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Soil Quality of Horticultural Sites in the Auckland Region in 2008

Changes since 1995-2000

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Soil Quality of Horticultural Sites in the Auckland Region in 2008

Changes since 1995-2000

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Contents

1 Executive Summary

1.1 Project and Client

The Auckland Regional Council (ARC) participated in two national soil quality monitoring projects in 1995–1998 and 1999–2001. The two projects, co-funded from the Ministry for the Environment Sustainable Management Fund (SMF), identified methods and protocols for soil quality monitoring (Hill et al. 2003). These protocols were used to examine a range of sites, soils, and land uses in the Auckland Region. Annual reports were provided by the science providers to the Auckland Regional Council and MFE (e.g. Sparling et al. 1998) and scientific summary reports of the whole national project are available (e.g., Sparling & Schipper, 2004). At the end of the SMF projects, popularly known as the "500 Soils Project", the Auckland Regional Council had more soil quality data (on an area basis) than any other region. However, after 2001, ARC did not participate in further similar soil quality monitoring until 2008. The strategy chosen by ARC in 2008 was to again sample those sites established under the earlier projects and considered to be most at risk of soil quality degradation. For the Auckland Region the highest priority sites were logically those under the most intensive land use such as market gardens, arable cropping, and horticulture.

1.2 Objectives

- Complete laboratory analyses on soil samples provided by the Auckland Regional Council staff, of soil quality on 18 sites, using methodologies consistent with those established under the 500 Soils Project.
- For each land use, identify which of the seven key indicators, soil pH, total C, total N, mineralisable N, Olsen P, bulk density, and macroporosity, were of most concern.
- Compare the current status of the soils against the condition when first sampled between 1995 and 2001 to identify any consistent changes in soil quality
- Provide an interpretive report to the ARC for use in landholder education and policy development.

1.3 Methods

- ARC staff collected soil samples using the recommended methods under the 500 Soils Project protocol. Soil analyses were completed using the same protocols and were consistent with those of earlier samplings.

- Seven key soil quality indicators, soil pH, total C, total N, mineralisable N, Olsen P, bulk density, and macroporosity were used to estimate the quality status of the soils and to determine whether the measured values fell within suggested target ranges specific to that soil and land use.
- The proportion of sites meeting the suggested target ranges for the seven indicators was calculated.
- The current status of the sites was compared with archive data from previous soil quality samples collected from the same sites between 1995 and 2001.

1.4 Results

- Eighteen sites, all originally under intensive land use for market gardens, vegetable production, orchards and vineyards were resampled. Three sites had recently been converted to pasture.
- Of the 18 sites, four met all the suggested targets (22%), six sites (33%) had one characteristic not meeting the suggested range, a further six sites (33%) had two characteristics not meeting the suggested range and 2 sites (11%) had 3 characteristics outside the suggested range.
- A total of 126 characteristics were used to assess the sites. Of those individual characteristics, 102 (81%) fell within the recommended range and 24 (19%) were outside the target range.
- Low macroporosity (indicating soil compaction) and both high and low Olsen P contents were the main indicators falling outside the recommended ranges
- No consistent changes in soil quality characteristic were detected between data collected in 2008 and earlier sampling times (1995–2000).

1.5 Conclusions

- As assessed by seven key indicators, four (22%) of the 18 sites sampled in 2008 fell within the suggested target ranges, the remaining 14 sites (78%) had one or more characteristics outside the suggested range.
- The main soil quality characteristics of concern were low macroporosity (values <8% on horticultural land uses or < 10% on pastoral land uses, indicating soil compaction) on 72% of the sites, and high fertility levels on 22% of the sites.
- The overall soil quality of the sites remains of concern. There were no consistent changes between the two sampling dates, the sites showed both positive and negative changes, these did not appear to be linked to land use or soil group.
- Recent site management by the land managers may have masked the ability to detect changes since the previous sampling.

- Changes may be difficult to detect on intensively cropped sites under the same long-term management, as the bulk of the changes are likely to occur during the first 0–10 years.

1.6 Recommendations

- The Auckland Regional Council continues the present strategy of resampling established soil quality sites, and to establish new sites as resources allow.
- The Auckland Regional Council adopt a longer term policy to obtain four or five repeat samples over a period of time from established sites to establish whether there are any trends in soil quality attributes.
- The current sampling methods should be retained to allow ready comparisons between samples collected at different times.

2 Introduction

The Resource Management Act (1991) Section 35 requires Regional Councils to report on the "life supporting capacity of soil" and whether current practices will meet the "foreseeable needs of future generations". To assist Councils to assess soil quality in their regions, between 1995–1997 and 1998–2001, the Ministry for the Environment (MfE) co-funded two Sustainable Management Fund (SMF) Projects commonly known as the 500 Soils Project (Hill et al. 2003; Sparling et al. 2004). The Auckland Regional Council (ARC) participated in both these projects and by the end of the SMF projects, had more soil quality data (on an area basis) than any other region. Annual reports were provided to ARC and MfE (e.g. Sparling et al., 1998) and scientific summary reports of the whole national project are available (see for example, Sparling & Schipper, 2004). However, once SMF support ceased, ARC opted not to participate in further similar soil quality monitoring until the current initiative in 2008.

The strategy chosen by the ARC for soil quality reporting in 2008 was to target sites and land uses considered to be most at risk of soil quality degradation. For the Auckland Region the highest priority sites were deemed to be those under the more intensive land uses such as market gardens and horticulture. Data for the region were available from the 500 Soils Project from 7–12 years earlier, and the opportunity existed to assess the current status of those sites and determine how soil quality had changed during the intervening period.

3 Objectives

- Complete laboratory analyses on the 18 soil samples provided by the Auckland Regional Council staff, using methodologies consistent with those established under the 500 Soils Project.
- For each land use, identify which of the seven key indicators, soil pH, total C, total N, mineralisable N, Olsen P, bulk density, and macroporosity, were of most concern.
- Compare the current status of the soils against the condition when first sampled between 1995 and 2001 to identify any consistent changes in soil quality.
- Provide and interpretive report to the Auckland Regional Council for use in landholder education and policy development.

4 Methods

4.1 Site selection

Sites were selected by ARC staff for soil quality monitoring. All sites selected for resampling were originally in the cropping and horticulture land use category and included market gardens, vegetable crops, a tree nursery, vineyards and orchards. ARC staff collected soil samples using the methods recommended by the 500 Soils Project protocol. Soil analyses were completed by Landcare Research using the 500 Soils Project protocols and consistent with those of earlier samplings.

4.2 Soil quality assessment

Seven key soil quality indicators (soil pH, total C, total N, mineralisable N, Olsen P, bulk density and macroporosity) were used to estimate the quality status of the soils. These indicators have been described in earlier reports to ARC (e.g., Sparling et al 2001). The target ranges, specific to soil order and land use, were taken from the provisional values suggested by Sparling et al. (2003). For each site, the number of times a value failed to meet the target range was recorded. The proportion of sites meeting the suggested target ranges for the 7 indicators was calculated. The current status of the sites was compared with archive data from previous samples collected between 1995 and 2001 (See Appendix 11.3).

4.3 Biochemical properties

Potentially mineralisable N was estimated by the anaerobic (waterlogged) incubation method; the increase in NH^{+}_{4} concentration was measured after incubation for 7 days at 40°C and extraction in 2M KCl (Keeney & Bremner 1966).

4.4 Chemical properties

Total C and N were determined by dry combustion of air-dry, finely ground soils using a Leco 2000 CNS analyser. 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).

4.5 Physical properties

Macroporosity was determined by subtraction of volumetric water content at -5 kPa (by drainage on pressure plates) from total porosity as described by Klute (1986). Bulk density was measured on a subsampled core dried at 105°C (Klute 1986) and the remaining soil analysed for particle size and density by the pipette method.

Note: The general definition of macroporosity has recently been expanded to cover a slightly larger range of pore sizes than the original definition. Several regional councils have adopted a macroporosity measurement based on volumetric water content at -10 kPa (technically referred to as air filled porosity or air capacity). For comparison and consistency with older ARC data we use the -5 kPa measurement, but include the measurement at -10 kPa for future reference.

4.6 Statistics and data presentation

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.

5 Results

5.1 Soils and land use categories

Eighteen sites were sampled for their current soil quality characteristics (Table 1). All sites were in the horticultural and cropping land use category when originally sampled and covered nine major soil types and seven soil orders. A variety of horticultural activities were sampled including market gardens for intensive vegetable production, strawberries, a tree nursery, vineyards, and orchards for citrus and pipfruit.

Three sites have recently been converted to pasture (drystock) and were evaluated by the drystock land use target values (in order to support best management practices under the new land use) but as conversion was recent, we have retained the sites in this analysis and report and generally refer to all sites as "horticultural" unless specifically noted. The original site and soil profile descriptions are shown in the Appendix 10.4.

The current characteristics of the sites are shown in Tables 2 and 3. Items shown in bold type are outside the recommended range for that soil and land use. For the reports produced in colour print or electronic versions the bold numbers in red are below the advised range, and those bold numbers in blue are greater than the expected range.

