	Optimal	5.97
Ruamāhanga	GW100	Dairy	Pastures on all except Organic	Slightly alkaline	6.54
Ruamāhanga	GW105	Dairy	Pastures on all except Organic	Very alkaline	6.71
Kāpiti Coast	GW109	Dairy	Pastures on all except Organic	Optimal	5.99
Kāpiti Coast	GW115	Dairy	Pastures on all except Organic	Optimal	6.12
Kāpiti Coast	GW116	Dairy	Pastures on all except Organic	Optimal	5.61

Fertility - Olsen P

Table A2.4: Phosphorus (P) results benchmarked against target ranges, see benchmarking for more information.

Whaitua	Site code	Land use	Soil order	Rating soil order	Rating	Olsen P (mg/kg)
Kāpiti Coast	GW005	Dairy	Brown	Other Soils	Within	30.66
Kāpiti Coast	GW006	Dairy	Brown	Other Soils	Above	138.21
Kāpiti Coast	GW010	Dairy	Recent	Recent Soils and Podzols	Above	67.85
Ruamāhanga	GW013	Dairy	Gley	Other Soils	Within	29.79
Ruamāhanga	GW015	Dairy	Gley	Other Soils	Above	89.70
Ruamāhanga	GW019	Dairy	Pallic	Other Soils	Above	66.85
Ruamāhanga	GW023	Dairy	Recent	Recent Soils and Podzols	Above	105.73
Ruamāhanga	GW032	Dairy	Pallic	Other Soils	Within	26.97
Ruamāhanga	GW036	Dairy	Pallic	Other Soils	Within	47.31
Ruamāhanga	GW038	Dairy	Pallic	Other Soils	Within	33.71
Ruamāhanga	GW042	Dairy	Pallic	Other Soils	Above	53.96
Kāpiti Coast	GW046	Dairy	Gley	Other Soils	Within	28.33
Kāpiti Coast	GW048	Dairy	Recent	Recent Soils and Podzols	Above	93.97
Ruamāhanga	GW076	Dairy	Pallic	Other Soils	Within	31.86
Ruamāhanga	GW078	Dairy	Recent	Recent Soils and Podzols	Above	62.12
Ruamāhanga	GW096	Dairy	Recent	Recent Soils and Podzols	Above	87.98
Ruamāhanga	GW098	Dairy	Pallic	Other Soils	Within	36.96
Ruamāhanga	GW100	Dairy	Pallic	Other Soils	Above	89.18
Ruamāhanga	GW105	Dairy	Pallic	Other Soils	Above	112.57
Kāpiti Coast	GW109	Dairy	Brown	Other Soils	Above	81.13
Kāpiti Coast	GW115	Dairy	Brown	Other Soils	Below	22.36
Kāpiti Coast	GW116	Dairy	Brown	Other Soils	Within	40.67

Arsenic (As)

Table A2.5: Arsenic results are compared against draft eco-soil guideline values (Eco-SGVs), see benchmarking for more information.

Whaitua	Site code	Land use	Soil order	Eco-SGV	Arsenic (mg/kg)
Kāpiti Coast	GW005	Dairy	Brown	Within	3.4
Kāpiti Coast	GW006	Dairy	Brown	Within	5.2
Kāpiti Coast	GW010	Dairy	Recent	Within	7.1
Ruamāhanga	GW013	Dairy	Gley	Within	5.2
Ruamāhanga	GW015	Dairy	Gley	Within	5.5
Ruamāhanga	GW019	Dairy	Pallic	Within	3.6
Ruamāhanga	GW023	Dairy	Recent	Within	6.1
Ruamāhanga	GW032	Dairy	Pallic	Within	2.5
Ruamāhanga	GW036	Dairy	Pallic	Within	4.3
Ruamāhanga	GW038	Dairy	Pallic	Within	4.2
Ruamāhanga	GW042	Dairy	Pallic	Within	4.2
Kāpiti Coast	GW046	Dairy	Gley	Within	2.8
Kāpiti Coast	GW048	Dairy	Recent	Within	4.8
Ruamāhanga	GW076	Dairy	Pallic	Within	4.7
Ruamāhanga	GW078	Dairy	Recent	Within	4.2
Ruamāhanga	GW096	Dairy	Recent	Within	12.0
Ruamāhanga	GW098	Dairy	Pallic	Within	1.7
Ruamāhanga	GW100	Dairy	Pallic	Within	2.9
Ruamāhanga	GW105	Dairy	Pallic	Within	3.3
Kāpiti Coast	GW109	Dairy	Brown	Within	6.6
Kāpiti Coast	GW115	Dairy	Brown	Within	1.5
Kāpiti Coast	GW116	Dairy	Brown	Within	3.6

