Auckland
Regional Council
TE RAUHĪTANGA TAIAO

An Overview of Soil Quality in the Auckland Region Using Data from the 500 Soils Project 1995-2001

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An overview of soil quality in the Auckland Region using data from the 500 Soils Project 1995-2001

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Contents

1 Executive Summary

1.1 Project and Client

Auckland Regional Council participated in two national soil quality monitoring initiatives 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, and then applied them to a range of sites, soils, and land uses in the Auckland region. Annual reports were provided to the Council and MFE (e.g., Sparling et al, 1998) and scientific summary reports of the national project are available (see for example, Sparling & Schipper, 2004). At the end of the SMF projects, 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 soil quality monitoring, and no overview specific to the Auckland region was completed. Other Regions (e.g., Greater Wellington, Taranaki, Bay of Plenty and Waikato) continued with annual monitoring, and have used such regional overviews for their environmental reporting. This report combines all the data collected by the 500 Soils Project relevant to the Auckland region during the period of participation in the soil quality projects 1995–2001.

1.2 Objectives

- For the Auckland region, combine soil quality monitoring data, derived from the 500 Soils Project (1995–2001) annual reports, sort into five major land use categories: dairy pasture, sheep-beef pasture, horticulture, forestry, and indigenous vegetation.
- 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.
- Calculate the proportion of each land use category meeting soil quality targets.
- Provide comment on soil quality in the Auckland region in comparison to other regions of New Zealand undertaking similar soil quality monitoring.
- Assess the findings of the programme to date and consider whether the programme objectives are being met and whether the location and number of sampling sites are appropriate (statistical robustness) for the monitoring programme
- Provide an overview of the proportion of total land area in the Auckland that was "satisfactory" or "of concern" for soil quality status.

1.3 Methods

- Soil quality monitoring data from the 500 Soils Project for the Auckland region were combined and sorted into five major land use categories: dairy pasture, sheep-beef pasture, horticulture, forestry, and indigenous vegetation.
- Seven key soil quality indicators , soil pH, total C, total N, mineralisable N, Olsen P, bulk density, and macroporosity (calculated using -5 kPa volumetric water content) 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 7 indicators, were calculated.
- For each land use, the area of land likely to be "satisfactory" or "of concern" was calculated. From these data, an overall regional "score" was calculated.

1.4 Results

- Data from a total of 88 sites were analysed, comprising 21 dairy pasture, 18 sheep-beef pasture, 20 horticulture, 9 forestry, and 20 indigenous vegetation sites.
- Over all land uses, and expressed on an area basis, approximately one–third (38%) of the sites met all the soil quality targets, 62% had one or more indicators outside the target range.
- Proportions of sites in the "satisfactory" category were greatest for indigenous vegetation (60%), followed by plantation forests (44%), drystock (28%), horticulture (20%) and least for dairy (19%).
- Main sources of soil quality concern were the compaction (low macroporosity) under pastoral and cropping land uses, and high fertility (Olsen P) under cropping and horticulture.

1.5 Conclusions

- The data from the 500 Soils Project, assessed by 7 key indicators for five major land use categories, suggested that, on an area basis, about one third (38%) of the monitored area met all the suggested soil quality targets.
- Indigenous forests and reserves had the highest proportion of sites (60%) meeting the suggested targets, and dairy pastures the lowest (19%).
- Sheep-beef farms (drystock) had the greatest area extent with sites of concern, because of the large area of land under that land use.

- The main soil quality indicators of concern were widespread soil compaction (low macroporosity) and high fertility levels under many market garden and pastoral farms.
- Overall the soil quality ranking for the Auckland region was similar to that of the Waikato, and issues regarding compaction and fertility were the same.

1.6 Recommendations

- Auckland Regional Council uses the summary of soil quality in the region for public information on soil quality, and to improve awareness and education among stakeholders.
- Auckland Regional Council recommence regular soil quality monitoring to show change in the current sites and to expand the range of sites especially on sheep-beef farms as this land use category is under represented in the current data set.

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". Protocols for monitoring land and soils were established by two 3-year Sustainable Management Fund Projects (1995–1997, 1998–2001), commonly known as the 500 Soils Project (Hill et al. 2003; Sparling et al. 2004). An interpretive framework for reporting at a regional scale was developed (Lilburne et al. 2004).

3 Objectives

- For the Auckland region, combine soil quality monitoring data derived from the 500 Soils Project annual reports (1995–2001), sort into five major land use categories: dairy pasture, sheep-beef pastures, crops and horticulture, forestry, and indigenous vegetation.
- 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.
- Calculate the proportion of each land use category meeting soil quality targets.
- Provide comment on soil quality in the Auckland region in comparison to other regions of New Zealand undertaking similar soil quality monitoring.
- Assess the findings of the programme to date and consider whether the programme objectives are being met and whether the location and number of sampling sites are appropriate (statistical robustness) for the monitoring programme.
- Provide an overview of the proportion of total land area in the Auckland region that was "satisfactory" or "of concern" for soil quality status.

4 Methods

Soil quality monitoring data from published Landcare Research contract reports to Auckland Regional Council and the Ministry for the Environment 1995–2001, were combined and sorted into 5 major land use categories: dairy pasture, sheep-beef pastures, crops and horticulture, forestry, and indigenous vegetation.

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. 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.

Data were grouped by land use category. For each land use category, the proportion of sites meeting or not meeting soil quality targets was calculated using the formula:

$$P = C / N \times 100,$$

where P is the proportion of sites not meeting targets, C is the count of sites exceeding the target range on one or more indicators, and N is the total number of sites sampled for that land use.

The proportion of the Auckland region under the five land use categories (dairy pasture, sheep-beef pasture, horticulture and cropping, plantation forests, and indigenous vegetation) was supplied by Auckland Regional Council. The proportion area of concern can then be calculated by multiplying by P derived as above:

$$Ac = P \times At,$$

where Ac is the area of concern, P is the proportion of sites of concern, and At is the total area. The calculation was completed for each land use individually, and also using all land uses combined to obtain a figure for the whole region.

To provide further detail for sites "of concern" for each land use, the proportion of sites not meeting the target ranges suggested for each of the 7 indicators were calculated:

$$Pi = Ic / Ni \times 100,$$

where Pi is the proportion of sites not meeting the target for that particular indicator, Ic is the count of sites exceeding the target range, and Ni is the total number of sites sampled for that indicator.

The findings are displayed as a series of figures in the text of the report. Numeric data are provided in the Appendix.