There was a large range in values for the various soil attributes, reflecting the differing soil type, soil order and land uses. Two soil quality characteristics stood out as having a larger number of sites outside the recommended range (see Tables 2 and 3). Soil macroporosity was the most common indicator "out of range" being low (<8% for horticultural sites, and indicating soil compaction) on the majority of sites. Olsen P was excessively high on four of the 18 sites, but surprisingly low on others (ARC 00-09 and ARC 00-17).

No one soil type appeared to be more at risk of exceeding the target ranges than another. However, site ARC 95-01 a Granular Soil under long-term (60 year) vegetable production was very low in organic reserves with low total C and low mineralisable N, indicating organic matter depletion. Site ARC 99-04, an Organic Soil used as an orchard, had a surprisingly low total C content for that soil class, yet had a high total N content. This may reflect the classification of the Ardmore peaty soil as Organic, and hence the total C content appearing low for an Organic Soil, but in that case the total N should have been low rather than high. This may indicate high applications of N to the site.

Data for NH_4-N, NO_3-N, particle density, and total porosity are also shown in Tables 2 and 3. This is for information and interest only; these data are necessary to derive the mineralisable N and macroporosity data, but to date, no target ranges have been suggested for these primary attributes. They are shown italicised in the tables to indicate they are not part of the soil quality assessment.

Table 1 Soils and land use classes in the Auckland region sampled in 2008 for soil quality attributes.

Site code	Site first established	Land cover	Current Land use	Classification	Soil Type
ARC95_01	1995	Bare cultivated soil	Outdoor vegetables	Allophanic Oxidic Granular	Patumahoe clay loam
ARC97_02	1997	Bare cultivated soil	Outdoor vegetables	Typic Orthic Allophanic	Karaka silt loam
ARC98_02	1998	Feijoa trees and pasture	Orchard	Typic Orthic Allophanic	Karaka silt loam
ARC98_08	1998	Apple trees and pasture	Orchard	Weathered Fluvial Recent	Waitemata silt loam
ARC99_04	1999	Kiwifruit vines and pasture	Orchard	Mellow Humic Organic	Ardmore peaty loam
ARC98_25	1998	Pasture (recently converted from market garden)	Drystock	Weathered Fluvial Recent	Waitemata silt loam
ARC00_03	2000	Persimmon orchard	Orchard	Typic Orthic Allophanic	Karaka silt loam
ARC00_05	2000	Citrus orchard	Orchard	Typic Orthic Allophanic	Matakawau sandy clay loam
ARC00_08	2000	Cabbages, garlic, lettuce	Outdoor vegetables	Typic Orthic Granular	Patumahoe silt loam
ARC00_06	2000	Pasture (recently converted from arable cropping)	Drystock	Typic Orthic Allophanic	Matakawau sandy loam
ARC00_09	2000	Young trees	Plant nursery	Mellow Humic Organic	Ardmore humic loam
ARC00_18	2000	Grape vines	Orchard	Typic Yellow Ultic	Warkworth clay loam
ARC00_17	2000	Pasture (recently converted from arable cropping)	Drystock	Typic Yellow Ultic	Warkworth clay loam
ARC00_19	2000	Pip fruit, banana's, figs, babaco	Orchard	Typic Yellow Ultic	Warkworth clay loam
ARC00_20	2000	Citrus and feijoa orchard	Orchard	Mottled Orthic Brown	Waitemata complex
ARC00_24	2000	Grape vines	Vineyard	Typic Orthic Gley	Waitemata complex
ARC00_25	2000	Apple orchard	Orchard	Typic Orthic Gley	Waitemata complex
ARC00_26	2000	Strawberries	Outdoor fruit	Typic Orthic Gley	Waitemata complex

Table 2 Soil chemical characteristics in 2008 of horticultural sites in the Auckland region, grouped by soil type.

Site code	Soil and land use	Soil pH	Total C mg/cm^3	Total N mg/cm^3	Olsen P µg/cm^3	Mineralisable N µg/cm^3	NO_3-N µg/cm^3	NH_4-N µg/cm^3
ARC 95-01	Patumahoe clay loam, market garden	6.41	23.5	2.23	209	15	*40*	*58.0*
ARC 97-02	Karaka silt loam, market garden	6.88	39.4	3.14	39	23	*6*	*0.3*
ARC 98-02	Karaka silt loam, orchard	6.31	59.2	5.12	155	111	*30*	*1.5*
ARC 98-08	Waitemata silt loam, orchard	5.97	57.4	3.75	104	99	*1.0*	*33.0*
ARC 98-25	Waitemata silt loam, drystock	7.2	62.9	4.32	53	86	*18*	*0.5*
ARC 99-04	Ardmore peaty loam, orchard	6.51	95.9	7.53	32	86	*18*	*0.6*
ARC 00-03	Karaka silt loam, orchard	6.81	62.0	5.04	65	77	*14*	*0.5*
ARC 00-05	Matakawau sandy clay loam, orchard	6.68	51.9	4.41	46	123	*20*	*1.6*
ARC 00-06	Matakawau sandy loam, drystock	6.09	74.0	6.38	28	132	*28*	*0.8*
ARC 00-08	Patumahoe silt loam, market garden	7.02	53.4	4.77	23	96	*14*	*0.4*
ARC 00-09	Ardmore humic loam, tree nursery	6.41	126.6	5.15	17	39	*3*	*1.0*
ARC 00-17	Warkworth clay loam, drystock	6.2	47.0	3.20	16	103	*3*	*0.4*
ARC 00-18	Warkworth clay loam, vineyard	5.57	57.1	4.87	21	112	*24*	*1.4*
ARC 00-19	Warkworth clay loam. orchard	6.11	50.3	3.90	15	151	*21*	*1.8*
ARC 00-20	Waitemata complex, orchard	5.89	55.2	4.87	38	127.60	*18*	*1.2*
ARC 00-24	Waitemata complex, vineyard	6.19	55.4	4.17	147	103.59	*1*	*27.0*
ARC 00-25	Waitemata complex, orchard	6.29	47.9	3.28	99	89.60	*0*	*22.1*
ARC 00-26	Waitemata complex, strawberries	5.97	36.7	2.06	67	28.86	*3*	*1.2*

Table 3 Soil physical characteristics in 2008 of cropping and horticultural sites in the Auckland region, grouped by soil type

Site code	Soil and land use	Dry bulk density Mg/m^3	Particle density Mg/m^3	Total porosity %v/v	Macroporosity (-5 KPa) %v/v
ARC 95-01	Patumahoe clay loam,	1.16	*2.64*	*56.3*	11.9
ARC 97-02	Karaka silt loam, market garden	0.90	*2.54*	*64.6*	20.1
ARC 98-02	Karaka silt loam, orchard	1.03	*2.50*	*58.6*	5.7
ARC 98-08	Waitemata silt loam, orchard	1.21	*2.53*	*52.2*	1.5
ARC 98-25	Waitemata silt loam, drystock	1.21	*2.56*	*53.0*	1.6
ARC 99-04	Ardmore peaty loam, orchard	0.62	*2.18*	*72.3*	5.5
ARC 00-03	Karaka silt loam, orchard	1.07	*2.52*	*57.4*	6.9
ARC 00-05	Matakawau sandy clay loam, orchard	1.07	*2.59*	*58.7*	15.4
ARC 00-06	Matakawau sandy loam, drystock	0.98	*2.54*	*61.4*	4.3
ARC 00-08	Patumahoe silt loam, market garden	1.06	*2.56*	*58.7*	12.6
ARC 00-09	Ardmore humic loam, tree nursery	0.63	*1.83*	*65.8*	6.7
ARC 00-17	Warkworth clay loam, drystock	1.02	*2.59*	*60.8*	2.8
ARC 00-18	Warkworth clay loam, vineyard	1.07	*2.54*	*57.9*	7.3
ARC 00-19	Warkworth clay loam. orchard	1.01	*2.52*	*60.0*	5.2
ARC 00-20	Waitemata complex, orchard	1.01	*2.54*	*60.1*	6.1
ARC 00-24	Waitemata complex, vineyard	1.28	*2.55*	*49.9*	2.5
ARC 00-25	Waitemata complex, orchard	1.25	*2.55*	*51.1*	4.8
ARC 00-26	Waitemata complex, strawberries	1.18	*2.58*	*54.4*	9.0

5.2 Overall soil quality of horticultural sites in 2008

Eighteen sites were sampled in the horticulture category. Seven soil Orders were covered. Of the 18 sites, four met all the suggested targets (22%), six sites (33%) had one characteristic not meeting the suggested range, a further six sites (33%) had two characteristics not meeting the suggested range and two sites (11%) had three characteristics outside the suggested range (Fig. 1). Low macroporosity (indicating soil compaction) and both high and low Olsen P contents were the main indicators falling outside the recommended ranges (Fig. 2).

A total of 126 characteristics were used to assess the sites. Of those individual characteristics, 102 fell within the recommended range (81%) and 24 (19%) were outside the target range.