Cadmium (Cd)

Table A2.6: Cadmium results are compared against draft eco-soil guideline values (Eco-SGVs) on the map and trigger values from the tiered fertiliser management system (TFMS) also in the table, see benchmarking for more information.

Whaitua	Site code	Land use	Soil order	Eco-SGV	Cadmium (mg/kg)
Kāpiti Coast	GW005	Dairy	Brown	Within	0.42
Kāpiti Coast	GW006	Dairy	Brown	Within	0.32
Kāpiti Coast	GW010	Dairy	Recent	Within	0.34
Ruamāhanga	GW013	Dairy	Gley	Within	0.25
Ruamāhanga	GW015	Dairy	Gley	Within	0.62
Ruamāhanga	GW019	Dairy	Pallic	Within	0.21
Ruamāhanga	GW023	Dairy	Recent	Within	0.45
Ruamāhanga	GW032	Dairy	Pallic	Within	0.31
Ruamāhanga	GW036	Dairy	Pallic	Within	0.23
Ruamāhanga	GW038	Dairy	Pallic	Within	0.27
Ruamāhanga	GW042	Dairy	Pallic	Within	0.32
Kāpiti Coast	GW046	Dairy	Gley	Within	0.54
Kāpiti Coast	GW048	Dairy	Recent	Within	0.40
Ruamāhanga	GW076	Dairy	Pallic	Within	0.26
Ruamāhanga	GW078	Dairy	Recent	Within	0.26
Ruamāhanga	GW096	Dairy	Recent	Within	0.25
Ruamāhanga	GW098	Dairy	Pallic	Within	0.19
Ruamāhanga	GW100	Dairy	Pallic	Within	0.57
Ruamāhanga	GW105	Dairy	Pallic	Within	0.16
Kāpiti Coast	GW109	Dairy	Brown	Within	0.63
Kāpiti Coast	GW115	Dairy	Brown	Within	0.19
Kāpiti Coast	GW116	Dairy	Brown	Within	0.38

Chromium (Cr)

Table A2.7: Chromium results are compared against draft eco-soil guideline values (Eco-SGVs), see benchmarking for more information.

Whaitua	Site code	Land use	Soil order	Eco-SGV	Chromium (mg/kg)
Kāpiti Coast	GW005	Dairy	Brown	Within	11
Kāpiti Coast	GW006	Dairy	Brown	Within	17
Kāpiti Coast	GW010	Dairy	Recent	Within	17
Ruamāhanga	GW013	Dairy	Gley	Within	25
Ruamāhanga	GW015	Dairy	Gley	Within	20
Ruamāhanga	GW019	Dairy	Pallic	Within	7
Ruamāhanga	GW023	Dairy	Recent	Within	17
Ruamāhanga	GW032	Dairy	Pallic	Within	12
Ruamāhanga	GW036	Dairy	Pallic	Within	13
Ruamāhanga	GW038	Dairy	Pallic	Within	15
Ruamāhanga	GW042	Dairy	Pallic	Within	13
Kāpiti Coast	GW046	Dairy	Gley	Within	14
Kāpiti Coast	GW048	Dairy	Recent	Within	15
Ruamāhanga	GW076	Dairy	Pallic	Within	17
Ruamāhanga	GW078	Dairy	Recent	Within	16
Ruamāhanga	GW096	Dairy	Recent	Within	22
Ruamāhanga	GW098	Dairy	Pallic	Within	7
Ruamāhanga	GW100	Dairy	Pallic	Within	12
Ruamāhanga	GW105	Dairy	Pallic	Within	11
Kāpiti Coast	GW109	Dairy	Brown	Within	19
Kāpiti Coast	GW115	Dairy	Brown	Within	8
Kāpiti Coast	GW116	Dairy	Brown	Within	13

Copper (Cu)

Table A2.8: Copper results are compared against draft eco-soil guideline values (Eco-SGVs), see benchmarking for more information.