5 Results

5.1 Dairy pasture

Pastoral farming of dairy cattle occupied 63 811 ha comprising 12.7% of the regional land area. Twenty–one sites under dairy farming had been sampled. Of these, 4 (19%) met all suggested targets for the 7 indicators, 33% did not meet the suggested target range for one indicator and 38% did not meet it for two (Fig. 1). The main reason for sites not meeting soil quality target values was low macroporosity, which occurred on over 50% of the dairy pastures sampled (Fig. 2)

Figure 1
Proportion of dairy pasture sites meeting suggested soil quality targets

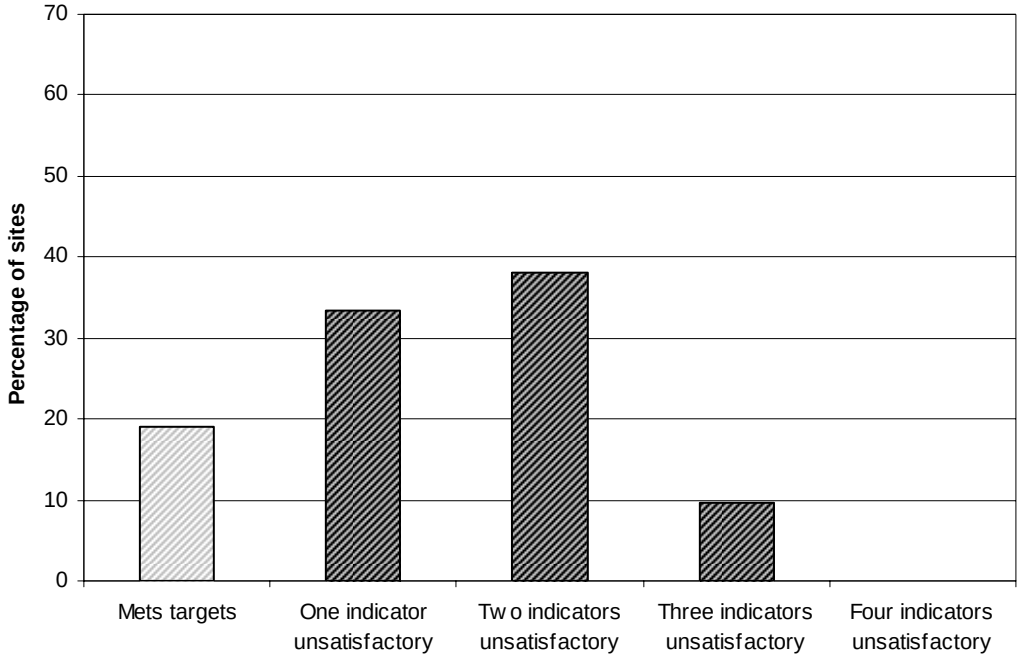
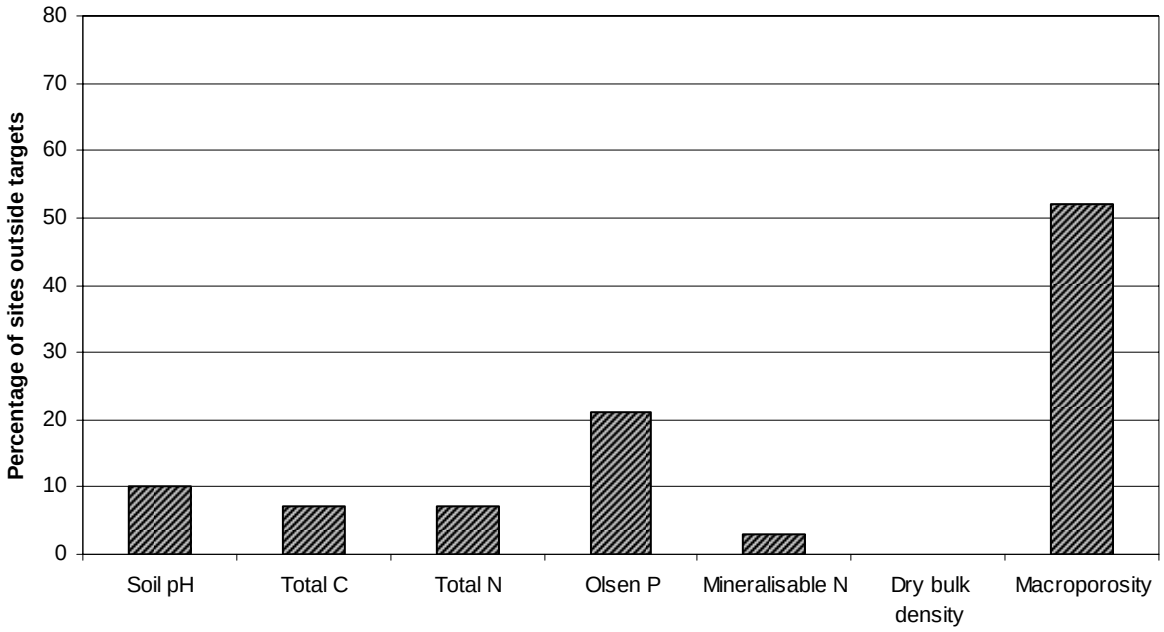


Figure 2
Soil quality concerns for dairy pasture sites



5.2 Sheep-beef pasture

The sheep-beef land use category was the most extensive in the region, comprising 185 257 ha, and 36.9% of the regional area. Eighteen sites had been sampled. Of these, five (28%) met all the suggested targets, 50% did not meet the target for one indicator, and 16.7% did not meet the target for two, while one sites (6%) did not meet the suggested target for three of the 7 indicators (Fig. 3). There were two main indicators of concern. One was low macroporosity, indicating soil compaction. The other concern was Olsen P, but in that case the fertility was well below the recommended level for drystock pasture, and there is a risk the soils were becoming depleted in available P (Fig. 4). (see Appendix 10.1 for numeric data).

Figure 3
Proportion of sheep-beef (drystock) pasture sites meeting suggested soil quality targets