Figure 1
Percentage of horticulture sites meeting suggested soil quality targets (Auckland Region, 2008)

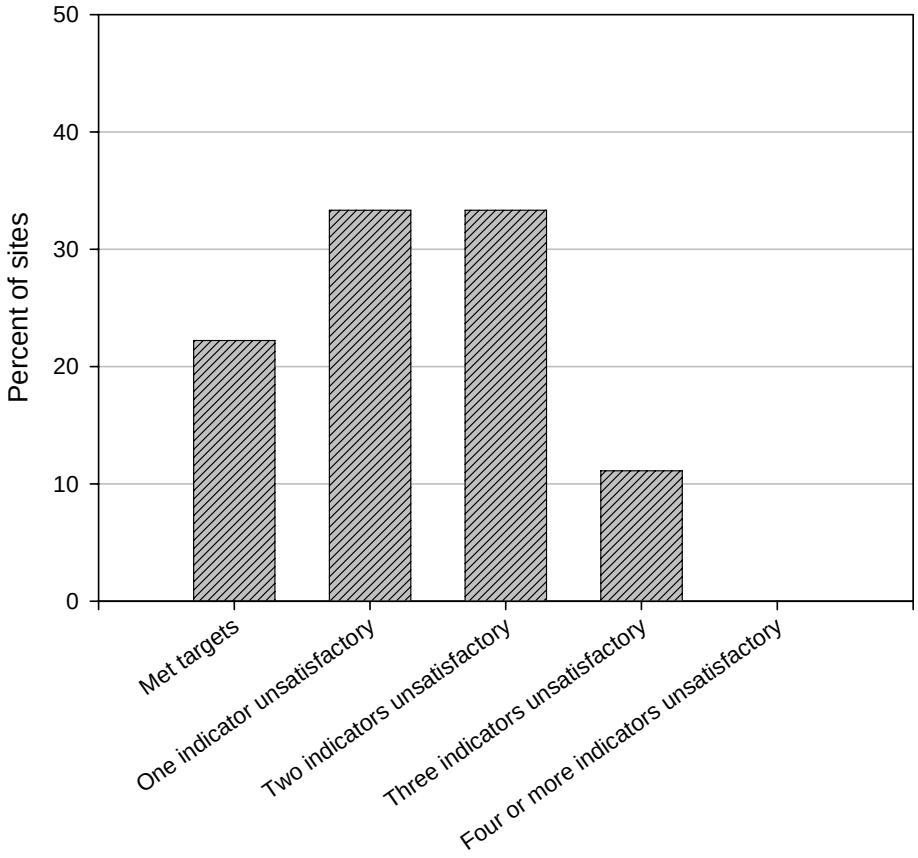
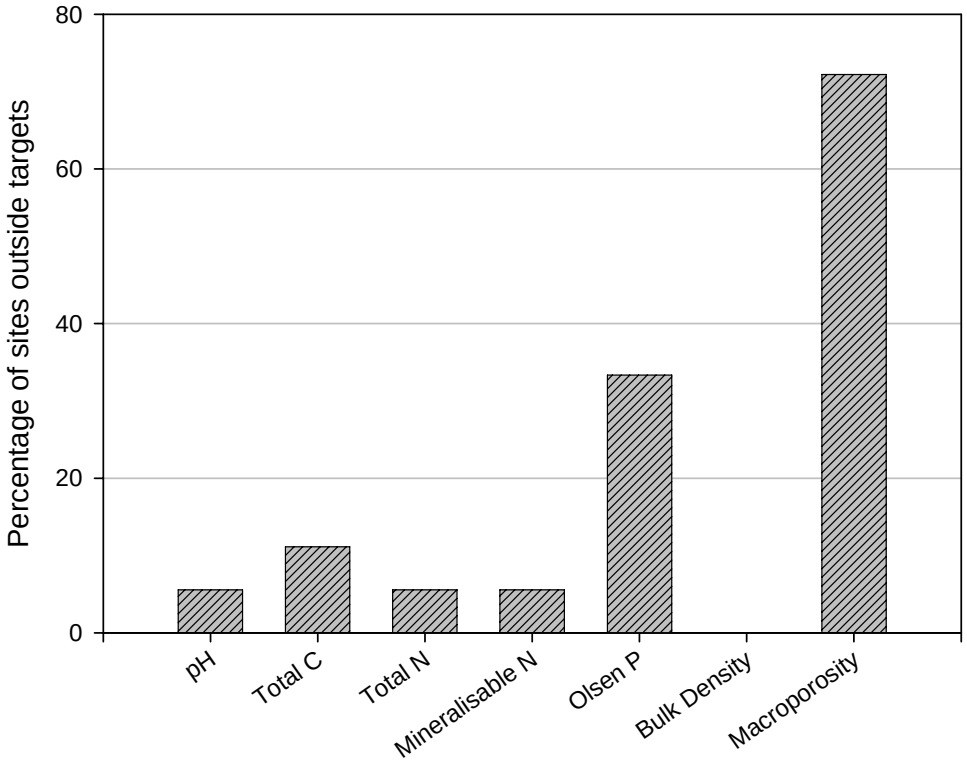


Figure 2
Soil quality concerns for horticulture sites in Auckland region, 2008.



5.3 Changes in soil quality between 1995-2001 and 2008

The current soil quality status of the horticultural sites sampled in 2008 was compared with archive soil quality data collected between 1995 and 2001, using the same collection and analysis methodologies. Full data for the archive samples are provided in Appendix 11.3.

Absolute changes in values of individual characteristics since the earlier sampling are shown in Table 4, and as percentage change in Table 5.

The data showed no consistent changes in soil quality across the different soils and land uses.

There were some very large increases in some soil attributes, but equally matched by decreases on other sites. Overall, it was not possible to detect consistent change in any of the seven key soil properties used to assess soil quality between the two sampling times. Grouping the data by land use (e.g., orchards), or by soil Order was also tested, but again, no consistent changes were apparent, and both positive and negative changes within the same soil Order or land use category were obtained. Subdividing the data set also meant that the number of samples was low for any rigorous statistical testing. Overall, the conclusion must be that the data are inherently "noisy" and that any soil management carried out shortly before sampling may have so modified the current data as to make it very difficult to detect changes since the earlier sampling. Mineralisable N and Olsen P were among the most variable of characteristics between the two sampling dates, as shown by the high standard deviation (Tables 4 and 5).

Care is needed when looking at percentage changes between the two sampling times. Percentage change is a useful measure in that it enables a ready appraisal of those characteristics which are changing the most. However, a large percentage change can be misleading. For example site ARC 00-06 showed a huge percentage increase in macroporosity. That percentage change only looked so massive because the rather minor improvement was large compared to the very low macroporosity at the earlier sampling. The earlier sampling had a macroporosity of 0.3 %v/v, whereas the current 2008 sample was 4.3%v/v. A small improvement against such a low base gives a large percentage change, and the impression that a large improvement has been observed. However, even with the improvement, the macroporosity is still very low, and the soil would still be regarded as badly compacted.

Table 4 Change in soil quality attributes of horticultural sites in Auckland Region between 1995–2000 and 2008

Code	Soil and use	Soil pH	Total C mg/cm^3	Total N mg/cm^3	Olsen P µg/cm^3	Mineralis-able N µg/cm^3	Total porosity %v/v	Macropor osity %v/v
ARC 95-01	Patumahoe clay loam, vegetable	-0.76	3.28	0.31	6.3	9.3	0.20	-18.3
ARC 97-02	Karaka silt loam, vegetables	0.3	-16.77	-1.65	-49.8	19.8	0.04	4.7
ARC 98-02	Karaka silt loam, orchard	0.14	-0.36	-0.22	13.0	107.4	0.12	-9.9
ARC 98-08	Waitemata silt loam, orchard	-0.41	-5.94	-0.61	32.5	3.3	0.18	-6.8
ARC 98-25	Waitemata silt loam, pasture (was market garden)	1.86	24.59	1.22	46.0	-58.8	0.21	-20.3
ARC 99-04	Ardmore peaty loam, orchard	-0.29	23.42	1.50	9.1	-2.7	0.17	-2.1
ARC 00-03	Karaka silt loam, orchard	0.24	3.68	0.53	-55.7	4.8	0.11	-10.6
ARC 00-05	Matakawau sandy clay loam, orchard	0.44	-3.75	-0.04	-65.1	28.8	-0.09	1.5
ARC 00-06	Matakawau sandy loam, pasture (was arable)	0.33	7.09	1.03	41.3	-55.1	-0.18	4.0
ARC 00-08	Patumahoe silt loam, market garden	0.66	6.90	0.95	-23.7	7.5	0.23	-12.3
ARC 00-09	Ardmore humic loam, tree nursery	0.01	-20.92	-0.79	-4.5	-4.7	-0.11	-3.8
ARC 00-17	Warkworth clay loam, pasture (was arable)	-0.13	8.28	0.41	-47.4	-0.8	0.02	0.4
ARC 00-18	Warkworth clay loam, vineyard	-0.27	9.12	0.96	-40.5	5.0	0.10	-9.9
ARC 00-19	Warkworth clay loam. orchard	0.34	2.75	0.45	7.3	-1.6	0.08	-5.2
ARC 00-20	Waitemata complex, orchard	-0.05	-5.39	-0.21	-111.4	-9.0	-0.04	-2.5
ARC 00-24	Waitemata complex vineyard	0.39	6.82	0.81	-23.4	-55.3	-0.12	-5.3
ARC 00-25	Waitemata complex, orchard	0.42	6.03	0.83	-51.4	-31.9	0.02	-8.1
ARC 00-26	Waitemata complex, strawberries	-0.21	0.27	-0.09	-17.1	-92.6	-0.17	4.8
Mean		0.17	2.73	0.30	-18.59	-7.03	0.04	-5.54
Std Dev		0.56	11.33	0.80	41.44	42.92	0.13	7.31
Significance		NS	NS	NS	NS	NS	NS	NS

