Environment Waikato Technical Report 2005/46

Soil Quality in the Waikato Region in 2004 : Changes Since 1997–1999

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Summary

Project and Client

Environment Waikato undertakes regular soil sampling, defined in Annual Plans, to assess soil quality in the region using a network around 80 sites. This network of sites, established between 1995 and 2002, provide a “snapshot” of soil quality at the time of sampling on a range of soils and land uses relevant to the region. To determine what changes in soil quality have occurred since the original samplings, Environment Waikato started a systematic resampling in 2003–2004 of some of those original sites. The rates and direction of changes in soil quality properties are useful to determine whether undesirable trends are emerging, and suggest which land managements are sustainable in the longer term.

The strategy for 2004–2005 was to expand the number of resampled of sites to establish whether changes noted of other sites resampled in 2003–2004 were occurring elsewhere. Soil quality on all sites was appraised using the sampling protocols and analytical methods as those originally used for soil chemical, physical and biological characteristics, and documented by Hill et al. (2003).

Objectives

- Using the methods as previously defined by Hill et al (2003), analyse samples collected by Environment Waikato and contractors from up to 15 previously characterised sites to assess their current chemical, physical, and biological characteristics.
- Relate soil quality status to land use and soil type.
- With reference to previous data, calculate changes over time on the resampled sites, and identify any overall trends that could affect sustainable use in the longer term
- Provide comment on the overall soil quality and sustainability in the Waikato region.
- Provide soil analytical data on any substitute sites identified by Environment Waikato

Methods

- Sites were preselected by Environment Waikato land resource staff
- Current sites details and surface soil samples (0–10 cm) were provided by Environment Waikato staff and contractors using methods established by the 500 Soils Project, and sent to Landcare Research for analyses and reporting
- A standard suite of 12 soil properties was used to characterise the chemical, biochemical and physical attributes and assess soil quality of the various soil and land-use combinations.
- Sites with unusual characteristics were identified by comparison with the expected characteristics for that soil and land use combination.
- Changes through time were calculated by reference to the previously published reports where the same collection methods, soil properties and analytical methods had been used.

Results

- Sites selected for resampling in 2004/5 were mainly on Pumice Soils and the predominant land uses were forestry or drystock farming.
- Overall, 20% of the sites met all the soil quality targets.
- High macroporosity, low Olsen P and low bulk density were the main reasons for soils not meeting soil quality targets.

Conclusions

- The current set of soil quality samples showed similar characteristics to those previously collected.
- No major changes in soil quality characteristics were detected

Recommendations

- Environment Waikato continues the policy of resampling previously characterised sites to confirm the trends in soil quality attributes arising from the current data. For reliable long-term detection and prediction of trends, at least 3 and preferably 5 points along a time sequence should be obtained.

- Land owners and managers of the current sites be made aware through land user groups, personal contact and community forums of the current state of their soils and possible consequences for production and the environment

1 Introduction

1.1 Background

Environment Waikato undertakes regular soil sampling as defined in the Annual Plan, to assess soil quality in the region using a network of around 80 sites. These sites, sampled between 1995 and 2003, provide a “snapshot” of soil quality at the time of sampling on a range of soils and land uses relevant to the region. To determine what changes in soil quality have occurred since first sampling, Environment Waikato has started a systematic resampling of a subset of sites each year. The rates and direction of changes in soil quality properties are used to determine whether undesirable trends are emerging, and show which land managements are sustainable in the longer term.

The strategy for 2004–2005 was to expand the number of sites with a second sampling to establish whether changes noted in previous years were also occurring at other locations. Soil quality on the sites was appraised using the same sampling protocols and analytical methods as those originally used for soil chemical, physical and biological characteristics in the 500 Soils Project, and are defined by Hill et al. (2003). Environment Waikato also required characterisation of 2 new sites using the same protocols for sampling and analyses.

1.2 Objectives

- Using the methods as previously defined by Hill et al. (2003), analyse samples collected by Environment Waikato and contractors from up to 15 previously characterised sites to assess their current chemical, physical, and biological characteristics.
- Relate soil quality status to land use and soil type.
- With reference to previous data, calculate changes over time on the resampled sites, and identify any overall trends that could affect sustainable use in the longer term.
- Provide comment on the overall soil quality and sustainability in the Waikato region.
- Provide soil analytical data on any substitute sites identified by Environment Waikato

2 Methods

Most of the methodologies have been described in earlier reports (Sparling et al. 1996, 2001; Hill et al. 2003), and only brief details are given here.

2.1 Soil Sampling

Fieldwork was completed by Environment Waikato staff (Reece Hill, Paul Smith) and contractor (Wim Rijkse). The previously established sampling methods were followed: soil cores of 2.5 cm diameter to a depth of 10 cm were taken every 2 m along a 50-m transect, for chemical and biochemical analyses. The 25 individual cores were bulked and mixed before analyses at the Landcare Research laboratory at Palmerston North. Three undisturbed soil samples for physical analyses were taken at 15-, 30- and 45-m positions along the transect, by pressing steel liners, 75-mm depth by 100-mm diameter, into the topsoil. The liner and soil cores were removed as a unit by careful excavation around the liner, bagged, loaded into padded crates, and transported to the Landcare Research laboratory in Hamilton. Sub-samples of the cores were then taken for bulk density and water release characteristics. If specified, spade samples (triplicate vertical blocks 2–5 cm width by 10 cm depth) were collected for aggregate stability analyses by Crop and Food Research, Lincoln. Where necessary, samples were stored at 5°C until analyses.

2.2 Soil-Quality Measurements

Twelve primary soil properties were measured to assess soil quality (Table 1). Chemical characteristics were assessed by the total C content, total N content, C:N ratio, Olsen P, exchangeable cations (Ca, Mg, K) and soil pH. Potentially mineralisable nitrogen (N) provided an estimate of the nitrogen status of soil organic matter, and a surrogate measure for soil microbial biomass. The mineralisable N also provided measures of extractable ammonium and nitrate. Soil physical condition was assessed using bulk density, particle density and water release characteristics (providing information on total porosity, macroporosity, total available water and readily available water). Moisture retention at -5 and -10 kPa was determined allowing the calculation of macroporosity (-5 kPa) and air capacity (-10 kPa).

Table 1: Indicators used for soil quality assessment

Indicators	Soil Quality Information	Method
Chemical properties		
Total C content	Organic matter status	Dry combustion, CNS Analyser
Total N content	Organic N reserves	Dry combustion, CNS Analyser
Soil pH	Acidity or alkalinity	Glass electrode pH meter, 1:2.5 in water
Olsen P	Plant-available phosphate	Bicarbonate extraction, molybdenum blue method.
Biological properties		
Potentially mineralisable N	Readily mineralised N reserves (also provides extractable ammonium and nitrate concentrations	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 macro porosity	Soil compaction, root environment, aeration and drainage	Pressure plates
Total and readily available water	Water for plant growth and soil biology	Pressure plates
Aggregate stability	Soil crumb size and resilience	Wet sieving

2.3 Analyses

2.3.1 Chemical Properties

Total C and N were determined by dry combustion of air-dry/air-dried, finely ground soils using a Leco 2000 CNS analyser (Blakemore et al. 1987). Olsen P was determined by extracting <2-mm air-dry soils for 30 min with 0.5 M $NaHCO_3$ at pH 8.5 (Olsen et al. 1954), and measuring the PO_4^{3-} concentration by the molybdenum blue method. Soil pH was measured in water using glass electrodes and a 2.5:1 water-to-soil ratio (Blakemore et al. 1987).