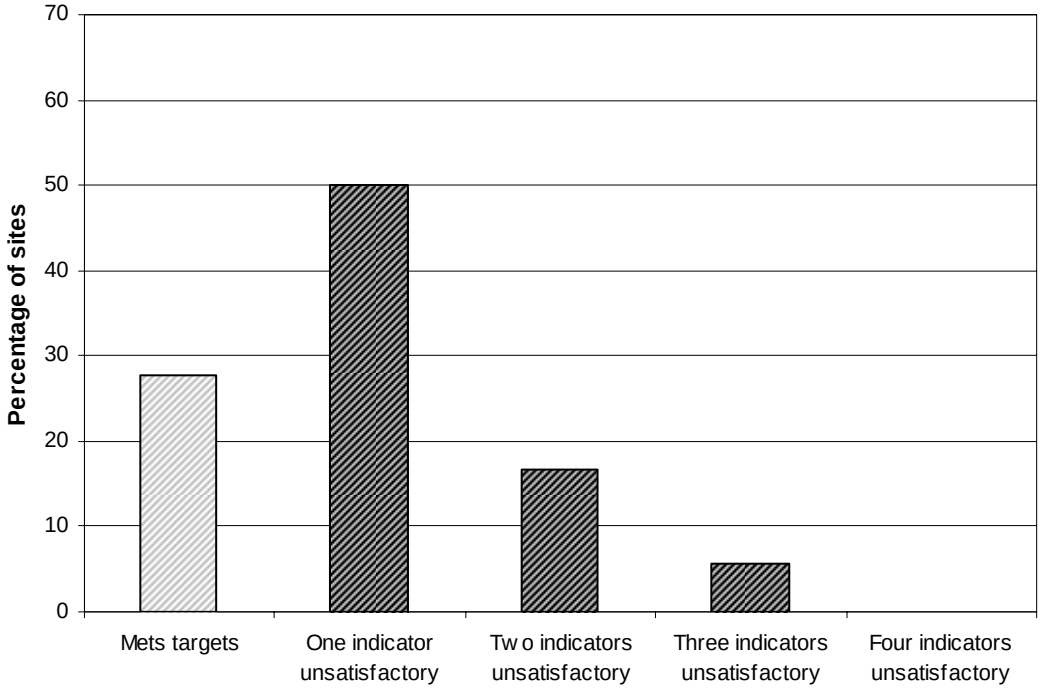
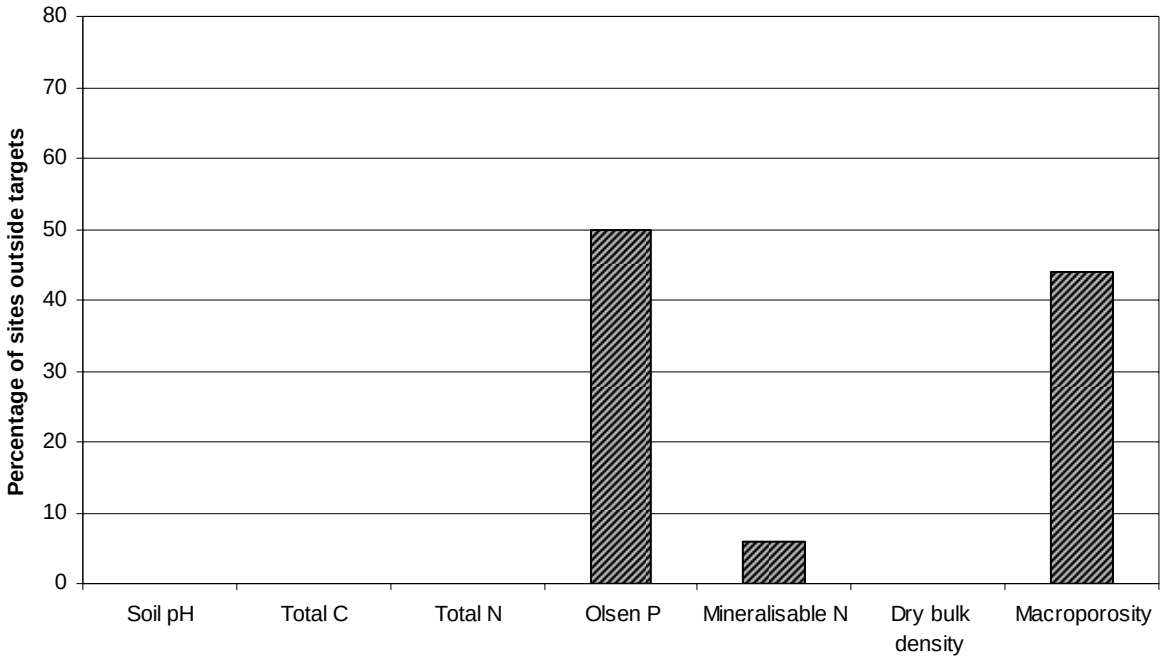


Figure 4
Soil quality concerns for sheep-beef (drystock) pastures



5.3 Horticulture

Horticulture occupies only a small proportion (1.8%, 9281 ha) of the regional land use. However, data were available for a comparatively large number (20) of sites. Of the 20 sites, 4 (20%) met the suggested targets, more than half (55%) failed to meet the target for one indicator and 15% did not meet the targets for two indicators, 2 sites did not meet the target for three or more indicators (Fig. 5). The main cause of concern was low macroporosity and variable Olsen P contents. For the latter, the P contents were sometimes excessively high (>200 μgP/cm^3) while on other sites the contents were surprisingly low (<15 μgP/cm^3) for this land use.

Figure 5
Proportion of horticulture sites meeting suggested soil quality targets

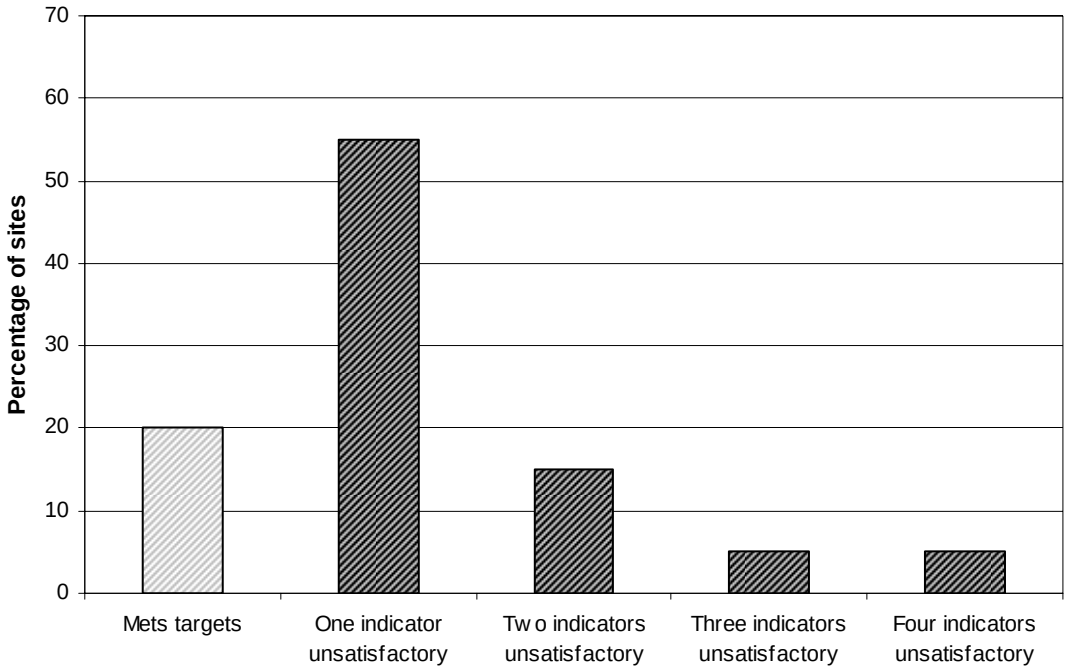
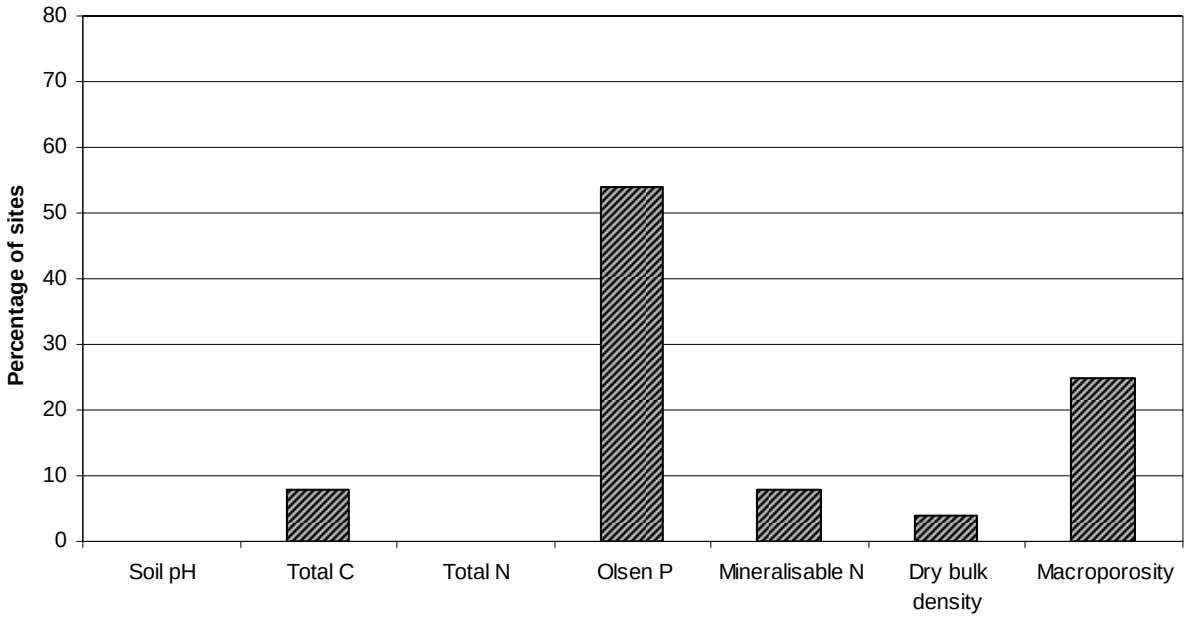