Table 5 Percentage change in soil quality attributes of horticultural sites in Auckland Region between 1995–2000 and 2008

Code	Soil and use	Soil pH	Total C mg/cm^3	Total N mg/cm^3	Olsen P µg/cm^3	Min-N µg/cm^3	Total porosity %v/v	Macro-porosity %v/v
ARC 95-01	Patumahoe clay loam, vegetable	-10.6	16.2	16.3	70.2	4.7	20.5	-60.7
ARC 97-02	Karaka silt loam, vegetables	4.6	-29.8	-34.3	-68.2	101.1	4.5	30.6
ARC 98-02	Karaka silt loam, orchard	2.3	-0.6	-4.2	13.1	223.2	13.7	-63.5
ARC 98-08	Waitemata silt loam, orchard	-6.4	-9.4	-14.1	48.6	3.3	17.5	-82.3
ARC 98-25	Waitemata silt loam, pasture (was market garden)	34.8	64.2	39.5	114.1	-52.4	20.5	-92.5
ARC 99-04	Ardmore peaty loam, orchard	-4.3	32.3	24.8	11.8	-7.8	38.0	-27.6
ARC 00-03	Karaka silt loam, orchard	3.7	6.3	11.9	-41.9	7.9	11.2	-60.4
ARC 00-05	Matakawau sandy clay loam, orchard	7.1	-6.7	-0.9	-34.6	171.1	-7.5	10.8
ARC 00-06	Matakawau sandy loam, pasture (was arable)	5.7	10.6	19.3	45.4	-66.2	-15.3	1322
ARC 00-08	Patumahoe silt loam, market garden	10.4	14.8	24.8	-19.8	50.0	28.0	-49.4
ARC 00-09	Ardmore humic loam, tree nursery	0.2	-14.2	-13.3	-10.2	-21.4	-14.4	-36.2
ARC 00-17	Warkworth clay loam, pasture (was arable)	-2.1	21.4	14.8	-31.4	-4.9	2.3	16.7
ARC 00-18	Warkworth clay loam, vineyard	-4.6	19.0	24.5	-26.5	31.4	10.2	-57.6
ARC 00-19	Warkworth clay loam. orchard	5.9	5.8	13.1	5.1	-9.7	8.0	-49.7
ARC 00-20	Waitemata complex, orchard	-0.8	-8.9	-4.1	-46.6	-19.4	-3.9	-29.5
ARC 00-24	Waitemata complex, vineyard	6.7	14.0	24.1	-18.4	-27.3	-8.9	-68.4
ARC 00-25	Waitemata complex, orchard	7.2	14.4	33.9	-36.5	-24.4	1.6	-62.8
ARC 00-26	Waitemata complex, strawberries	-3.4	0.7	-4.1	-37.3	-57.9	-12.8	115.1
Mean		3.1	8.3	9.6	-3.5	16.7	6.3	-33.4
Std Dev		9.7	20.5	19.2	47.0	77.0	15.2	51.3
Significance		NS	NS	NS	NS	NS	NS	NS

6 Discussion

Overall the current soil condition of these horticultural sites is similar to that observed in earlier sampling. In particular, the issue of high fertility status on some sites and low macroporosity on a large majority seem persistent. We were unable to show consistent changes attributable to one land use practice or soil type. In some cases soil condition had improved between the sampling dates in other cases it had worsened.

In general, there is less spatial variability in soil quality characteristics in horticultural sites compared to pastures or forest. This is because repeated tillage operations for cultivation have mixed the surface soil to provide a more uniform sampling medium (Giltrap & Hewitt, 2004). However, it is still difficult to detect charges on cultivated and fertilised sites with only one repeat sampling. This is probably because of the numerous interventions during the growing season by the land managers. Some sites grow three crops a year with multiple cultivations which can greatly influence soil condition at the time of sampling, particularly for bulk density and macroporosity measures. In the current sampling macroporosity was on of the measures that showed greatest variability, and this may have reflected the timing of the sample collection relative to cultivation. It is notable that vegetation cover on several of the sites was described as bare soil, suggesting recent cultivation. Similarly, the timing of fertiliser applications by the land manager can greatly alter the values obtained for Olsen P and N status when using a single annual sample for soil quality assessment.

The main soil quality indices of concern, low macroporosity indicating compaction, and high Olsen P indicating high/excessive chemical fertility status, have also been noted on market garden sites in Greater Wellington and Waikato Regions, and this appears to be a widespread problem in North Island for that land use and management.

There are many examples in the scientific literature of intensive vegetable cropping resulting in the loss of soil organic matter (e.g., Haynes & Tregurtha 1999). However, only one site (ARC 95-02) a long term market garden site on Patumahoe clay loam, showed very low organic matter status. This site also showed little change since the earlier sampling in 1995, suggesting that the organic matter had stabilised at a new lower level. The bulk of the change in organic matter seems to occur during the first 0-10 years (Haynes & Tregurtha 1999). In the case of site ARC95-02, the usually adverse effects of organic matter loss are partly offset by characteristics of the Patumahoe clay loam soil as it is a Granular Soil. Comparison with a pasture site on the same soil, suggests some 60–70% of the topsoil organic matter has been lost. However, the unique iron and aluminium minerals of this soil maintain structural integrity even when the organic matter is depleted, enabling its continued use for cultivation. Large organic matter losses on other soils with less forgiving mineralogy can result in high bulk density, massive blocky structure, poor seedbeds, increased compaction and poor drainage (Sparling et al. 2000 a, b). Despite the maintenance of soil structure following the loss of organic matter from the Putumahoe soil, the loss of organic matter has adversely affected other desirable characteristics, and nitrogen storage and mineralisation were much depleted. Intensive vegetable production on soils that are

not in the Granular Order is likely to result in much more rapid decline in all soil quality attributes.

The present sampling strategy appears to be working reasonably well to detect the current status of the sites and soils. However, detecting consistent change between sampling times has proved difficult, and the results from the Auckland Region are similar to those obtained in the Wellington and Waikato Regions. Wheeler and Edmeades (1991) suggested that as many as five repeat samplings may be needed to establish a definite trend.

7 Conclusions

- As assessed by seven key indicators, four sites (22%) of the 18 horticulture and cropping sites sampled in 2008 fell within the suggested target ranges, the remaining 14 sites (88%) had one or more characteristics outside the suggested range.
- The main soil quality characteristics of concern were low macroporosity (values <8% on horticultural land uses or <10% on pastoral land uses, indicating soil compaction) on 72% of the sites, and high fertility levels on 22% of the site.
- The overall soil quality of the sites remains of concern. There were no consistent changes between the two sampling dates, the sites showed both positive and negative changes, these did not appear to be linked to land use or soil group.
- Recent site management by the land managers may have masked the ability to detect changes since the previous sampling.
- Changes may be difficult to detect on intensively cropped sites under the same long-term management, as the bulk of the changes are likely to occur during the first 0–10 years.

8 Recommendations

- Auckland Regional Council continues the present strategy of resampling established soil quality sites, and to establish new sites as resources allow.
- Auckland Regional Council adopt a longer term policy to obtain four or five repeat samples over a period of time from established sites to establish whether there are any trends in soil quality attributes.
- The current sampling methods should be retained to allow ready comparisons between samples collected at different times.

9 Acknowledgements

Soil samples were collected by Auckland Regional Council. We thank the landowners for allowing access to their properties and for supplying management information. Laboratory analyses were completed at Landcare Research at the Soil Physics Laboratory, Hamilton and Environmental Chemistry Laboratory, Palmerston North. Original soil descriptions (in appendix) were by Wim Rijkse and Doug Hicks.