Exchangeable cations were determined using “Quick Test” methodology. The shaking extraction (1:50 soil: extractant, 1 M ammonium acetate, pH 7.0, 1 hour shake) was adapted from the method described by Daly et al. (1984). Caesium was added to eliminate ionization interference in the determination of potassium and sodium, and strontium was added to prevent chemical interference in the determination of calcium and magnesium by atomic absorption spectrometry. Concentrations are presented as centimoles of positive charge per kg (cmol(+)/kg). This has the same numeric value as the old meq/100g. These values are then converted to Quick Test units if required.

2.3.2 Biochemical Properties

Potentially mineralisable N was estimated by the anaerobic (waterlogged) 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 & Bremner 1966). This assay also provided data on NH_4^+-N and NO_3^--N concentrations at the start of incubation.

2.3.3 Physical Properties

Water release was determined by drainage on pressure plates at 5, 10, 100 and 1500 kPa (Klute 1986). Dry bulk density was measured on a sub-sampled core dried at 105°C (Klute 1986), and the remaining soil analysed for particle size and density by the pipette method. Macroporosity (-5 kPa), air capacity (-10 kPa) and total porosity were calculated as described by Klute (1986). Aggregate stability, on selected samples only, was measured by a wet sieving method (Kemper & Rosenau 1986).

2.4 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. Where appropriate, data from the same land-use category or soil type were combined to allow statistical testing. Values from the current samples were compared against archive data, mainly from 1998–2001, to calculate the extent of change in soil properties.

2.5 Target Ranges

Target ranges for individual soil characteristics were taken from Sparling et al. (2003).

3 Results

3.1 Soils and Sites

Summaries of the site characteristics and land uses are shown in Table 2. Fourteen sites were sampled in November 2004. In addition, 2 new sites were characterised. Full site and soil profile descriptions were provided in the original reports and are not repeated here. Laboratory chemical data on a gravimetric basis and the soil physical data on replicated cores are presented in the Appendices.

3.2 Current Chemical and Physical Characteristics

The current chemical and physical characteristics are shown in Tables 3 and 4. For the 2004 data, for pH, total C total N, mineralisable N, Olsen P, bulk density and macroporosity, figures in bold type fell outside the recommended range for that soil and land-use combination. In contrast with previous samples, where Olsen P concentrations were very high, on this set of soils dominated by forestry and drystock pastures, Olsen P contents were below the recommended level on 8 of the 16 sites.

Soil physical condition also differed compared with previous trends on other soils. Macroporosity was low on 3 of the sites under grazed pasture, and higher than recommended on 3 of the soils under forestry. Overall, the bulk density of these Pumice Soils was low rather than high.

- Overall, 20% of the sites met all the soil quality targets.
- High macroporosity, low Olsen P and low bulk density were the main reasons for soils not meeting soil quality targets.

3.3 Changes in Soil Quality Since Previous Sampling

Analytical data for these sites from previous samplings in 1997 and 1999 are shown in Tables 3 and 4. The differences between the earlier sample and the current data are shown as a series of bar graphs (Figs 3–11). A negative bar on the graph shows that the characteristic has declined since the earlier sampling. Note that a decline in a characteristic is not always a bad thing. A decline in an excessively high fertility level would be regarded as a positive trend. However, a decline in organic C would generally be regarded as a negative trend. Each individual soil quality characteristic is considered separately.

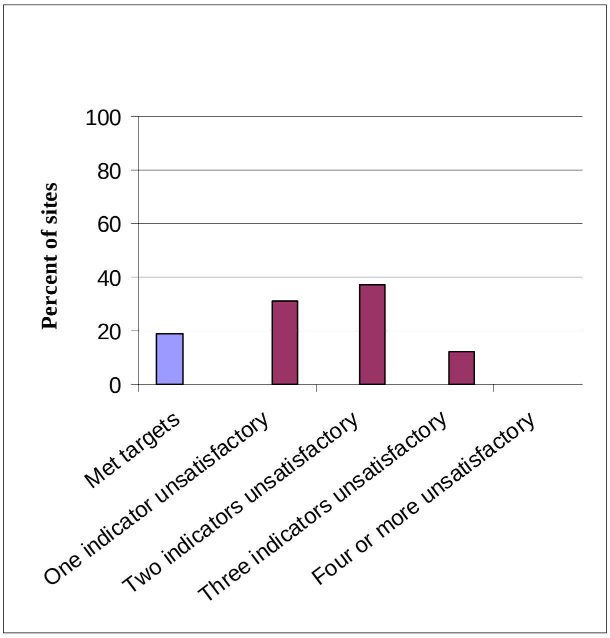

Figure 1: Proportion of sites sampled in 2004, meeting soil quality targets

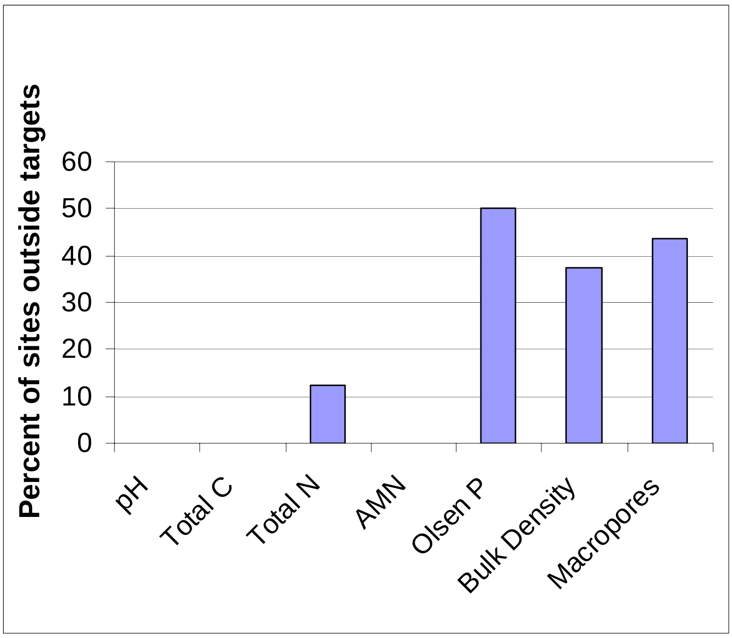

Figure 2: Proportion of sites sampled in 2004 not meeting targets for specific indicators

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Table 2: Soils and land uses sampled for soil quality characteristics in the Waikato, March 2005