Whaitua	Site code	Land use	Soil order	Eco-SGV	Copper (mg/kg)
Kāpiti Coast	GW005	Dairy	Brown	Within sensitive limits	6
Kāpiti Coast	GW006	Dairy	Brown	Within sensitive limits	18
Kāpiti Coast	GW010	Dairy	Recent	Within sensitive limits	16
Ruamāhanga	GW013	Dairy	Gley	Within sensitive limits	17
Ruamāhanga	GW015	Dairy	Gley	Within sensitive limits	22
Ruamāhanga	GW019	Dairy	Pallic	Within sensitive limits	10
Ruamāhanga	GW023	Dairy	Recent	Within sensitive limits	19
Ruamāhanga	GW032	Dairy	Pallic	Within sensitive limits	7
Ruamāhanga	GW036	Dairy	Pallic	Within sensitive limits	11
Ruamāhanga	GW038	Dairy	Pallic	Within sensitive limits	10
Ruamāhanga	GW042	Dairy	Pallic	Within sensitive limits	7
Kāpiti Coast	GW046	Dairy	Gley	Within sensitive limits	17
Kāpiti Coast	GW048	Dairy	Recent	Within sensitive limits	14
Ruamāhanga	GW076	Dairy	Pallic	Within sensitive limits	13
Ruamāhanga	GW078	Dairy	Recent	Within sensitive limits	12
Ruamāhanga	GW096	Dairy	Recent	Within sensitive limits	17
Ruamāhanga	GW098	Dairy	Pallic	Within sensitive limits	6
Ruamāhanga	GW100	Dairy	Pallic	Within sensitive limits	14
Ruamāhanga	GW105	Dairy	Pallic	Within sensitive limits	9
Kāpiti Coast	GW109	Dairy	Brown	Within sensitive limits	19
Kāpiti Coast	GW115	Dairy	Brown	Within sensitive limits	7
Kāpiti Coast	GW116	Dairy	Brown	Within sensitive limits	9

Lead (Pb)

Table A2.9: Lead results are compared against draft eco-soil guideline values (Eco-SGVs), see benchmarking for more information.

Whaitua	Site code	Land use	Soil order	Eco-SGV	Lead (mg/kg)
Kāpiti Coast	GW005	Dairy	Brown	Within	10.1
Kāpiti Coast	GW006	Dairy	Brown	Within	15.9
Kāpiti Coast	GW010	Dairy	Recent	Within	21.0
Ruamāhanga	GW013	Dairy	Gley	Within	19.8
Ruamāhanga	GW015	Dairy	Gley	Within	19.4
Ruamāhanga	GW019	Dairy	Pallic	Within	8.5
Ruamāhanga	GW023	Dairy	Recent	Within	40.0
Ruamāhanga	GW032	Dairy	Pallic	Within	7.8
Ruamāhanga	GW036	Dairy	Pallic	Within	15.7
Ruamāhanga	GW038	Dairy	Pallic	Within	16.0
Ruamāhanga	GW042	Dairy	Pallic	Within	16.3
Kāpiti Coast	GW046	Dairy	Gley	Within	12.2
Kāpiti Coast	GW048	Dairy	Recent	Within	16.7
Ruamāhanga	GW076	Dairy	Pallic	Within	17.8
Ruamāhanga	GW078	Dairy	Recent	Within	13.6
Ruamāhanga	GW096	Dairy	Recent	Within	21.0
Ruamāhanga	GW098	Dairy	Pallic	Within	8.0
Ruamāhanga	GW100	Dairy	Pallic	Within	11.0
Ruamāhanga	GW105	Dairy	Pallic	Within	10.6
Kāpiti Coast	GW109	Dairy	Brown	Within	18.8
Kāpiti Coast	GW115	Dairy	Brown	Within	7.0
Kāpiti Coast	GW116	Dairy	Brown	Within	11.3

Nickel (Ni)

Table A2.10: Nickel results are compared against New Zealand Water and Wastes Association (NZWWA) limits, see benchmarking for more information.