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11 Appendices

11.1 2008 Soil Physics Data

Auckland Regional Council Soil Quality 2008/2009
Moisture Release Results
Job Code: 682 202 0033
October 2008

Lab Number	Client ID	Distance	Initial Water Content (%, w/w)	Dry Bulk Density (t/m3)	Particle Density (t/m3)	Total Porosity (%, v/v)	Macro Porosity (%, v/v)	Air Filled Porosity (%, v/v)	Vol. WC 5kPa (%, v/v)	Vol. WC 10kPa (%, v/v)
HP3699a	ARC00_03 (site 65)	15 m	51.0	1.04	2.51	58.7	4.9	6.5	53.8	52.2
HP3699b		30 m	43.4	1.08	2.53	57.2	10.1	11.6	47.1	45.6
HP3699c		45 m	47.8	1.10	2.51	56.4	5.8	7.9	50.6	48.5
HP3700a	ARC00_05 (site 67)	15 m	35.2	1.10	2.61	58.0	20.4	24.0	37.6	34.0
HP3700b		30 m	48.1	1.01	2.57	60.8	13.1	15.7	47.7	45.1
HP3700c		45 m	39.3	1.12	2.61	57.2	12.7	14.8	44.6	42.4
HP3701a	ARC00_09 (site 71)	15 m	97.9	0.65	1.83	64.6	2.6	6.1	62.0	58.5
HP3701b		30 m	97.8	0.60	1.84	67.7	10.8	14.3	56.9	53.4
HP3701c		45 m	103.5	0.65	1.82	65.2	<1	4.1	65.2	61.1
HP3702a	ARC00_18 (site 80)	15 m	59.4	1.00	2.55	60.9	4.4	7.6	56.6	53.3
HP3702b		30 m	46.3	1.06	2.54	58.2	10.1	12.4	48.1	45.8
HP3702c		45 m	47.1	1.16	2.52	54.6	<1	1.4	54.6	52.7
HP3703a	ARC00_19 (site 81)	15 m	58.0	0.98	2.49	60.8	6.0	9.0	54.8	51.8
HP3703b		30 m	59.5	0.97	2.52	61.5	5.8	8.9	55.8	52.6
HP3703c		45 m	50.4	1.08	2.55	57.7	3.9	6.3	53.8	51.4
HP3704a	ARC00_20 (site 82)	15 m	55.9	1.02	2.52	59.6	3.4	5.9	56.2	53.7
HP3704b		30 m	58.2	0.99	2.55	61.3	5.7	9.8	55.6	51.5
HP3704c		45 m	50.1	1.03	2.54	59.4	9.1	12.2	50.3	47.2
HP3705a	ARC00_24 (site 86)	15 m	34.4	1.36	2.54	46.4	1.4	3.3	45.1	43.1
HP3705b		30 m	38.1	1.29	2.56	49.5	2.2	4.4	47.3	45.1
HP3705c		45 m	43.5	1.18	2.55	53.7	3.8	6.6	49.9	47.1
HP3706a	ARC00_25 (site 87)	15 m	34.6	1.26	2.54	50.4	7.7	9.3	42.7	41.1
HP3706b		30 m	41.0	1.23	2.55	51.6	3.2	5.6	48.4	46.0
HP3706c		45 m	41.8	1.24	2.54	51.2	3.5	6.4	47.6	44.8
HP3707a	ARC98_02 (site 14)	15 m	59.1	0.99	2.46	59.9	4.6	7.0	55.3	52.9
HP3707b		30 m	53.1	1.05	2.51	58.3	5.9	8.6	52.4	49.7
HP3707c		45 m	47.1	1.07	2.53	57.7	6.6	8.3	51.1	49.4
HP3708a	ARC98_08 (site 20)	15 m	42.8	1.22	2.52	51.7	1.6	3.9	50.0	47.8
HP3708b		30 m	40.5	1.25	2.54	50.7	1.3	3.2	49.4	47.5
HP3708c		45 m	46.6	1.16	2.53	54.1	1.5	4.5	52.5	49.6
HP3709a	ARC99_04 (site 41)	15 m	114.0	0.59	2.20	73.1	5.5	8.1	67.6	65.0
HP3709b		30 m	100.8	0.69	2.13	70.1	<1	1.1	70.1	69.0
HP3709c		45 m	126.8	0.58	2.19	73.6	<1	1.2	73.6	72.4
HP3710a	ARC00_06 (site 68)	15 m	50.8	1.01	2.53	60.2	3.5	6.7	56.8	53.5
HP3710b		30 m	50.2	0.97	2.54	61.6	5.1	9.6	56.5	52.0
HP3710c		45 m	54.4	0.96	2.54	62.3	4.2	7.6	58.1	54.7
HP3711a	ARC00_08 (site 70)	15 m	38.0	1.14	2.57	55.7	10.9	12.6	44.8	43.1
HP3711b		30 m	42.2	1.08	2.58	58.2	11.2	13.5	47.0	44.7
HP3711c		45 m	47.5	0.96	2.54	62.2	15.7	17.9	46.4	44.3
HP3712a	ARC00_17 (site 79)	15 m	58.8	1.01	2.58	60.9	2.6	4.6	58.3	56.3
HP3712b		30 m	57.5	1.03	2.58	59.9	1.5	4.1	58.4	55.8
HP3712c		45 m	60.0	1.01	2.61	61.5	4.3	7.0	57.2	54.5
HP3713a	ARC00_26 (site 88)	15 m	40.3	1.12	2.54	56.0	13.3	16.1	42.7	39.9
HP3713b		30 m	44.3	1.13	2.62	57.1	10.0	12.1	47.1	45.0
HP3713c		45 m	36.5	1.28	2.57	50.1	3.8	6.1	46.2	44.0
HP3714a	ARC95_01 (site 1)	15 m	36.9	1.15	2.63	56.5	14.1	15.3	42.4	41.2
HP3714b		30 m	39.0	1.17	2.66	56.0	9.3	10.3	46.6	45.7
HP3714c		45 m	37.5	1.15	2.64	56.4	12.2	12.9	44.2	43.5
HP3715a	ARC97_02 (site 10)	15 m	41.5	0.97	2.57	62.2	22.3	26.0	39.9	36.2
HP3715b		30 m	52.9	0.86	2.52	65.7	18.4	22.3	47.2	43.4
HP3715c		45 m	47.7	0.86	2.53	66.0	19.7	24.9	46.3	41.1
HP3716a	ARC98_25 (site 37)	15 m	40.1	1.23	2.56	51.8	1.9	3.8	49.9	48.0
HP3716b		30 m	45.4	1.18	2.57	54.0	1.7	4.6	52.3	49.4
HP3716c		45 m	43.5	1.20	2.56	53.2	1.3	3.1	51.9	50.1

Analyst: DT

11.2 2008 Soil Chemistry data

Environmental Chemistry Laboratory Analytical Report

Landcare Research
Manaaki Whenua

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Palmerston North 4442

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Client: Bryan Stevenson, Landcare Research Ltd
Date Received: 22 August 2008

Job Number: LJ08044
Date Reported: 22 September 2008

Method details are available online at: http://www.landcareresearch.co.nz/services/laboratories/eclab/eclabtest_list.asp

Client ID	Sample No.	Water Content (method 104) (% dry wt)	pH (water) (method 106)	Total C (method 114) (%)	Total N (method 114) (%)	KCl-extractable NO3-N (method 118) (mg/kg)	KCl-extractable NH4-N (method 118) (mg/kg)	Anaerobic Mineralisable-N (method 120) (mg/kg)	Olsen P (method 124) (mg/kg)
ARC 95-01	M8/1631	34	6.41	2.03	0.19	34.7	50.5	13.2	181
ARC 97-02	M8/1632	44	6.88	4.39	0.35	7.2	0.4	25.8	44
ARC 98-02	M8/1633	49	6.31	5.73	0.49	29.2	1.4	108	150
ARC 98-08	M8/1634	54	5.97	4.74	0.31	0.9	27.3	82.1	86
ARC 98-25	M8/1635	44	7.20	5.22	0.36	15.3	0.4	71.6	44
ARC 99-04	M8/1636	108	6.51	15.4	1.21	28.9	0.9	139	52
ARC 00-03	M8/1637	52	6.81	5.79	0.47	12.8	0.4	72.2	61
ARC 00-05	M8/1638	42	6.68	4.84	0.41	18.2	1.5	115	42
ARC 00-06	M8/1639	56	6.09	7.55	0.65	28.6	0.8	135	29
ARC 00-08	M8/1640	43	7.02	5.05	0.45	12.9	0.4	90.9	21
ARC 00-09	M8/1641	94	6.41	20.0	0.82	4.1	1.5	62.6	27
ARC 00-17	M8/1642	63	6.20	4.63	0.32	3.2	0.4	102	15
ARC 00-18	M8/1643	50	5.57	5.33	0.45	22.6	1.3	105	19
ARC 00-19	M8/1644	61	6.11	4.98	0.39	21.1	1.7	150	15
ARC 00-20	M8/1645	57	5.89	5.45	0.48	16.5	1.2	126	37
ARC 00-24	M8/1646	47	6.19	4.34	0.33	1.0	21.1	81.1	115
ARC 00-25	M8/1647	43	6.29	3.85	0.26	0.0	17.7	71.9	79
ARC 00-26	M8/1648	40	5.97	3.12	0.18	2.6	1.0	24.5	57

Brian Daly, Senior Chemist

new zealand accredited laboratory

11.3 Archived Soil Chemical and Physical Data:

used to assess changes in soil quality of cropping and horticultural sites compiled from annual reports 1995–2001 for the 500 Soils Projects.