LCR 2004-2005 Code	Historic LCR code	Soil type and soil order	Current land use	EW Code and date of previous sample(s)	
EW04_1	WAI97_2	Taupo silt loam, Pumice	Forestry 2nd rotation 7 yr pine	97/08	1997
EW04_2	WAI97_1	Taupo silt loam, Pumice	Forestry (8 yr pine)	97/09	1997
EW04_3	WAI97_3	Taupo silt loam, Pumice	Dairy pasture	97/10	1997
EW04_4	WAI97_4	Taupo silt loam, Pumice	Forestry (80 yr pine)	97/11	1997
EW04_5	WAI97_5	Taupo silt loam, Pumice	Forestry (7 yr pine)	97/12	1997
EW04_6	WAI99_4	Te Kuiti loam, Allophanic	Forestry, replanted (3 yr pine)	99/04	1999
EW04_7	WAI99_5	Whenuaroa gravelly sand, Pumice	Lucerne cropping	99/05	1999
EW04_8	WAI99_6	Tihoi loamy sand, Podzol	Indigenous forest	99/06	1999
EW04_9	WAI99_7	Tihoi loamy sand, Podzol	Forestry, pines	99/07	1999
EW04_10	WAI99_8	Tihoi loamy sand, Podzol	Drystock pasture	99/08	1999
EW04_11	WAI99_12	Korakanui sandy loam, Recent	Forestry, pines	99/12	1999
EW04_12	WAI99_13	Otorohanga loam, Allophanic	Drystock pasture	99/13	1999
EW04_13	WAI99_14	Waihou loam, Allophanic	Arable cropping	99/14	1999
EW04_14	WAI99_15	Waihou loam, Allophanic	Dairy pasture	99/15	1999
EW04_15		Waihou loam, Allophanic	Drystock pasture	EW04/01	2004
EW04_16		Waihou loam, Allophanic	Arable cropping 2nd year maize, former pasture	EW04/02	2004

Table 3: Changes in soil quality chemical characteristics, Waikato Region, 1998–2005

Site code(s)	Year	Soil	Land use	pH	Total Cmg/cm^3	Total Nmg/cm^3	C:N ratio	Olsen Pµg/cm^3	NO_3^--Nµg/cm^3	NH_4^+-Nµg/cm^3	AMNµg/cm^3
97/08	1997	Taupo silt loam, pumice	Forestry 2nd rotation 7 yr pine	5.39	41.4	1.86	22.3	5	n.d.	n.d.	48
WAI97_2	2004			5.24	63.0	3.14	20	**5**	1.03	5.4	92
97/09	1997	Taupo silt loam, pumice	Forestry (8 yr pine)	5.21	49.8	2.16	23.1	5	n.d.	n.d.	45
WAI97_1	2004			5.27	45.8	2.50	18	**4**	0.44	6.0	82
97/10	1997	Taupo silt loam, pumice	Dairy pasture	6.49	45.3	3.75	12.1	23	n.d.	n.d.	114
WAI97_3	2004			5.73	56.6	5.02	11	49	10.69	10.3	174
97/11	1997	Taupo silt loam, pumice	Forestry (80 yr pine)	5.04	49.2	2.03	24.3	3	n.d.	n.d.	54
WAI97_4	2004			4.41	62.7	2.16	29	**3**	0.00	13.4	24
97/12	1997	Taupo silt loam, pumice	Forestry (7 yr pine)	5.04	57.0	2.68	21.3	17	n.d.	n.d.	41
WAI97_5	2004			5.57	41.6	2.41	17	18	0.97	3.5	79
99/04	1999	Te Kuiti loam	Forestry, replanted (3 yr pine)	5.38	19.3	0.79	25	4		2.6	21
	2004			5.44	36.1	1.49	24	**4**	0.10	3.7	44
99/05	1999	Whenuaroa gravelly sand	Lucerne cropping	5.22	41.3	3.39	12	14	22.6	5.4	51
	2004			6.02	39.2	3.12	13	**20**	14.3	11.1	53
99/06	1999	Tihoi loamy sand	Indigenous forest	4.34	40.9	2.33	18	5	9.4	4.5	60
	2004			4.56	37.3	2.23	17	8	5.53	4.5	48
99/07	1999	Tihoi loamy sand	Forestry Pines	5.01	44.3	2.39	19	3	5.8	8.7	72
	2004			4.27	48.6	2.68	18	8	8.50	4.4	39
99/08	1999	Tihoi loamy sand	Drystock pasture	5.66	63.3	4.54	14	6	7.1	15.0	204
	2004			5.92	47.8	3.02	16	17	2.7	5.4	107
99/12	1999	Korakanui sandy loam	Forestry pines	5.58	84.6	7.09	12	5	9.4	4.0	138
	2004			5.60	91.1	6.55	14	**3**	5.5	4.0	93
99/13	1999	Otorahanga loam	Drystock pasture	5.56	95.9	6.94	14	5	13.0	17.4	129
	2004			5.46	107.5	**9.02**	12	**5**	13.4	4.1	144
99/14	1999	Waihou loam	Arable cropping	6.25	45.9	4.48	10	39	17.0	3.3	43
	2004			6.17	38.9	3.78	10	60	21.1	4.7	33

Site code(s)	Year	Soil	Land use	pH	Total Cmg/cm^3	Total Nmg/cm^3	C:N ratio	Olsen Pµg/cm^3	NO_3^--Nµg/cm^3	NH_4^+-Nµg/cm^3	AMNµg/cm^3
99/15	1999	Waihou loam	Dairy pasture	5.49	68.1	6.80	10	44	54.9	5.5	144
	2004			5.77	72.6	**7.36**	10	56	24.4	5.1	137
EW04/01	1999	Waihou loam	Drystock pasture	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	2004			6.25	59.4	5.83	10	**3**	13.1	5.50	131
EW04/02	1999	Wahou loam	Arable cropping 2nd year	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	2004		maize, former pasture	6.39	46.6	4.50	10	38	36.1	5.34	42

* Figures shown in bold type for 2004 data only, were outside recommended ranges for that land use and soil order

Table 4: Changes in soil quality physical characteristics, Waikato Region, 1998–2005

Site code	Year	Soil	Land use	Bulk density Mg/m^3	Particle density Mg/m^3	Total porosity % v/v	Macro pores % v/v	Air capacity % v/v
97/08, WAI97_2	1997 2004	Taupo silt loam, pumice	Forestry 2[nd] rotation 7 yr pine	0.49 0.66	2.16 2.29	77.3 71.0	19.5 17.2	 22.0
97/09, WAI97_1	1997 2004	Taupo silt loam, pumice	Forestry (8 yr pine)	0.52 **0.51**	2.22 2.26	76.4 77.5	29.4 **30.8**	 37.8
97/10, WAI97_3	1997 2004	Taupo silt loam, pumice	Dairy pasture	0.67 0.63	2.22 2.23	70.1 71.8	7.9 **7.1**	 10.7
97/11, WAI97_4	1997 2004	Taupo silt loam, pumice	(Forestry 80 yr pine)	0.67 **0.44**	2.22 2.20	70.1 80.2	7.9 38.3	 43.3
97/12, WAI97_5	1997 2004	Taupo silt loam, pumice	Forestry (7 yr pine)	0.57 0.60	2.17 2.27	73.6 73.4	20.4 25.3	 30.2
99/04, WAI97_04	1999 2004	Te Kuiti loam	Forestry, replanted (3 yr pine)	0.81 0.51	2.41 2.29	66.4 77.9	44.3 32.5	54.4 43.1
99/05	1999 2004	Whenuaroa gravelly sand	Lucerne cropping	0.57 0.73	2.23 2.29	74.5 68.3	21.5 16.2	53.8 24.9
99/06	1999 2004	Tihoi loamy sand	Indigenous forest	0.39 **0.45**	2.14 2.08	81.8 78.8	29.7 26.8	49.5 32.6
99/07	1999 2004	Tihoi loamy sand	Forestry Pines	0.60 0.46	2.29 2.21	73.7 79.4	31.6 27.0	52.2 33.3
99/08	1999 2004	Tihoi loamy sand	Drystock pasture	0.68 **0.46**	2.27 2.09	70.2 78.1	16.0 **7.4**	36.6 14.7