Figure 6
Soil quality concerns for horticulture sites



5.4 Forestry

Plantation forests only occupy a moderate amount of the regions land, amounting to 54 371ha, or 10.8% of the regional land area. Only 9 sites had been sampled and thus may not be representative of the whole region. Four of the sites (44%) met the suggested soil quality targets, and three soils (33%) met all but one indicator target (Fig. 7). Two sites did not meet the target for four or more indicators. The main source of concern was high macroporosity (Fig. 8). This suggests the soils were non-coherent with poor crumb structure, and depending on topography could be susceptible to erosion. However, the forestry plantations were often on very young and poorly developed soils (such as sand dunes), and caution is needed when interpreting such findings. Forestry may be a very helpful means to stabilise such soils.

Figure 7
Proportion of forestry sites meeting suggested soil quality targets

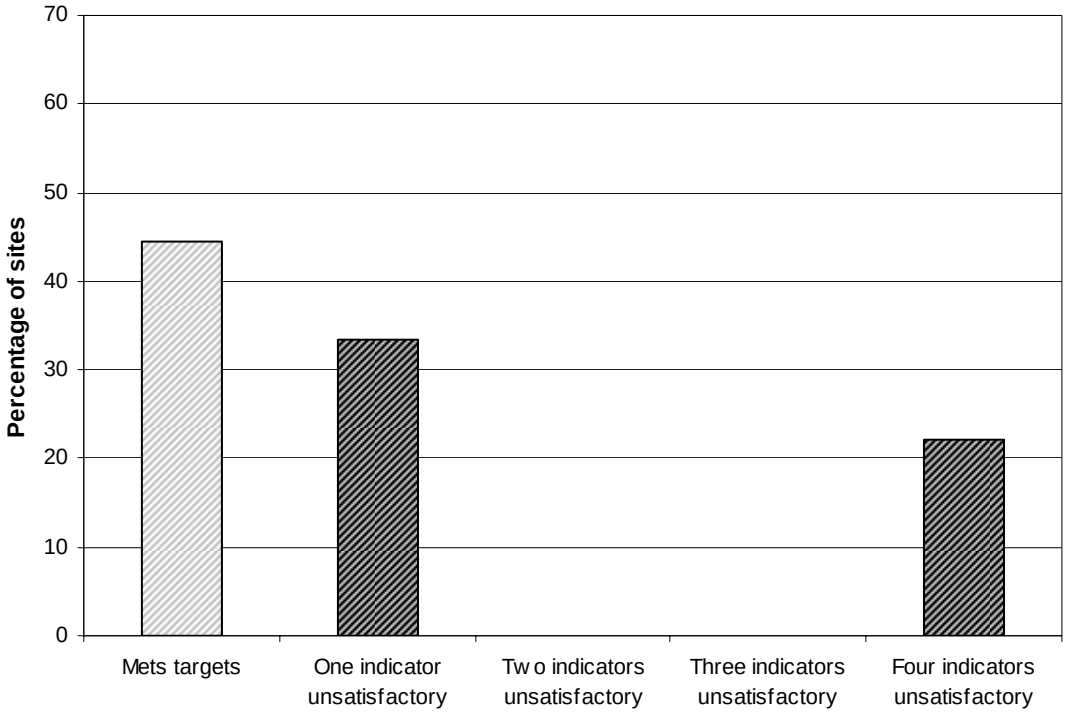
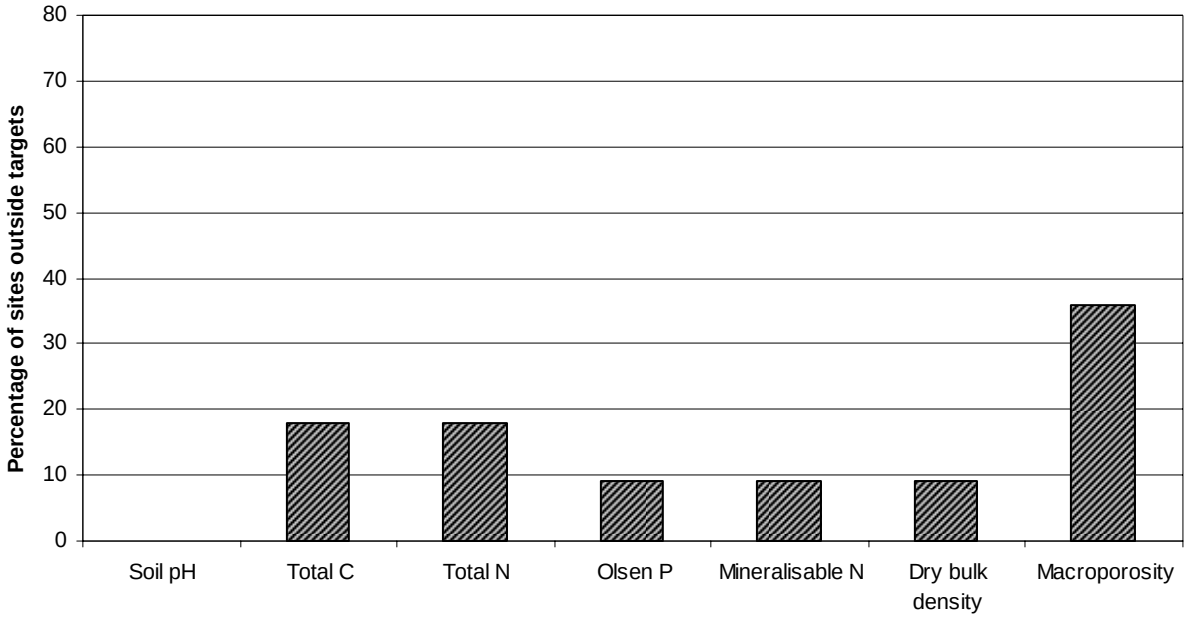