Site code	Soil pH	Total C Mg/m^3	Total N Mg/m^3	Min N $\mu g/cm^3$	Olsen P $\mu g/cm^3$	Bulk density Mg/m^3	Particle density Mg/m^3	Total porosity %v/v	Macro-Porosity @-5kPa %v/v
ARC 95-01	7.17	20.22	1.92	9	199.5	0.96	*2.6*	*63.18*	30.2
ARC 97-02	6.58	56.2	4.79	73	19.6	0.86	*2.46*	*65.04*	15.42
ARC 98-02	6.17	59.6	5.34	98.9	48.1	0.91	*2.31*	*60.7*	15.6
ARC 98-08	6.38	63.3	4.36	66.9	100.4	1.03	*2.41*	*57.2*	8.3
ARC 98-25	5.34	38.3	3.1	40.3	112.3	1	*2.49*	*59.7*	21.9
ARC 99-04	6.8	72.5	6.03	77	35.2	0.45	*2.03*	*77.8*	7.6
ARC 00-03	6.57	58.3	4.51	133	60.4	0.963	*2.52*	*61.8*	17.5
ARC 00-05	6.24	55.7	4.45	188	16.8	1.16	*2.56*	*54.6*	13.9
ARC 00-06	5.76	66.9	5.35	91	83.3	1.158	*2.55*	*55.9*	0.3
ARC 00-08	6.36	46.5	3.82	120	15.1	0.827	*2.45*	*66.2*	24.9
ARC 00-09	6.4	147.5	5.94	44	21.8	0.738	*1.86*	*62*	10.5
ARC 00-17	6.33	38.7	2.79	151	16.4	0.993	*2.58*	*61.5*	2.4
ARC 00-18	5.84	48	3.91	153	15.9	0.973	*2.51*	*61.2*	17.1
ARC 00-19	5.77	47.5	3.45	144	16.2	0.934	*2.48*	*62.3*	10.4
ARC 00-20	5.94	60.6	5.08	239	46.6	1.053	*2.49*	*57.8*	8.6
ARC 00-24	5.8	48.6	3.36	127	202.5	1.402	*2.52*	*44.8*	7.8
ARC 00-25	5.87	41.9	2.45	141	130.9	1.226	*2.53*	*51.6*	12.9
ARC 00-26	6.18	36.4	2.15	46	160	1.349	*2.57*	*47.5*	4.2

11.4 Site and Soil Profile Descriptions

Site: ARC 95-01

Soil series	Patumahoe clay loam
Classification	Allophanic Oxidic Granular
Land use	Market garden site: 30+ years market gardening, at sampling bare cultivate, fertilised
Vegetation	Bare
Slope	2°
Landform	footslope
Annual rainfall (mm)	1200 mm
Elevation (m)	100 m
Parent material	Hamilton ash formation
Drainage	Imperfectly drained

Description

Horizon	Depth	Description
Ap1	0–6 cm	7.5YR 3/2 silt loam; friable; strongly developed medium and coarse nut structure crushing under pressure to moderately developed fine crumb structure; few black Mn nodules up to 8 mm; abundant roots; many coarse pores; distinct irregular boundary
Ap2	6–15 cm	near 10YR 3/3 silt loam; moderately firm; brittle; weakly developed fine nut structure crushing under pressure to weakly developed crumb structure; few distinct inclusions of underlying B horizon; few fine hard black Mn concretions; few fine distinct 2.5YR 4/8 nodules (porcelinite); many roots; few coarse and medium pores; few very fine black charcoal fragments; diffuse wavy boundary
Ap3	15–26 cm	10YR 3/3 heavy silt loam; moderately firm; brittle; moderately developed coarse and medium granular structure; many roots; many large (to 4 cm) inclusions of B horizon; abundant coarse and medium pores (few up to 5mm); many black Mn concretions; distinct irregular boundary
Bt1	26–38 cm	7.5YR 4/6 crushing to 7.5YR 5/8 clay loam; moderately firm; brittle; few distinct fine inclusions of overlying horizons; many roots, few coarse and many medium pores; abundant continuous very thin cutans (skeletans) moderately developed fine block structure crushing to strongly developed coarse crumb structure; moderately sticky; non plastic; diffuse wavy boundary
Bt2	38–58 cm	7.5YR 4/6 crushing to 5 YR 5/8 clay loam; moderately weak; brittle; slightly sticky; non plastic; strongly developed coarse block structure crushing to strongly developed coarse and medium crumb structure; few roots; few fine distinct 5YR 4/4 hard mottles; few coarse pores; many thin discontinuous cutans (skeletans); diffuse wavy boundary
Bt3	58–82 cm	Between 7.5YR 5/6 and 5YR 5/6 crushing to near 5YR 5/8 clay loam; very weak; brittle; slightly sticky; slightly plastic; few coarse diffuse 5YR 4/6 soft mottles; few roots; few coarse and medium pores; many thin discontinuous cutans (skeletans); moderately developed fine block structure crushing to strongly developed coarse crumb structure; distinct wavy boundary.

Site: ARC 97-02

Soil series	Karaka
Classification	Typic Orthic Allophanic Soils
Land use	Market Garden
Vegetation	Cultivated (bare at sampling) ex onions
Slope	2° north east
Landform	Old marine terrace
Annual rainfall (mm)	1200 – 1400 mm
Elevation (m)	40 m
Parent material	Redeposited volcanic ash
Drainage	Moderately well drained

Description

Horizon	Depth	Description
App	0–17 cm	10YR 3/2 silty clay; very friable; peds very weak and brittle; earth; very fine polyhedral peds; few roots; distinct wavy boundry
Bw1	17–46 cm	10YR 4/6 silty clay; very friable;earth; very fine polyhedral peds; peds very weak and brittle; few roots; indistinct wavy boundry
Bw2	46-74 cm	7.5YR 5/8 clay
Bw3	74-90 cm	10YR 5/8
C(f)	90+ cm	10YR 5/6 clay; 5% very fine distinct 10YR 6/4 mottles

Site: ARC 98/2 Feijoa orchard on Karaka silt loam

Soil series	Karaka silt loam
Classification	Typic Orthic Allophanic Soil
Land use	Orchard
Vegetation	Feijoa and grasses
Slope	0 degrees
Landform	Planar terrace
Annual rainfall (mm)	1300
Elevation (m)	30
Parent material	Tephra
Drainage	Well drained

Description

Similar to ARC 1, but some yellowish red mottling below 62 cm related to less weathered parent material rather than a drainage restriction.

Description

Horizon	Depth	Description
Ah	0-20 cm	Dark brown (10YR 3/3) silt loam; slightly sticky, non plastic; very weak soil strength; friable; earthy; common fine and medium roots; distinct smooth boundary,
Bw	20 - 80 cm	Dark yellowish brown (10YR 4/4) silt loam; slightly sticky, slightly plastic; very weak soil strength; friable; weakly pedal; few fine roots; distinct wavy boundary,
BC	80 - 100 cm+	Light olive brown (2.5Y 5/4) clay loam; sticky, slightly plastic; moderately weak soil strength; brittle; weakly pedal; no live roots.

Site: ARC 98/8 Waitemate silt loam under orchard

Soil series	Waitemate silt loam
Classification	Weathered Fluvial Recent Soil
Land use	Orchard
Vegetation	Apple trees and grasses
Slope	Flat
Landform	River terrace
Annual rainfall (mm)	1400
Elevation (m)	20
Parent material	alluvium partly derived from tephra
Drainage	Well drained

Description

Horizon	Depth	Description
Ap	0-28 cm	Very dark grey (10YR 3/1) silt loam; slightly sticky, slightly plastic; moderately weak soil strength; friable failure; earthy; common fine roots; indistinct smooth boundary, moderate NaF reaction)
AB	28 - 70 cm	Dark yellowish brown (10YR 3/4) loam; slightly sticky, non plastic; moderately weak soil strength; friable failure; weakly pedal; few fine roots; distinct smooth boundary, (moderate NaF reaction)
BC	70 - 100 cm+	Brown (10YR 5/3) to light yellowish brown (2.5Y 6/4) loam; slightly sticky, non plastic; moderately weak soil strength; friable failure; massive; no live roots.

Site ARC98/25: Waitemata silt loam under market gardening

Soil series	Waitemata silt loam
Classification	Weathered Fluvial Recent Soil
Land use	Market garden since 1983/84 (15 yrs at sampling)compare with ARC98/22 which has been under market garden for 3 years
Vegetation	Fallow
Slope	Flat
Landform	River terrace
Annual rainfall (mm)	1400
Elevation (m)	30 m
Parent material	Alluvium
Drainage	Well drained

Description: similar to profiles ARC 98/22, but subsoil is light yellowish brown and there are fewer mottles in the subsoil.