Site code	Year	Soil	Land use	Bulk density Mg/m^3	Particle density Mg/m^3	Total porosity % v/v	Macro pores % v/v	Air capacity % v/v
99/12	1999	Korakanui sandy loam	Forestry pines	0.48	2.18	78.0	30.8	39.4
	2004			**0.57**	2.21	74.1	14.3	17.1
99/13	1999	Otorahanga loam	Drystock pasture	0.52	2.15	76.0	22.5	32.2
	2004			0.52	2.11	75.4	13.2	18.8
99/14	1999	Waihou loam	Arable cropping	0.77	2.35	67.5	8.2	32.4
	2004			0.68	2.38	71.6	20.8	26.4
99/15	1999	Waihou loam	Dairy pasture	0.74	2.25	67.2	5.6	27.2
	2004			0.76	2.27	66.6	**2.9**	5.3
EW04/01	1999	Waihou loam	Drystock pasture	N.A.	N.A.	N.A.	N.A.	N.A.
	2004			0.73	2.34	68.7	**2.7**	5.7
EW04/02	1999	Wahou loam	Arable cropping 2 nd year maize, former pasture	N.A.	N.A.	N.A.	N.A.	N.A.
	2004			0.73	2.36	69.0	15.8	20.4

*For bulk density and macroporosity, measured in 2004, figures in bold type fell outside recommended ranges for that land use and soil order

Soil pH

Soil pH showed both positive and negative changes depending on the site (Fig. 3). However, all values still fell within acceptable ranges. Overall, the average soil pH had increased marginally by 0.02, but was highly variable (Standard deviation = 0.45, n=16).

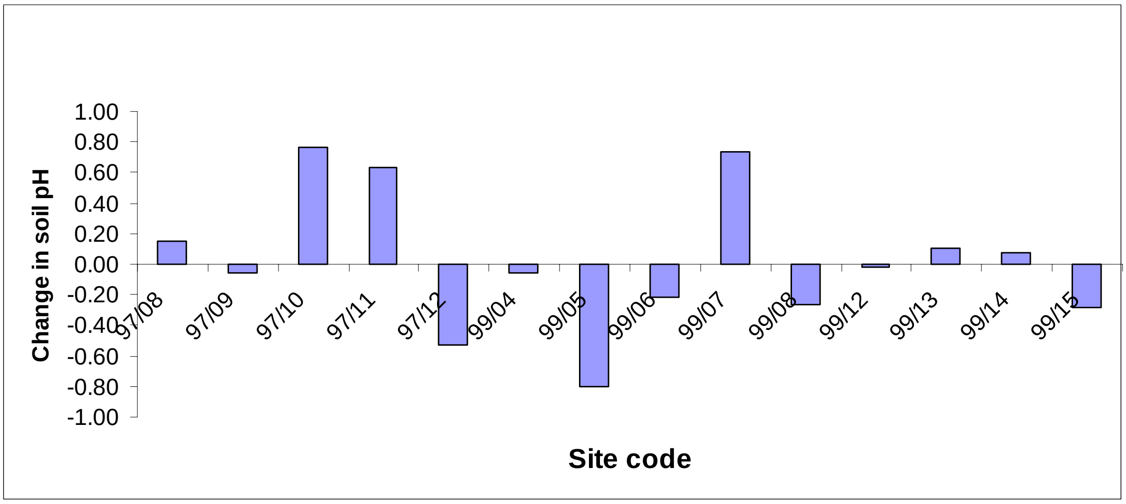

Figure 3: Change in soil pH in a range of Waikato soils between 1997/9 and 2004

Total C Content

There was an overall small decline in total C contents of 3.03±11.47 µg/cm^3, but this value had a wide scatter (Fig 4.). The C contents remained within the target ranges. The apparent large changes that occurred between the two sampling times for some soils are unlikely for pastoral and forest land uses, where the C contents are usually stable. The changes could be through site variability or, for the forest ecosystems, the difficulty of getting mineral soil samples without including some total C from forest floor litter and humus in the cores.

Figure 4: Change in total soil C contents (µg/cm3) in a range of Waikato soils between 1997/9 and 2004

Total N Content

The increase (or decrease) in total N matched the increases and decreases in total C, indicating that the N was mostly associated with organic matter. There was an overall increase of 0.23±0.92 µg/cm^3. Two sites, 99/13 and 99/15, a drystock and dairy farm respectively, had higher N contents than expected for those soils and land uses (Fig. 5).

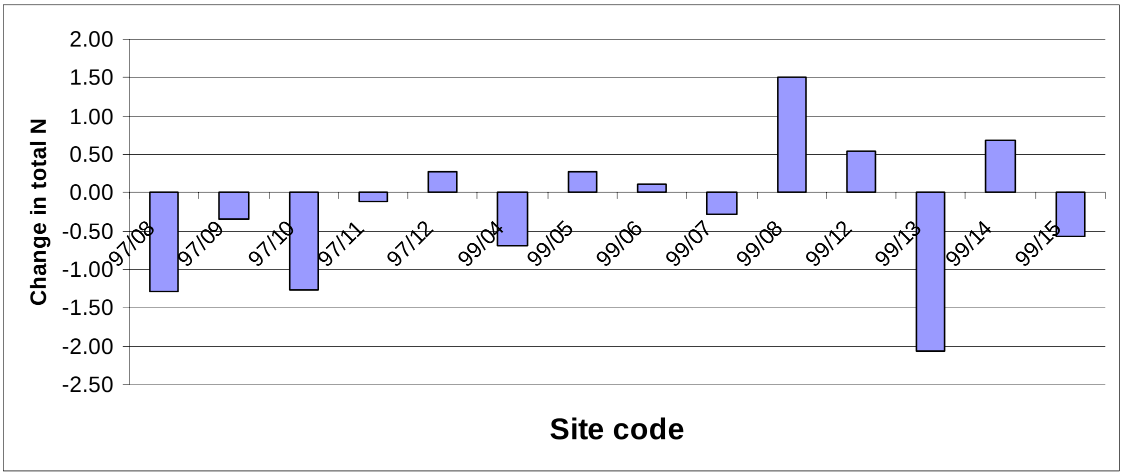

Figure 5: Change in total soil N contents (µg/cm3) in a range of Waikato soils between 1997/9 and 2004

C:N Ratio

There was a slight rise in C:N ratio of 0.44±2.42 when averaged across all soils (Fig 6). Some soils particularly under forestry, showed unexpectedly large changes and further sampling will be needed to confirm those trends. There was a wide range in ratios from >20 on the forestry sites to about 10 on the pastures, reflecting the historic accumulation of N that has occurred in Waikato pasture soils.