Figure 8
Soil quality concerns for forestry sites



5.5 Indigenous vegetation

Indigenous vegetation comprises 27.0%, 135 856 ha of the regional land area. Data were available for 20 sites. The sites were generally in good condition, with 60% (12 of the 20 sites) meeting the suggested targets for that land use. Eight sites did not meet the target criteria for one indicator (Fig. 9). The main concerns appeared to be macroporosity (both high and low) and unusually high pH on a few sites (Fig. 10). The latter can indicate some influence from adjacent farming activity, where agrichemicals, such as lime, also find their way into the forests and reserve. Target ranges for indigenous vegetation are poorly defined, and based largely on requirements for plantation forestry trees. Consequently, these findings should be accepted with caution until better evidence of the soil quality requirements of native forest trees is established.

Figure 9
Proportion of indigenous vegetation sites meeting suggested soil quality targets

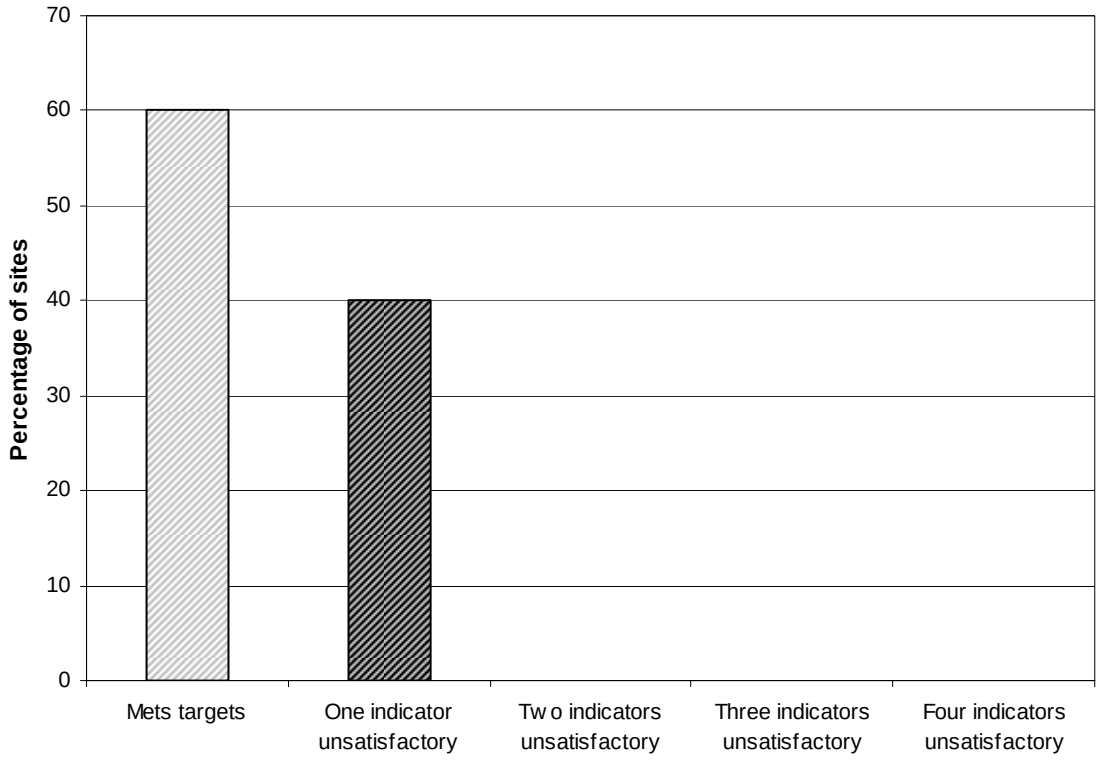
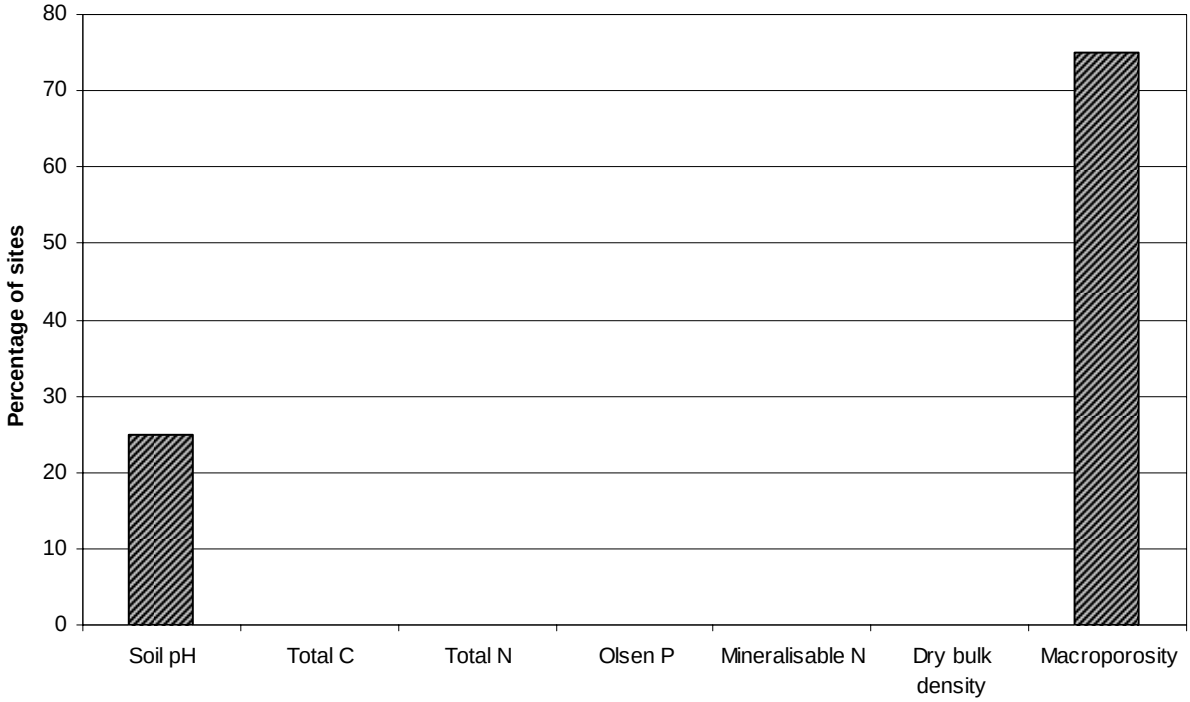