Description (98/22)

Horizon	Depth	Description
Ap	0 - 30 cm	Very dark greyish brown (10YR 3/2) silt loam; slightly sticky, slightly plastic; very weak soil strength; very friable failure; earthy; few fine roots; distinct smooth boundary,
Bwf1	30 - 35 cm	Strong brown (7.5YR 4/6) sandy loam; with common medium distinct strong brown mottles; slightly sticky, non plastic; moderately weak soil strength; brittle failure; massive; no live roots; distinct smooth boundary,
Bwf2	35 - 55 cm	Light yellowish brown (2.5Y 6/4) sandy loam; with few fine distinct strong brown mottles; non sticky, non plastic; moderately weak soil strength; friable failure; massive; no live roots; indistinct wavy boundary,
Bg1	55 - 67 cm	Light brownish grey (2.5Y 6/2) loamy sand; no mottles; moderately weak soil strength; friable failure; massive; no live roots; distinct smooth boundary,
Bg2	67 - 100 cm	Light brownish grey (2.5Y 6/2) sandy clay with common medium distinct yellowish brown mottles; sticky, plastic; moderately firm soil strength; deformable failure; massive; no live roots (low permeable layer)

Site: ARC 99/4

Soil series	Ardmore peaty loam
Classification	Mellow Humic Organic Soil
Landuse	Kiwi fruit (irrigated)
Vegetation	Kiwi fruit with grass strips
Slope	0°
Landform	Flat basin
Annual rainfall (mm)	1300
Elevation (m)	20
Parent material	Thin alluvium overlying peat
Drainage	Imperfectly drained

Description

Horizon	Depth	Description
Ap	0–13 cm	Dark brown (7.5YR 3/2) peaty loam; slightly sticky; non-plastic; very weak soil strength; friable failure; earthy; many fine and medium roots; indistinct wavy boundary,
BC	13–25 cm	Dark brown (7.5YR 3/2) and 10% light brownish grey (2.5Y 6/2) peaty loam; slightly sticky; non-plastic; very weak soil strength; friable failure; common fine roots; sharp wavy boundary,
2Cg	25–28 cm	Light brownish grey (2.5Y 6/2) sand; with many medium distinct yellowish brown (10YR 5/8) mottles; non-sticky; non-plastic; moderaely weak soil strength; massive; few very fine roots; sharp smooth boundary, (Probably Taupo Pumice)
2Ch	28–32 cm	Black (5YR 2.5/1) loamy sand; no mottles; non-sticky; non-plastic; moderately weak soil strength; friable failure; massive; few very fine roots; distinct irregular boundary,
3bA	32–66 cm	Very dark brown (10YR 2/2) decomposed peat; non-sticky; non-plastic; very weak soil strength; friable failure; massive; no live roots; indistinct wavy boundary,
3Oh	66–100 cm+	Black (5YR 2.5/1) decomposed peat; non-sticky; non-plastic; very weak soil strength; friable failure; massive; no live roots.

Site: ARC00_ 3

Soil Type	Karaka silt loam
Classification	Typic Orthic Allophanic Soil
Land use	Persimmon orchard
Date sampled	20/11/00
Land-use history	Has been in persimmons for 10 yrs, conventional fertiliser regime, irrigated
Present vegetation	Persimmons, mowed grasses
Slope	Flat
Landform	Terrace
Annual rain (mm)	1300
Elevation (m)	17
Parent material	Tephra (andesitic)
Drainage	Moderately well drained
Topsoil depth (cm)	32
Total rooting depth (cm)	About 90
Limiting horizon	Heavy subsoil textures and imperfect drainage at lower depth

Description

Horizon	Depth (cm)	Description
Ap	0–32	Very dark grey (10YR 3/1) clay loam; sticky; plastic; weak soil strength; friable failure; earthy; common fine and medium roots and many at the base of the horizon; indistinct smooth boundary; no NaF reaction.
Bw	32–58	Brown (7.5YR 4/4) and 20% very dark grey (10YR 3/1) clay; sticky; plastic; slightly firm soil strength; semi-deformable soil failure; weakly pedal; few fine and very fine roots; indistinct smooth boundary; weak NaF reaction.
Bw(f)1	58–90	Light olive brown (2.5Y 5/4) clay with common medium distinct strong brown (7.5YR 5/8) mottles; sticky; plastic; firm soil strength; deformable failure; massive; no live roots; indistinct wavy boundary.
Bw(f)2	90–120+	Light yellowish brown (2.5Y 6/4) clay with many medium and coarse prominent strong brown (7.5YR 5/8) mottles; sticky; plastic; firm soil strength; deformable failure; massive; no live roots.

Site: ARC00_ 5

Soil Type	Matakawau sandy clay loam
Classification	Typic Orthic Allophanic Soil
Land use	Citrus orchard
Date sampled	20/11/00
Land-use history	Fertilised, super plus lime
Present vegetation	Citrus, mowed grass and weeds, shelterbelts
Slope	2 °
Landform	Planar shoulder in rolling land
Annual rain (mm)	1250
Elevation (m)	24
Parent material	Sandstone
Drainage	Well drained
Topsoil depth (cm)	19
Total rooting depth (cm)	55

Description: Similar to that of Site ARC00_ 4, but somewhat more clay, especially in the topsoil

Description (ARC00_4)

Horizon	Depth (cm)	Description
Ap	0–20	Dark brown (7.5YR 3/2) sandy loam; non-sticky; non-plastic; weak soil strength; friable failure; earthy; many fine and very fine roots; indistinct smooth boundary; moderate NaF reaction.
Bw1	20–62	Dark yellowish brown (10YR 4/6) clay loam; sticky; slightly plastic; slightly firm soil strength; semi-deformable failure; weakly pedal; common fine and very fine roots; diffuse wavy boundary; moderate NaF reaction.
Bw2	62–80	Strong brown (7.5YR 4/6) sandy clay loam; sticky; slightly plastic; firm soil strength; semi-deformable failure; weakly pedal; few fine and very fine roots; indistinct smooth boundary; no NaF reaction.
2Bw3	80–120+	Yellowish brown (10YR 5/6) coarse sandy clay loam; slightly sticky; slightly plastic; firm soil strength; brittle failure; massive; no live roots.

Site: ARC00_ 6

Soil Type	Matakawau sandy loam
Classification	Typic Orthic Allophanic Soil
Land use	Market gardening
Date sampled	20/11/00
Land-use history	Has been in potatoes for 4 years, not used this year.Probably in dairying before present land use. Land-use change imminent.
Present vegetation	Weeds
Slope	0°
Landform	Flat part of rolling terrace
Annual rain (mm)	1250
Elevation (m)	119
Parent material	Sandstone with a veneer of tephra
Drainage	Well drained
Topsoil depth (cm)	19
Total rooting depth (cm)	120+

Description

Horizon	Depth (cm)	Description
Ap	0–19	Dark brown (10YR 3/3) sandy loam; slightly sticky; non-plastic; weak soil strength; friable failure; earthy; common fine and very fine roots; distinct smooth boundary; strong NaF reaction.
Bw1	19–58	Brown (7.5YR 4/4) sandy loam; slightly sticky; non-plastic; weak soil strength; friable failure; weakly pedal; few fine and very fine roots; distinct smooth boundary; strong NaF reaction.
2Bw2	58–120+	Dark yellowish brown (10YR 4/6) clay loam; sticky; slightly plastic; slightly firm soil strength; friable failure; weakly pedal; no roots; strong NaF reaction.

Site: ARC00_ 8

Soil Type	Patumahoe silt loam
Classification	Typic Orthic Granular Soil
Land use	Market gardening
Date sampled	21/11/00
Land-use history	Has been a market garden patch for 4 years, irrigated
Present vegetation	Cabbage, garlic, lettuce
Slope	1 to 2°
Landform	Convex midslope of rolling country
Annual rain (mm)	1300
Elevation (m)	69
Parent material	Strongly weathered tephra
Drainage	Well drained
Topsoil depth (cm)	26
Total rooting depth (cm)	120+

Description: see profile of ARC00_ 7

Description (ARC00_ 7)

Horizon	Depth (cm)	Description
Ap	0-18	Dark brown (10YR 3/3) silt loam; slightly sticky; slightly plastic; weak soil strength; friable failure; moderately pedal; many fine and very fine roots; distinct smooth boundary; weak NaF reaction.
Bw1	18–48	Brown (7.5YR 4/4) silt loam; slightly sticky; slightly plastic; slightly firm soil strength; friable failure; moderately pedal; common distinct strong brown (7.5YR 4/6) clay skins on peds; common fine and very fine roots; distinct smooth boundary; moderate NaF reaction.
Bw2	48–65	Brown (7.5YR 4/4) clay; sticky; slightly plastic; firm soil strength; deformable failure; moderately pedal; few fine and very fine roots; indistinct smooth boundary.
Bw3	65–120+	Brown (7.5YR 4/4) clay; sticky; plastic; very firm soil strength; deformable failure; massive; few very fine roots.

Site: ARC00_ 9

Soil Type	Ardmore humic loam
Classification	Mellow Humic Organic Soil
Land use	Tree nursery
Date sampled	21/11/00
Land-use history	Has been a tree nursery for 40 years, the sampled part has not been worked for at least a year, no fertiliser in past 2 years.
Present vegetation	Young trees
Slope	0°
Landform	Flat basin
Annual rain (mm)	1300
Elevation (m)	119
Parent material	Sandstone with a veneer of tephra
Drainage	Well drained
Topsoil depth (cm)	19
Total rooting depth (cm)	120+

Description

Horizon	Depth (cm)	Description
Ap	0–45	Very dark brown (10YR 2/2) humic loam; slightly sticky; non– plastic; very weak soil strength; friale failure; earthy; common fine and very fine roots; distinct smooth boundary.
Oh	45–100	Black (10YR 2/1) loamy peat; slightly sticky; plastic; weak soil strength; massive; no roots; indistinct wavy boundary.
Om	100–120+	Black (10YR 2/1) fibrous peat with 10% brown (7.5YR 4/4) loam (tephra); non-sticky; non-plastic; soft; very weak soil strength; very friable failure; massive.