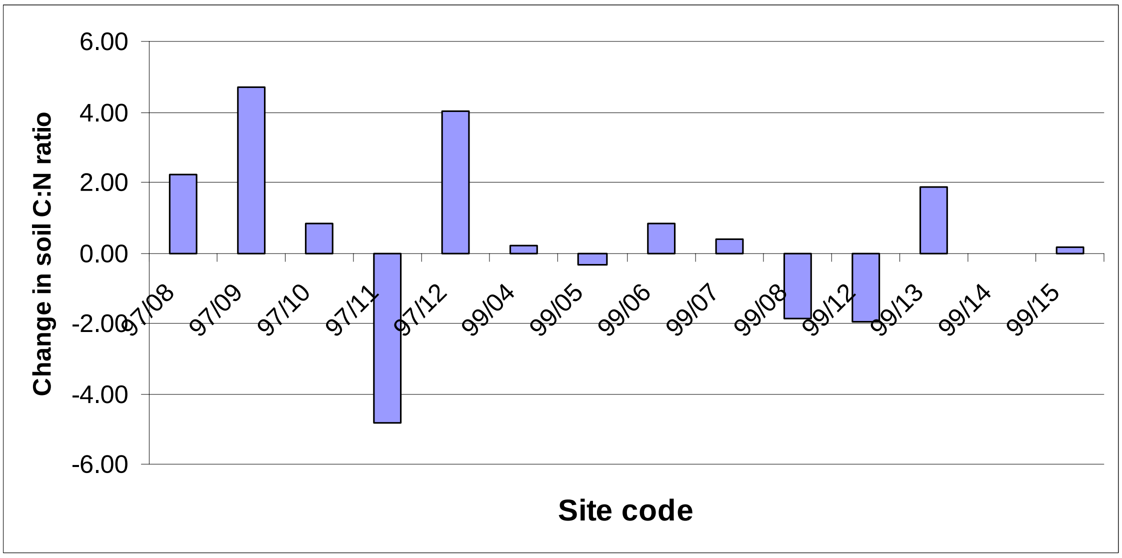

Figure 6: Change in soil C:N ratio in a range of Waikato soils between 1997/9 and 2004

Mineralisable N

There were some large changes in mineralisable N on some sites (e.g., 97/08: a Podzol under drystock farming), but these same soils were also those that showed large changes in total C and total N. The difference is probably due to sampling problems (see earlier comments) rather than real changes. Averaged across all sites there was a slight increase (0.85±41.7 µg.cm^3, mean and standard deviation) in mineralisable N, but that value was driven by large changes on relatively few sites. Further samples are needed to judge if these trends are real.

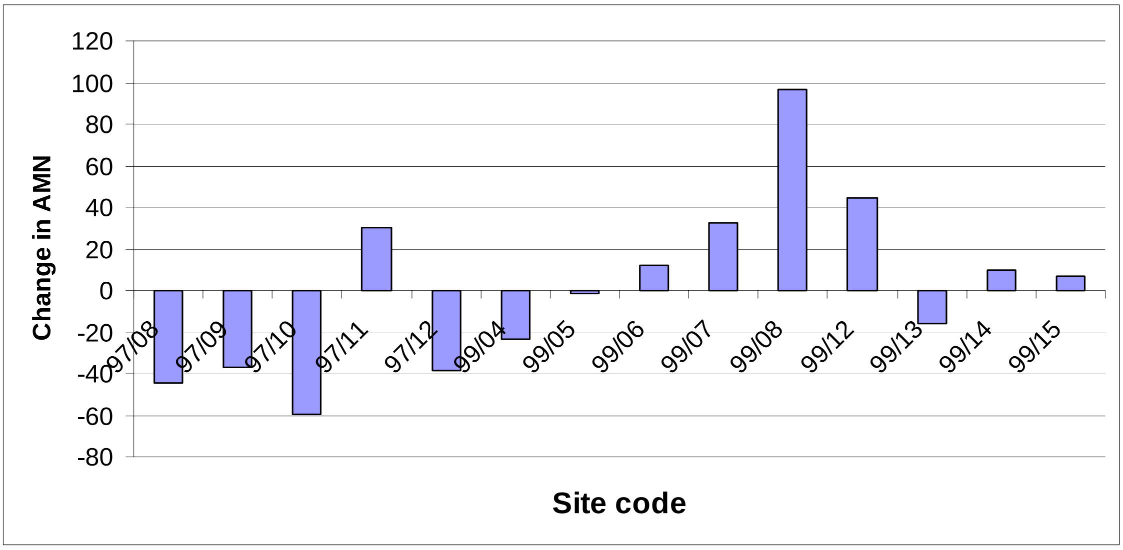

Figure 7: Change in anaerobically mineralisable N contents (µg/cm3) in a range of Waikato soils between 1997/9 and 2004

Olsen P

The Olsen P contents of the soils were generally low, with the exception of sites 99/14 under lucerne cropping (60 µg/cm^3) and two dairy sites (99/15 and 97/10). It was these three sites that showed a drop in Olsen P contents (Fig 8) and were largely responsible for the decline of 5.83±8.65 µg/cm^3 (mean and standard deviation) in the Olsen P content when averaged across all sites.

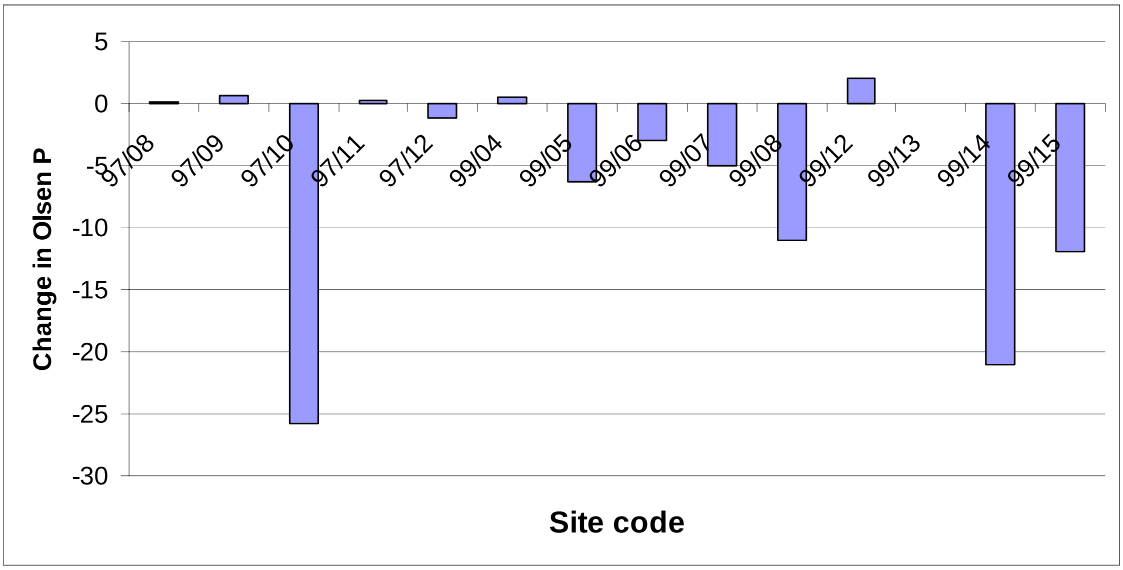

Figure 8: **Change in soil Olsen P contents (µg/cm3) in a range of Waikato soils between 1997/9 and 2004**

Bulk Density

Bulk densities were low as is typical for Pumice Soils, and overall, soils were less dense (0.02±0.13, mean and standard deviation) than when sampled earlier (Fig. 9). This may reflect tree development on the forested sites (99/04) in the intervening years, and the absence of machinery or animals resulting in less compaction. However, site 99/08 also was less dense in 2004 and that site was under drystock pasture. Very low bulk densities are not desirable, as they suggest the soil is not cohesive, could have poor capillarity and root contact, and on some landforms may be susceptible to erosion.