Whaitua	Site code	Land use	Soil order	NZWWA limit	Nickel (mg/kg)
Kāpiti Coast	GW005	Dairy	Brown	Within	4.4
Kāpiti Coast	GW006	Dairy	Brown	Within	10.1
Kāpiti Coast	GW010	Dairy	Recent	Within	15.7
Ruamāhanga	GW013	Dairy	Gley	Within	22.0
Ruamāhanga	GW015	Dairy	Gley	Within	16.9
Ruamāhanga	GW019	Dairy	Pallic	Within	2.7
Ruamāhanga	GW023	Dairy	Recent	Within	15.4
Ruamāhanga	GW032	Dairy	Pallic	Within	7.8
Ruamāhanga	GW036	Dairy	Pallic	Within	8.8
Ruamāhanga	GW038	Dairy	Pallic	Within	10.5
Ruamāhanga	GW042	Dairy	Pallic	Within	7.0
Kāpiti Coast	GW046	Dairy	Gley	Within	10.1
Kāpiti Coast	GW048	Dairy	Recent	Within	13.2
Ruamāhanga	GW076	Dairy	Pallic	Within	13.4
Ruamāhanga	GW078	Dairy	Recent	Within	14.9
Ruamāhanga	GW096	Dairy	Recent	Within	17.2
Ruamāhanga	GW098	Dairy	Pallic	Within	4.0
Ruamāhanga	GW105	Dairy	Pallic	Within	5.1
Kāpiti Coast	GW109	Dairy	Brown	Within	15.4
Ruamāhanga	GW100	Dairy	Pallic	Within	5.3
Kāpiti Coast	GW115	Dairy	Brown	Within	4.6
Kāpiti Coast	GW116	Dairy	Brown	Within	6.5

Zinc (Zn)

Table A2.11: Zinc results are compared against draft eco-soil guideline values (Eco-SGVs), see benchmarking for more information.

Whaitua	Site code	Land use	Soil order	Eco-SGV	Zinc (mg/kg)
Kāpiti Coast	GW005	Dairy	Brown	Within sensitive limits	44
Kāpiti Coast	GW006	Dairy	Brown	Within sensitive limits	85
Kāpiti Coast	GW010	Dairy	Recent	Within sensitive limits	92
Ruamāhanga	GW013	Dairy	Gley	Within sensitive limits	99
Ruamāhanga	GW015	Dairy	Gley	Within sensitive limits	96
Ruamāhanga	GW019	Dairy	Pallic	Within sensitive limits	21
Ruamāhanga	GW023	Dairy	Recent	Within sensitive limits	115
Ruamāhanga	GW032	Dairy	Pallic	Within sensitive limits	65
Ruamāhanga	GW036	Dairy	Pallic	Within sensitive limits	67
Ruamāhanga	GW038	Dairy	Pallic	Within sensitive limits	65
Ruamāhanga	GW042	Dairy	Pallic	Within sensitive limits	52
Kāpiti Coast	GW046	Dairy	Gley	Within sensitive limits	68
Kāpiti Coast	GW048	Dairy	Recent	Within sensitive limits	91
Ruamāhanga	GW076	Dairy	Pallic	Within sensitive limits	72
Ruamāhanga	GW078	Dairy	Recent	Within sensitive limits	73
Ruamāhanga	GW096	Dairy	Recent	Within sensitive limits	77
Ruamāhanga	GW098	Dairy	Pallic	Within sensitive limits	28
Ruamāhanga	GW100	Dairy	Pallic	Within sensitive limits	56
Ruamāhanga	GW105	Dairy	Pallic	Within sensitive limits	37
Kāpiti Coast	GW109	Dairy	Brown	Within sensitive limits	107
Kāpiti Coast	GW115	Dairy	Brown	Within sensitive limits	32
Kāpiti Coast	GW116	Dairy	Brown	Within sensitive limits	55

Bulk density

Table A2.12: Bulk density results benchmarked against the target range of 'Loose' to 'Compact', see benchmarking for more information.