Figure 10
Soil quality concerns for indigenous vegetation sites



5.6 Overall soil quality in the Auckland Region (all land uses)

The overall soil quality for the region was calculated in two ways: (1) by the total number of **sites** where all indicators met the specified target range (Fig. 11), and (2) by the proportion of all **indicators** that met the target range (Fig. 12) (section 5.8). Because the site selection is biased, this has been corrected and expressed on an area basis (section 5.7)

A total of 88 sites were sampled, but this sample is biased towards the more intensive land uses. For example the horticulture land use category forms 23% of sites in the data set but comprises only 1.8% of the regional land area (see Table 1).

Figure 11
Proportion of all monitored sites and land uses meeting suggested soil quality targets

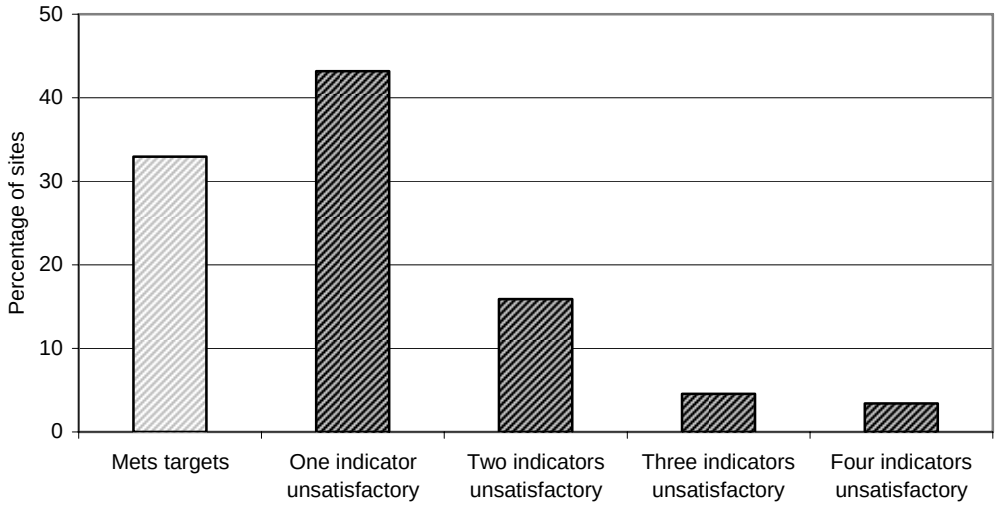
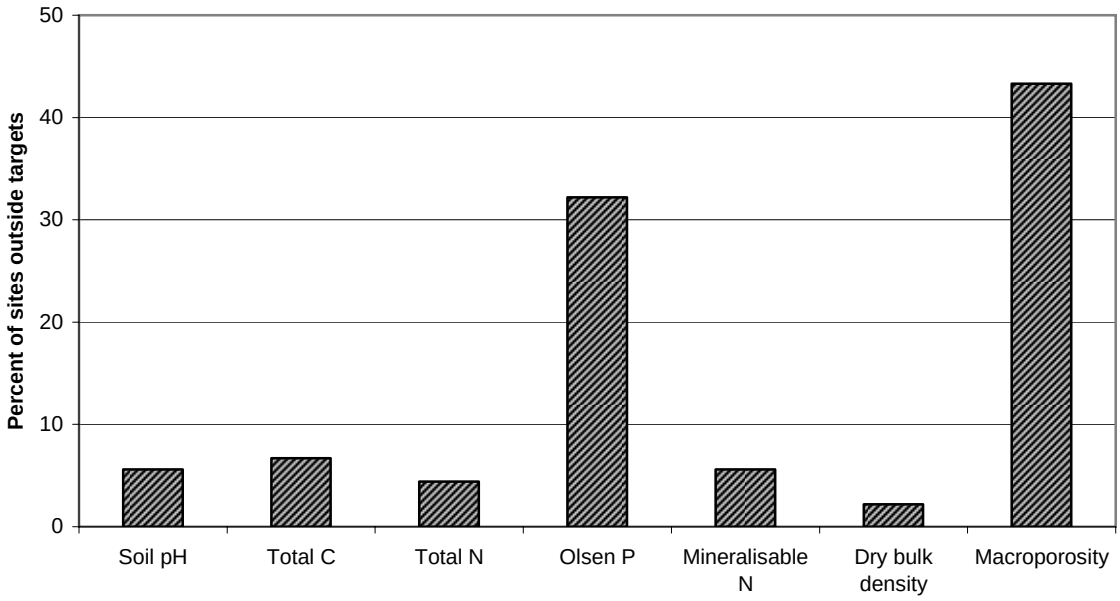


Figure 12
Proportion of all monitored sites and land uses not meeting suggested soil quality targets for specific indicators



5.7 Bias in the data set

The areas of land under the broad land use categories of: horticulture, dairy farming, sheep-beef (drystock) farming, plantation forestry and indigenous vegetation were expressed as percentage of the regional land area (Table 1). The category "other" was then discarded as sealed surfaces, lakes, etc. are not a meaningful category for soil quality assessment. The recalculated proportion of the remaining land uses were compared against those in the dataset (shown in bold type in Table 1). The match was reasonable for diary, forestry and indigenous land uses, indicating the intensity of sampling had been consistent with their area extent in the region. However, drystock farms (sheep-beef) were much under-represented, whereas horticulture was over-represented. At first glance that may seem an error in sampling strategy, but with limited resources, it does make sense to target sites and land uses perceived to be most at risk of soil quality decline, and to under-sample those deemed to be of low risk. That strategy is reinforced because the more intensive land uses are frequently located near urban centres, meaning the consequences of a decline in soil quality are soon obvious to local communities.