Figure 9: **Change in soil dry bulk density (g/cm3) in a range of Waikato soils between 1997/9 and 2004**

Macroporosity and Air Capacity

Macroporosity had increased between the two sampling times (Fig. 10), with an average across all sites of 3.04±7.4 (%v/v, mean and standard deviation). Sites with low macroporosity were mainly those under pastures, which showed little change, but also of some concern were the soils under forestry with very high macroporosity, which had increased further. Very high macroporosity suggest poor soil cohesion, excessive drainage and poor moisture retention.

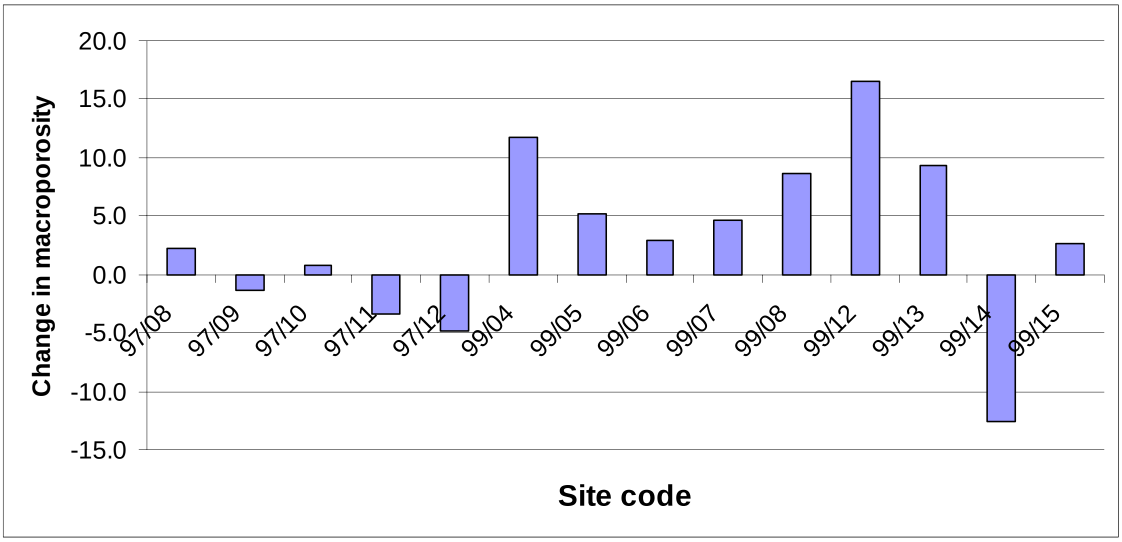

Figure 10: Change in soil macroporosity (%v/v) in a range of Waikato soils between 1997/9 and 2004

The archive data were recalculated to derive the air capacity, which is becoming favoured as the preferred measurement to assess soil compaction and its influence on crops. Figure 11 shows the close relationship (R^2=0.96) between macroporosity (measured at -5 kPa) and air capacity (measured at -10 kPa). Both sets of data provide similar information.

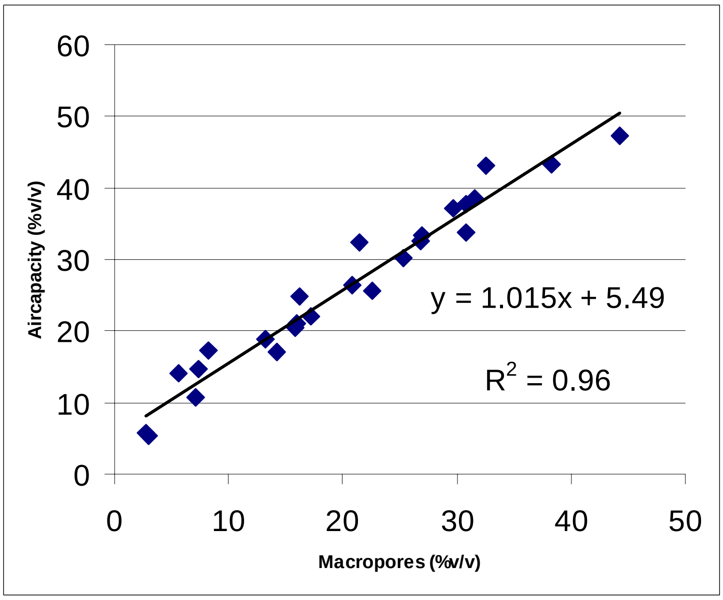

Figure 11: Relationship between air capacity and macroporosity

4 Discussion

Clear trends in soil quality between the two sampling times were difficult to discern. This was partly because the overall changes were small and heavily influenced by unexplained large changes on a small number of sites. Soil variability remains a problem in detecting trends between different sampling times. It is particularly important that the sampling location be accurately identified and the same sampling protocol used each time. Times of soil disturbance should be avoided if at all possible, and heavily pugged pastures or recently cultivated land are not suitable for sampling as they are not representative of soil condition through the year. The current recommendation for sampling of arable sites is that wherever practicable, this should be done immediately prior to harvest.

Several of the current sites were developing forests. Changes through time over a harvesting cycle of 20–30 years are a natural consequence of the forest maturing. However, care needs to be exercised when sampling mature forest sites to ensure forest floor litter and humus does not contaminate the mineral soil sample. This is a recognised problem when sampling forest sites as there is often no clear demarcation between the organic and mineral horizons. At present there is no satisfactory answer to this problem, and it is important that field workers involved in resampling are familiar with the manner and criteria used to collect earlier soil samples.

Forest soils are also problematic in that the soil quality indicators are not well developed, and Olsen P is not the preferred measure of long term P availability. It is likely that the target ranges may be modified in the future, probably revised downward, which will mean that most of the present forest sites will fall within target criteria. Although the bulk densities on some sites were high, the sites are mostly in high rainfall areas, so despite being well and excessively well drained, they are unlikely to shown water stress. Foresters often rip and mound Pumice Soils at higher altitude, mainly to prevent frost damage to young pines, but this also has the effect of improving drainage on compacted sites and improving the rooting environment.