Whaitua	Site code	Land use	Soil order	Rating	Bulk density (t/m^3)
Ruamāhanga	GW038	Dairy	Semi-arid, pallic and recent	Adequate	0.98
Ruamāhanga	GW042	Dairy	Semi-arid, pallic and recent	Adequate	0.94
Ruamāhanga	GW023	Dairy	Semi-arid, pallic and recent	Adequate	1.01
Ruamāhanga	GW100	Dairy	Semi-arid, pallic and recent	Adequate	1.11
Ruamāhanga	GW078	Dairy	Semi-arid, pallic and recent	Compact	1.31
Kāpiti Coast	GW115	Dairy	Allophanic	Adequate	0.87
Ruamāhanga	GW098	Dairy	Semi-arid, pallic and recent	Compact	1.36
Ruamāhanga	GW036	Dairy	Semi-arid, pallic and recent	Loose	0.84
Kāpiti Coast	GW006	Dairy	Allophanic	Compact	1.19
Kāpiti Coast	GW046	Dairy	All other	Adequate	0.97
Kāpiti Coast	GW109	Dairy	Allophanic	Compact	0.94
Ruamāhanga	GW076	Dairy	Semi-arid, pallic and recent	Compact	1.27
Ruamāhanga	GW015	Dairy	All other	Adequate	0.94
Ruamāhanga	GW032	Dairy	Semi-arid, pallic and recent	Adequate	1.17
Ruamāhanga	GW105	Dairy	Semi-arid, pallic and recent	Loose	0.82
Ruamāhanga	GW013	Dairy	All other	Adequate	1.12
Ruamāhanga	GW096	Dairy	Semi-arid, pallic and recent	Adequate	1.16
Ruamāhanga	GW019	Dairy	Semi-arid, pallic and recent	Compact	1.37
Kāpiti Coast	GW005	Dairy	Allophanic	Adequate	0.75
Kāpiti Coast	GW048	Dairy	Semi-arid, pallic and recent	Adequate	1.12
Kāpiti Coast	GW010	Dairy	Semi-arid, pallic and recent	Adequate	1.08
Kāpiti Coast	GW116	Dairy	Allophanic	Adequate	0.75

Macroporosity

Table A2.13: Macroporosity results benchmarked against the target range of 'Adequate', see benchmarking for more information.

Whaitua	Site code	Land use	Rating land use	Rating	Macroporosity (% v/v)
Ruamāhanga	GW038	Dairy	Pastures, cropping and horticulture	Very low	4.3
Ruamāhanga	GW042	Dairy	Pastures, cropping and horticulture	Low	9.3
Ruamāhanga	GW023	Dairy	Pastures, cropping and horticulture	Low	6.3
Ruamāhanga	GW100	Dairy	Pastures, cropping and horticulture	Very low	5.4
Ruamāhanga	GW078	Dairy	Pastures, cropping and horticulture	Very low	4.6
Kāpiti Coast	GW115	Dairy	Pastures, cropping and horticulture	Adequate	10.7
Ruamāhanga	GW098	Dairy	Pastures, cropping and horticulture	Very low	6.0
Ruamāhanga	GW036	Dairy	Pastures, cropping and horticulture	Adequate	16.0
Kāpiti Coast	GW006	Dairy	Pastures, cropping and horticulture	Very low	3.4
Kāpiti Coast	GW046	Dairy	Pastures, cropping and horticulture	Low	6.4
Kāpiti Coast	GW109	Dairy	Pastures, cropping and horticulture	Low	8.6
Ruamāhanga	GW076	Dairy	Pastures, cropping and horticulture	Low	7.8
Ruamāhanga	GW015	Dairy	Pastures, cropping and horticulture	Very low	4.3
Ruamāhanga	GW032	Dairy	Pastures, cropping and horticulture	Very low	5.1
Ruamāhanga	GW105	Dairy	Pastures, cropping and horticulture	Very low	3.9
Ruamāhanga	GW013	Dairy	Pastures, cropping and horticulture	Very low	4.4
Ruamāhanga	GW096	Dairy	Pastures, cropping and horticulture	Adequate	14.3
Ruamāhanga	GW019	Dairy	Pastures, cropping and horticulture	Very low	1.9
Kāpiti Coast	GW005	Dairy	Pastures, cropping and horticulture	Adequate	10.7
Kāpiti Coast	GW048	Dairy	Pastures, cropping and horticulture	Low	8.5
Kāpiti Coast	GW010	Dairy	Pastures, cropping and horticulture	Low	7.9
Kāpiti Coast	GW116	Dairy	Pastures, cropping and horticulture	Adequate	14.6