Table 1
Land area in the Auckland region under different land use categories, the proportion of the total land area, and the match (weighting) to the number of sites in the 500 Soils data set

Land use	Area (ha)	% regional land area	% area excluding "other"	Number of sites in the SQ dataset	%	Weighting	Comment
Dairy	63811	12.7	14.2	21	23.9	1.7	Good match
Sheep-Beef	185257	36.9	41.3	18	20.5	0.5	Under represented
Horticulture	9281	1.8	2.1	20	22.7	11.0	Over represented
Forestry	54371	10.8	12.1	9	10.2	0.8	Good match
Indigenous	135856	27.0	30.3	20	22.7	0.7	Good match
Other	53697	10.7	0.0	0	0.0	n.a.	
Total	502273	100.0	100.0	88	100.0		

5.8 Proportion of all indicators

A total of 616 soil characteristics were measured, of which 526 (85%) met the target ranges.

This figure should not be applied to calculate a proportion of land area affected, as some sites had more than one indicator that did not meet the target criteria, and there is a risk of masking sites of concern by a large number of "satisfactory" rankings, or multiple failures to meet targets on a single site. There is also bias in the data set by land use categories as this is not representative of the region on an area basis. The calculation also carries the risk of masking soil quality attributes of concern. A useful analogy may be a warrant of fitness for a car, where the vehicle must meet all the tests applied, and is failed if any one does not meet the specified target. A preferred option is to express the number of sites meeting soil quality targets on an area basis as shown below.

5.9 Soil quality expressed using land area

The area of land under each of the five main land use categories designated "satisfactory" was the proportion of that category that fully met the 7 soil quality targets. Areas not meeting the suggested target ranges for one or more indicators were designated "of concern".

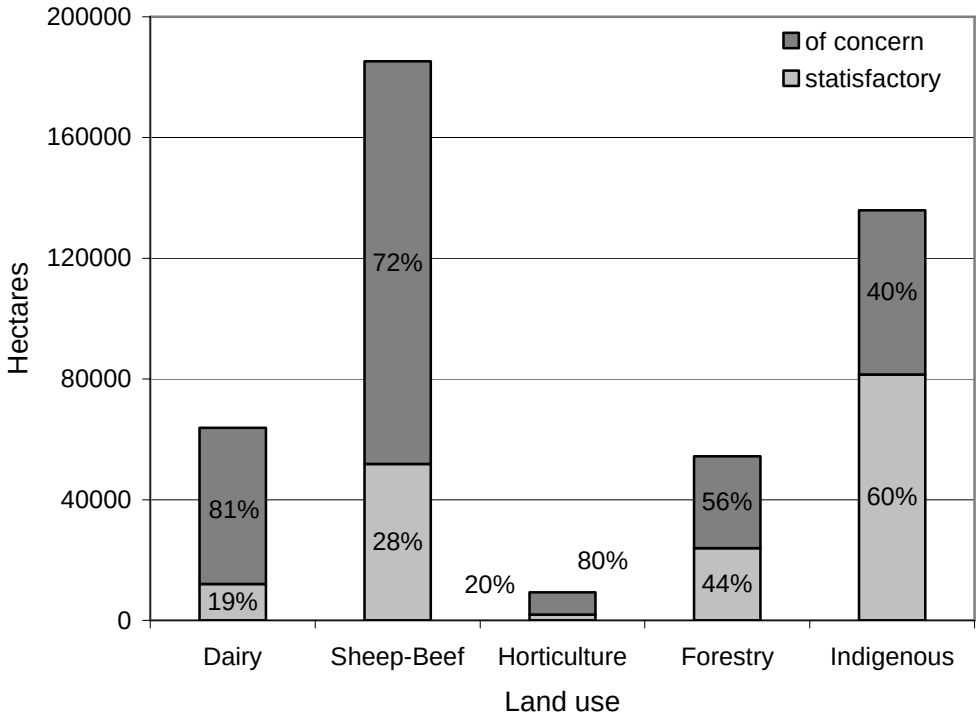
The land use with the greatest area meeting the soil quality targets was the indigenous forest (Table 2). The land use with the greatest area of concern was sheep-beef farming, largely because of the greater area extent of that land use category. Horticulture and cropping, although having the least proportion of sites meeting the suggested targets, had a relatively small impact on the total regional assessment because the land area under cropping and horticulture is comparatively small. The effect is seen clearly in Figure 13, where the dominance of the drystock sheep-beef land use, and the comparatively small area under cropping and horticulture are displayed.

Using the area data for land uses in the "satisfactory" or "of concern" categories suggested that 38% of the regional land area met the satisfactory category and 62% had some soil quality item of concern.

Table 2
Land area in the Auckland region under different land use categories, the proportion of the land use category meeting soil quality targets, and the estimated areas meeting "satisfactory" or "of concern' categories

Land use	Area (ha)	Proportion (%) meeting SQ targets	Land area (ha) satisfactory	Land area (ha) of concern
Dairy	63811	19	12124	51687
Sheep-Beef	185257	28	51872	133385
Horticulture	9281	20	1856	7425
Forestry	54371	44	23923	30448
Indigenous	135856	60	81513	54342
Total	448576		171865 (38%)	276711 (62%)

Figure 13
Overall soil quality in the Auckland region, expressed by area (ha) for five main land uses



5.10 Comparison with soil quality in other regions

Between 2001 and 2006 there were several region-specific soil quality overview reports completed under contract by Landcare Research for other Regional Councils – Environment Waikato, Environment Bay of Plenty, Taranaki Regional Council, and Greater Wellington Regional Council. However, these were contract reports specific to the client, and as far as I am aware the information in the reports remains confidential and has not yet been released for public use. There may also have been other soil quality reports connected with the Land Use Change Indicators (LUCI) project undertaken by Crop and Food Research, but Landcare Research does not have access to any of that information or data. We therefore have limited ability to provide an overview of how the Auckland region compares with other regions in the country. It would be helpful if the Regional Council Land Monitoring Forum could promote free exchange of such information.

Comparable approaches to report regional soil quality were completed by Landcare Research for Greater Wellington, Environment Bay of Plenty and Environment Waikato. Some of that data is reproduced here, but the permission of the Regional

Councils should be sought by Auckland Regional Council if the data are to be made available to the public.

Wellington Region had sampled 116 sites. Expressing the data on an area basis for the 5 main land use categories showed that 43% of the Greater Wellington Region met the suggested soil quality targets. Main concerns were very high fertility on market garden and cropping sties and soil compaction under pastures.

Environment Bay of Plenty have sampled 163 sites, and expressed on an area basis, 46% of them met the suggested soil quality targets.

Environment Waikato had sampled 191 sites, and on an area basis, 33% of them met the suggested target ranges. The reasons for the lower figure for Waikato were the large extent of dairy pasture in the region, the high occurrence of low macroporosity (compaction) on those pastures, and their high Olsen P status.

As calculated above (Table 2), the equivalent figure for the Auckland region is 38% of the land area meeting suggested soil quality targets, similar to that in the Waikato.