A general recommendation for showing trends in soil characteristics through time is that three, and preferable five, sampling points are needed (Wheeler & Edmeades 1991). Soils differ in the spatial variability of their soil quality characteristics, and land use also affects spatial variability (Giltrap & Hewitt 2004). Individual soil characteristics also differ in their variability, and to achieve equivalent precision, greater numbers of samples are needed for the more highly variable soil characteristics. The indicators in the current soil quality set were selected after initial trials to select the less variable, but still responsive, characteristics (Schipper & Sparling 2000). The recommendation from Wheeler and Edmeades (1991) that 3–5 samples are required to identify trends with certainty refers mainly to soil chemical fertility (pH, Olsen, etc.) but is also applicable to the current set of soil quality indicators. Soil physical and biological characteristics are generally more variable than chemical, but changes in these characteristics also tend to be larger and more readily detected (Schipper & Sparling 2000). A resampling programme to collect 3–5 samples per site to identify trends remains justified.

5 Conclusions

- The current set of soil quality samples showed similar characteristics to those previously collected.
- No major changes in soil quality characteristics were detected.

6 Recommendations

- Environment Waikato continues the policy of resampling previously characterised sites to confirm the trends in soil quality attributes arising from the current data. For reliable long-term detection and prediction of trends, at least 3 and preferably 5 points along a time sequence should be obtained.

- Through land user groups, personal contact and community forums, land owners and managers of the current sites be made aware of the current state of their soils and the possible consequences for production and the environment.

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Appendix I: Soil Profiles and Site Descriptions for New Sites in 2004

Site: EW04_15

Soil Series	Waihou loam
Classification	Typic Orthic Allophanic Soil
Land use	Dry stock
Date sampled	19 November 2004
Land use history	Ex dairy farm, now small lifestyle block, has had little or no fertilizer.
Present vegetation	Pasture (horses).
Slope °	1 to 2 degrees.
Landform	Rolling terrace.
Annual rain (mm)	1400
Elevation (m)	81
Parent material	Tephra.
Erosion	None
Drainage	Well drained
Topsoil depth (cm)	18
Total rooting depth (cm)	120+
Limiting horizon	None
Sampled by	W. Rijkse and P. Smith (EW)

.

Description:

Horizon	Depth (cm)	Description
Ap	0–18	Very dark greyish brown (10YR 3/2) loam; slightly sticky; slightly plastic; weak soil strength; friable failure; earthy; strong NaF reaction; many fine and very fine roots; distinct smooth boundary.
Bw	18–70	Yellowish brown (10YR 5/6) loam; slightly sticky; slightly plastic; weak soil strength; friable failure; weakly pedal; strong NaF reaction; common fine and very fine roots; indistinct smooth boundary.
BC1	70–90	Yellowish brown (10YR 5/6) sandy loam; slightly sticky; slightly plastic; weak soil strength; friable failure; weakly pedal; few fine and very fine roots; distinct smooth boundary
BC2	90–120+	Light brownish grey to light yellowish brown (2.5Y 6/2 to 6/4) loamy fine sand; common medium prominent yellowish brown (10YR 5/6) mottles; non-sticky; non-plastic; weak soil strength; friable failure; massive; no live roots.

Site: EW04_16

Soil Series	Waihou loam
Classification	Typic Orthic Allophanic Soil
Land use	Cropping.
Date sampled	19 November 2004
Land use history	Ex dairy farm, has been in crops for only 2 years.
Present vegetation	Maize.
Slope °	1 to 2 degrees.
Landform	Rolling terrace.
Annual rain (mm)	1400
Elevation (m)	80
Parent material	Tephra.
Erosion	None
Drainage	Well drained
Topsoil depth (cm)	20
Total rooting depth (cm)	120+
Limiting horizon	None
Sampled by	W.Rijkse and P.Smith (EW)

.

Description:

Horizon	Depth (cm)	Description
Ap	0–20	Very dark greyish brown (10YR 3/2) loam; slightly sticky; slightly plastic; weak soil strength; friable failure; earthy; strong NaF reaction; few fine and very fine roots; distinct smooth boundary.
Bw	20–70	Yellowish brown (10YR 5/6) loam; slightly sticky; slightly plastic; weak soil strength; friable failure; weakly pedal; strong NaF reaction; few fine and very fine roots; indistinct smooth boundary.
BC1	70–90	Yellowish brown (10YR 5/6) loam; slightly sticky; slightly plastic; weak soil strength; friable failure; weakly pedal; no live roots; distinct smooth boundary
BC2	90–120+	Light olive brown (2.5Y 5/4) loamy fine sand; non-sticky; non-plastic; weak soil strength; friable failure; massive; no live roots.

Appendix II: Soil Chemical Analyses 2004

Environmental Chemistry Laboratory

Client: Graham Sparling, Landcare Research, Hamilton **Date In:** 23/11/2004
Job No.: LJ04067 **Date Out:** 20/12/2004

Client	Sample	pH	Total	Total	C/N	KCl-extractable		Anaerobic	Olsen	Exchangeable			
ID	No.	(water)	C	N	ratio	NO3-N	NH4-N	Mineralisable-N	P	Ca	Mg	K	Na
		(method 106)	(method 114)	(method 114)	(calculation)	(method 118)		(method (120)	(method 124)	(method 142)			
			(%)	(%)		(mg/kg)		(mg/kg)	(mg/kg)	(cmol(+)/kg)			
99/12	M4/1933	5.60	15.9	1.14	14	9.6	7.0	163	5	5.32	1.50	0.35	0.30
99/13	M4/1934	5.46	20.6	1.73	12	25.7	7.9	278	10	6.86	1.83	0.58	0.17
97/10	M4/1935	5.73	8.98	0.80	11	17.0	16.3	276	77	10.7	1.03	0.41	0.18
97/9	M4/1936	5.27	9.00	0.49	18	0.9	11.9	161	8	3.97	1.11	0.70	0.22
97/8	M4/1937	5.24	9.49	0.47	20	1.5	8.1	139	7	3.14	0.94	0.67	0.12
97/11	M4/1938	4.41	14.3	0.49	29	0.0	30.7	55	7	2.45	1.42	0.38	0.41
97/12	M4/1939	5.57	6.89	0.40	17	1.6	5.9	131	30	5.89	1.02	0.69	0.11
99/5	M4/1940	6.02	5.39	0.43	13	19.6	15.3	73	28	7.69	0.86	0.60	0.05
99/4	M4/1941	5.44	7.15	0.29	24	0.2	7.3	88	8	2.37	0.63	0.55	0.05
99/7	M4/1942	4.27	10.6	0.59	18	18.6	9.6	86	17	3.78	1.00	0.31	0.13
99/8	M4/1943	5.92	10.4	0.66	16	5.8	11.9	234	38	18.4	1.55	0.27	0.13
99/6	M4/1944	4.56	8.29	0.50	17	12.3	10.2	107	17	6.61	1.16	0.35	0.11
99/14	M4/1945	6.17	5.76	0.56	10	31.2	7.0	49	89	12.6	1.66	1.06	0.05
99/15	M4/1946	5.77	9.57	0.97	10	32.2	6.8	181	74	11.7	2.22	0.70	0.18
4/1	M4/1947	6.25	8.11	0.80	10	17.8	7.5	178	4	11.3	1.29	0.66	0.12
4/2	M4/1948	6.39	6.38	0.62	10	49.4	7.3	57	53	14.4	1.59	1.00	0.10