Site: ARC00_ 17

Soil Type	Warkworth clay loam
Classification	Typic Yellow Ultic Soil
Land use	Organic cropping
Date sampled	23/11/00
Land-use history	In garlic for 3 years, maize straw cover, applications of fish manure
Present vegetation	Mature garlic
Slope	2°, concavo-convex midslope
Landform	Moderately dissected hill country
Annual rain (mm)	1400
Elevation (m)	85
Parent material	Fine strongly weathered sandstone
Drainage	Well drained
Topsoil depth (cm)	18
Total rooting depth (cm)	120+

Description: see profile ARC00_ 16 on the same property, topsoil was olive (5Y 4/3) under maize mulch.

Description (ARC00_16)

Horizon	Depth	Description
Ap	0–18	Dark brown (10YR 3/3) clay loam; sticky; slightly plastic; weak soil strength; friable failure; moderately pedal; common fine and very fine roots; distinct smooth boundary.
Bt	18–32	Dark yellowish brown (10YR 4/4) clay; sticky; plastic; slightly firm soil strength; friable failure; common distinct dark yellowish brown (10YR 3/4) clay coatings on peds; few fine and very fine roots; distinct wavy boundary.
Bw	32–120+	Yellowish brown (10YR 5/6) clay; few medium faint yellowish red (5YR 5/8) mottles; sticky; plastic; slightly firm soil strength; deformable failure; moderately pedal; few fine and very fine roots.

Site: ARC00_ 18

Soil Type	Warkworth clay loam
Local contact person	Heron's Flight Vineyard, 49 Sharp Road, Matakana, RD Warkworth, ph 4227915
Classification	Typic Yellow Ultic Soil
Land use	Merlot 1989 grapes
Date sampled	23/11/00
Land-use history	Planted 1989, conventionally fertilised for the first 3 or 4 years, but none since. Chicory is grown under the vines for weed suppression and as a green manure
Present vegetation	Grapes with strips of grasses and clover
Slope	3°, planar midslope
Landform	Rolling country
Annual rain (mm)	1400
Elevation (m)	43
Parent material	Fine strongly weathered sandstone
Drainage	Well drained
Topsoil depth (cm)	14
Total rooting depth (cm)	120+

Description

Horizon	Depth	Description
Ap	0–14	Very dark grey (10YR 3/1) clay loam; sticky; slightly plastic; weak soil strength; friable failure; earthy; abundant fine, very fine and medium roots; distinct smooth boundary.
Bt1	14–58	Light olive brown (2.5Y 5/4) clay; few fine faint strong brown (7.5YR 5/6) mottles; sticky; plastic; firm soil strength; deformable failure; common distinct very dark grey (10YR 3/1) clay and organic coatings on peds; moderately pedal; few fine and medium roots; indistinct smooth boundary.
Bt2	58–100+	Light olive brown (2.5Y 5/4) clay; many medium distinct strong brown (7.5YR 5/6) mottles; sticky; plastic; very firm soil strength; deformable failure; common distinct very dark grey (10YR 3/1) clay coatings on peds; moderately pedal; few fine roots.

Site: ARC00_ 19

Soil Type	Warkworth clay loam
Classification	Typic Yellow Ultic Soil
Land use	Organic orchard
Date sampled	23/11/00
Land-use history	Small orchard block, has been organic for 15 years, fertilised with fruit mulch, compost and manure from free-range poultry
Present vegetation	Mixed orchard: pip fruit; banana's, figs, babaco
Slope	1°, planar midslope
Landform	Rolling country
Annual rain (mm)	1400
Elevation (m)	30
Parent material	Sandstone
Drainage	Imperfectly drained
Topsoil depth (cm)	20
Total rooting depth (cm)	80

Description

Horizon	Depth (cm)	Description
A	0–20	Dark brown (10YR 3/3) clay loam; sticky; slightly plastic; weak soil strength; friable failure; earthy; common medium, fine and very fine roots; distinct smooth boundary.
Bw	20–42	Light olive brown (2.5Y 5/4) clay; sticky; plastic; slightly firm soil strength; friable failure; moderately pedal; common faint olive brown (2.5Y 4/4) clay coatings on peds; few medium, fine and very fine roots; indistinct smooth boundary.
Bg1	42–60	Light yellowish brown (2.5Y 6/4) clay; many medium distinct strong brown (7.5YR 5/6) mottles; sticky; plastic; slightly firm soil strength; deformable failure; moderately pedal; few fine and very fine roots; distinct wavy boundary.
Bg2	60–80	Light brownish grey (2.5Y 6/2) clay; many medium prominent strong brown (7.5YR 5/6) mottles; sticky; plastic; slightly firm soil strength; deformable failure; massive; few fine and medium roots; distinct smooth boundary.
Bg3	80–120+	Light grey (2.5YR 7/2) clay; many medium prominent strong brown (7.5YR 5/6) mottles; sticky; plastic; firm soil strength; deformable failure; massive; no roots.

Site: ARC00_ 20

Soil complex	Waitemata complex
Classification	Mottled Orthic Brown Soil
Land use	Citrus-feijoa orchard
Date sampled	27/11/00
Land-use history	Orchard block, has been organic for 30 years, fertilised with grass clippings, fruit mulch, and blood and bone
Present vegetation	Citrus, feijoa, grasses, white clover, flat weeds
Slope	1°, planar midslope
Landform	Terrace
Annual rain (mm)	1600
Elevation (m)	54
Parent material	Alluvium and colluvium
Drainage	Poorly drained
Topsoil depth (cm)	16
Total rooting depth (cm)	80

Description

Horizon	Depth	Description
Ap	0–16	Very dark greyish brown (10YR 3/2) clay loam; sticky; slightly plastic; weak soil strength; friable failure; earthy; abundant fine and very fine roots; distinct smooth boundary.
Bg1	16–32	Light olive brown (2.5Y 5/4) clay; common fine and medium distinct dark yellowish brown and yellowish brown (10YR 4/6 and 5/6) mottles; sticky; plastic; slightly firm soil strength; friable failure; weakly pedal; common fine and very fine roots; indistinct smooth boundary.
Bg2	32–80	Olive (5Y 5/4) clay; common medium distinct yellowish brown (10YR 5/6) mottles; sticky; plastic; firm soil strength; deformable failure; weakly pedal; few fine and very fine roots; indistinct smooth boundary.
Bg3	80–120+	Olive (5Y 5/4) clay; common medium distinct yellowish brown (10YR 5/6) and light brownish grey (2.5Y 6/2) mottles; very sticky; very plastic; firm soil strength; deformable failure; massive; no roots.

Site: ARC00_ 24

Soil complex	Waitemata complex
Transect length and direction °	40 m, W 260°
Local contact person	A & J Zaknic & Sons, Kumeu, ph 4128020
Classification	Typic Orthic Gley Soil
Land use	Vineyard
Date sampled	29/11/00
Land-use history	Conventional fertiliser with heavy applications, orchard has been producing for over 40 years, replanted about 10 years ago
Present vegetation	Vines, mown grasses, white clover, flat weeds
Slope	0°, planar midslope
Landform	Terrace
Annual rain (mm)	1400
Elevation (m)	42
Parent material	Alluvium
Drainage	Poorly drained
Topsoil depth (cm)	27
Total rooting depth (cm)	60

Description

Horizon	Depth (cm)	Description
Ap	0–27	Very dark grey (10YR 3/1) silt loam; slightly sticky; non-plastic; weak soil strength; friable failure; earthy; common fine and medium roots; distinct smooth boundary.
Bg1	27–60	Olive brown (2.5Y 4/4) clay; many fine and medium distinct yellowish brown (10YR 5/6) and light grey (2.5Y 7/2) mottles; sticky; plastic; firm soil strength; semi-deformable failure; weakly pedal; few very fine roots; indistinct smooth boundary.
Bg2	60–120+	Light brownish grey (2.5Y 6/2) clay; many fine and medium prominent yellowish brown (10YR 5/6) and yellowish red (5YR 5/6) mottles; sticky; plastic; firm soil strength; deformable failure; massive; no roots.

Site: ARC00_ 25

Soil complex	Waitemata complex
Classification	Typic Orthic Gley Soil
Land use	Apple orchard
Date sampled	29/11/00
Land-use history	Conventional fertiliser with heavy applications, orchard has been producing for over 40 years, replanted about 6 years ago
Present vegetation	Apple trees, grasses, white clover, weeds
Slope	0°, planar midslope
Landform	Terrace
Annual rain (mm)	1400
Elevation (m)	42
Parent material	Alluvium
Drainage	Poorly drained
Topsoil depth (cm)	30
Total rooting depth (cm)	120

Description: see profile ARC00_ 24

Site; ARC00_ 26

Soil complex	Waitemata complex
Classification	Typic Orthic Gley Soil
Land use	Strawberries cultivated on 40 to 50 cm beds.
Date sampled	29/11/00
Land-use history	Conventional fertiliser with heavy applications
Present vegetation	Strawberries.
Slope	0°, planar midslope
Landform	Terrace
Annual rain (mm)	1400
Elevation (m)	42
Parent material	Alluvium
Drainage	Poorly drained
Topsoil depth (cm)	30
Total rooting depth (cm)	41

Description: Similar soil to ARC00_ 24 and 25, but because of frequent cultivation, mixing with the clay subsoil has occurred.