ID	Sample No.	Exchangeable Ca (method 142) ('Quick test' units)	Mg	K	Na
99/12	M4/1933	6	31	5	10
99/13	M4/1934	7	38	8	6
97/10	M4/1935	11	21	6	6
97/9	M4/1936	4	23	10	8
97/8	M4/1937	3	19	10	4
97/11	M4/1938	3	30	5	14
97/12	M4/1939	6	21	10	4
99/5	M4/1940	8	18	9	2
99/4	M4/1941	2	13	8	2
99/7	M4/1942	4	21	4	5
99/8	M4/1943	19	32	4	5
99/6	M4/1944	7	24	5	4
99/14	M4/1945	13	35	15	2
99/15	M4/1946	12	46	10	6
4/1	M4/1947	12	27	9	4
4/2	M4/1948	15	33	14	3

Appendix III: Soil Physical Analyses 2004

Environment Waikato Soil Quality Resampling 2004
Moisture Release Results
Job Code: 334 202 4301 Date January 2005

Lab Number	Client Id. (Depth, cm)	Initial Water Content (%, w/w)	Dry Bulk Density (t/m3)	Particle Density (t/m3)	Total Porosity (%, v/v)	Macro porosity (%, v/v)	Air-capacity (%, v/v)	Vol. WC5kPa (%, v/v)	Vol. WC10kPa (%, v/v)
HP2368a	99 / 12	96.0	0.64	2.31	72.4	9.6	13.0	62.8	59.4
HP2368b		97.2	0.55	2.18	74.8	19.8	22.4	55.1	52.4
HP2368c		114.8	0.53	2.14	75.2	13.4	15.9	61.8	59.3
HP2369a	99 / 13	103.0	0.57	2.20	74.1	13.4	17.8	60.7	56.3
HP2369b		105.7	0.45	1.98	77.2	15.3	20.7	61.9	56.5
HP2369c		102.9	0.54	2.15	74.8	10.8	17.9	64.0	56.9
HP2370a	97 / 10	112.8	0.57	2.22	74.2	5.9	10.5	68.3	63.7
HP2370b		82.0	0.75	2.24	66.6	0.7	3.0	65.9	63.6
HP2370c		98.3	0.57	2.23	74.6	14.7	18.7	59.9	55.9
HP2371a	97 / 9	75.3	0.56	2.26	75.0	25.2	32.0	49.9	43.0
HP2371b		58.5	0.37	2.16	82.9	38.6	46.1	44.3	36.8
HP2371c		63.3	0.59	2.35	74.7	28.7	35.4	46.0	39.3
HP2372a	97 / 8	70.0	0.73	2.29	68.2	13.6	19.5	54.6	48.7
HP2372b		105.7	0.53	2.25	76.6	19.6	23.9	57.0	52.7
HP2372c		62.0	0.74	2.32	68.3	18.5	22.6	49.8	45.7
HP2373a	97 / 11	160.1	0.24	2.16	89.0	45.6	51.0	43.4	38.0
HP2373b		48.8	0.54	2.19	75.3	35.6	40.9	39.6	34.4

Lab Number	Client Id.	Initial Water Content	Dry Bulk Density	Particle Density	Total Porosity	Macro porosity	Air-capacity	Vol. WC5kPa	Vol. WC10kPa
	(Depth, cm)	(%, w/w)	(t/m3)	(t/m3)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)
HP2373c		69.3	0.53	2.24	76.2	33.6	38.0	42.7	38.2
HP2374a	97 / 12	81.9	0.55	2.25	75.5	23.0	28.3	52.5	47.2
HP2374b		67.0	0.61	2.29	73.3	25.8	30.8	47.6	42.5
HP2374c		51.4	0.65	2.26	71.3	27.0	31.5	44.3	39.8
HP2375a	99 / 5	57.7	0.71	2.29	69.2	18.5	28.4	50.7	40.8
HP2375b		58.7	0.76	2.30	67.0	14.3	22.4	52.7	44.6
HP2375c		62.8	0.71	2.27	68.6	15.9	24.0	52.6	44.6
HP2376a	99 / 4	53.9	0.44	2.29	80.7	40.3	51.9	40.4	28.8
HP2376b		50.9	0.59	2.33	74.7	28.5	38.4	46.2	36.3
HP2376c		68.5	0.49	2.25	78.4	28.8	39.0	49.6	39.4
HP2377a	99 / 7	102.4	0.50	2.32	78.3	26.3	33.4	52.0	44.9
HP2377b		126.7	0.45	2.20	79.7	24.4	29.9	55.2	49.8
HP2377c		105.0	0.42	2.12	80.1	30.2	36.7	50.0	43.4
HP2378a	99 / 8	130.6	0.53	2.19	75.7	6.1	11.4	69.6	64.3
HP2378b		184.2	0.42	1.95	78.7	3.1	10.6	75.6	68.1
HP2378c		160.0	0.43	2.12	79.8	13.0	22.1	66.8	57.7
HP2379a	99 / 6	139.8	0.39	1.92	79.6	23.4	29.5	56.2	50.1
HP2379b		205.5	0.23	2.02	88.5	38.8	43.5	49.7	45.0
HP2379c		73.8	0.72	2.29	68.4	18.1	24.8	50.4	43.6
HP2380a	99 / 14	55.0	0.72	2.39	69.8	18.6	23.9	51.2	45.9
HP2380b		58.2	0.67	2.37	71.7	20.0	25.6	51.7	46.1

Lab Number	Client Id.	Initial Water Content	Dry Bulk Density	Particle Density	Total Porosity	Macro porosity	Air-capacity	Vol. WC5kPa	Vol. WC10kPa
	(Depth, cm)	(%, w/w)	(t/m3)	(t/m3)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)
HP2380c		59.8	0.64	2.38	73.3	23.9	29.6	49.4	43.7
HP2381a	99 / 15	58.0	0.82	2.28	64.1	2.6	4.6	61.5	59.5
HP2381b		72.4	0.79	2.27	65.4	0.7	3.2	64.8	62.2
HP2381c		83.7	0.67	2.26	70.2	5.5	8.2	64.8	62.0
HP2382a	04 / 1	97.5	0.65	2.28	71.7	4.6	7.8	67.0	63.9
HP2382b		74.7	0.82	2.41	66.2	1.7	4.8	64.5	61.4
HP2382c		84.6	0.74	2.32	68.3	1.8	4.6	66.6	63.7
HP2383a	04 / 2	62.6	0.77	2.34	67.2	10.7	15.5	56.5	51.7
HP2383b		61.6	0.68	2.37	71.1	20.9	25.5	50.3	45.6
HP2383c		60.1	0.74	2.37	68.8	15.9	20.2	52.8	48.6

Notes:

Sample 97/10 (HP2370b) – appeared to have been compacted.

Sample 97/9 (HP2371b) – was a different colour relative to its replicates.

Sample 97/11 (HP2373a) – had a higher organic matter (roots and litter) than its replicates.

Samples 97/12 (HP2374a-c) – all the replicates differed in colour and texture

Sample 99/4 (HP2376a) – had a large block of pumice in the sub-sampled core which accounted for about a third of the core volume

Samples 99/6 (HP2379a-c) – all the replicates differed in colour and texture

Sample 99/6 (HP2379b) – the field core, and sub-sampled core, were almost entirely composed of litter material

Analyst:
DT