6 Conclusions

- The data from the 500 Soils Project, assessed by the 7 key indicators for five major land use categories suggested that, on an area basis, about one third (38%) of the monitored area met all the suggested soil quality targets.
- Indigenous forests and reserves had the highest proportion of sites (60%) meeting the suggested targets, and dairy pastures the lowest (19%).
- Sheep-beef farms (drystock) had the greatest area extent of sites of concern, because of the large area of land under that land use.
- The main soil quality indicators of concern were widespread soil compaction (low macroporosity) and high fertility levels under many market garden and pastoral farms.
- Overall, the soil quality ranking for the Auckland region was similar to that of the Waikato, and issues regarding compaction and fertility were the same.

7 Recommendations

- Auckland Regional Council uses the summary of soil quality in the region to inform the public on soil quality, and to improve awareness and education among stakeholders.
- Auckland Regional Council recommence regular soil quality monitoring to show change in the current sites and to expand the range of sites, especially on sheep-beef farms as this land use category is under-represented in the current data set.

8 Acknowledgements

Soil samples were collected by Auckland Regional Council, Landcare Research staff, and contractors. We thank the landowners for allowing access to their properties and for supplying management information. Laboratory analyses were completed by Landcare Research, Hamilton and Palmerston North.

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10 Appendix

10.1 Archived Soil Chemical and Physical Data 1995-2000

Total out of range		90	5	6	4	5	29	2	39
Total samples		616	88	88	88	88	88	88	88
			pH	Total C	Total N	AMN	Olsen P	Bulk Density	Macropores
Code	Soil	Land Use		T/ha	T/ha	µg/cm^3	µg/cm^3	T/m^3	%v/v
ARC97_02	Allophanic	Horticulture	6.58	56.2	4.79	73	20	0.86	15.4
ARC98_02	Allophanic	Horticulture	6.17	59.6	5.34	99	48	0.91	15.6
ARC00_03	Allophanic	Horticulture	6.57	58.3	4.51	133	60	0.96	17.5
ARC00_05	Allophanic	Horticulture	6.24	55.7	4.45	188	17	1.16	13.9
ARC00_06	Allophanic	Horticulture	5.76	66.9	5.35	91	83	1.16	0.3
ARC00_20	Brown	Horticulture	5.94	60.6	5.08	239	47	1.05	8.6
ARC00_24	Gley	Horticulture	5.80	48.6	3.36	127	203	1.40	7.8
ARC00_25	Gley	Horticulture	5.87	41.9	2.45	141	131	1.23	12.9
ARC00_26	Gley	Horticulture	6.18	36.4	2.15	46	160	1.35	4.2
ARC95_01	Granular	Horticulture	7.17	20.2	1.92	9	200	0.96	30.2
ARC98_03	Granular	Horticulture	6.27	56.2	4.46	104	39	0.97	13.8
ARC00_08	Granular	Horticulture	6.36	46.5	3.82	120	15	0.83	24.9
ARC99_04	Organic	Horticulture	6.82	72.5	6.03	77	35	0.45	7.6
ARC00_09	Organic	Horticulture	6.40	147.5	5.94	44	22	0.74	10.5
ARC98_08	Recent	Horticulture	6.38	63.3	4.36	67	100	1.03	8.3
ARC98_22	Recent	Horticulture	6.09	48.2	3.96	42	37	0.94	21.5
ARC98_25	Recent	Horticulture	5.34	38.3	3.10	40	112	1.00	21.9

			pH	Total C	Total N	AMN	Olsen P	Bulk Density	Macropores
ARC00_17	Ultic	Horticulture	6.33	38.7	2.79	151	16	0.99	2.4
ARC00_18	Ultic	Horticulture	5.84	48.0	3.91	153	16	0.97	17.1
ARC00_19	Ultic	Horticulture	5.77	47.5	3.45	144	16	0.93	10.4
ARC97_01	Allophanic	Dairy	6.19	67.8	6.15	155	51	0.95	13.6
ARC99_01	Allophanic	Dairy	6.33	67.7	6.12	124	29	0.92	3.3
ARC99_25	Allophanic	Dairy	5.68	65.9	5.80	61	24	1.07	2.5
ARC00_02	Allophanic	Dairy	6.85	67.8	6.18	211	74	0.86	11.7
ARC00_04	Allophanic	Dairy	6.00	69.4	6.09	174	6	0.86	7.6
ARC98_13	Brown	Dairy	5.46	70.6	6.51	106	15	1.00	6.9
ARC00_11	Gley	Dairy	5.90	68.4	5.52	244	72	1.02	3.7
ARC00_15	Gley	Dairy	6.02	56.7	4.66	222	7	0.98	7.5
ARC97_04	Granular	Dairy	6.91	66.4	6.2	257	51	0.96	8.1
ARC99_10	Granular	Dairy	6.12	64.2	5.43	152	15	0.92	6.3
ARC00_13	Granular	Dairy	6.03	72.1	5.98	200	75	1.03	6.6
ARC96_05	Organic	Dairy	5.93	87.2	6.57	155	33	0.75	3.1
ARC96_06	Organic	Dairy	6.07	81.5	6.70	156	20	0.62	2.9
ARC99_05	Organic	Dairy	5.75	154.4	10.06	126	43	0.64	5.8
ARC99_06	Organic	Dairy	5.91	138.3	9.85	142	35	0.58	4.3
ARC98_19	Recent	Dairy	5.85	49.2	4.65	140	21	0.91	12.2
ARC98_16	Ultic	Dairy	6.13	71.7	6.11	174	19	0.94	11.8
ARC98_21	Ultic	Dairy	6.73	64.5	5.87	138	114	1.01	6.9
ARC98_23	Ultic	Dairy	6.07	50.2	4.79	127	57	0.95	13.7
ARC99_16	Ultic	Dairy	6.02	72.9	5.75	171	14	0.84	12.7
ARC99_18	Ultic	Dairy	5.55	66.0	5.47	217	7	0.62	5.6
ARC00_01	Allophanic	Drystock	6.59	57.8	4.98	158	23	0.77	14.4
ARC98_09	Brown	Drystock	5.55	66.9	6.78	177	22	1.01	6.5

			pH	Total C	Total N	AMN	Olsen P	Bulk Density	Macropores
ARC99_11	Brown	Drystock	5.52	47.5	3.54	115	53	1.06	6.4
ARC99_13	Brown	Drystock	6.10	37.4	3.06	80	16	0.88	22.2
ARC99_14	Brown	Drystock	5.49	34.0	2.5	52	17	1.17	15.1
ARC00_12	Gley	Drystock	5.5	55.1	4.66	210	36	0.84	10.4
ARC00_14	Gley	Drystock	5.99	61.9	4.95	231	86	1.00	8.9
ARC95_02	Granular	Drystock	6.30	52.6	4.98	98	14	0.87	9.5
ARC98_04	Granular	Drystock	5.88	60.6	5.26	113	11	0.92	12.8
ARC99_09	Granular	Drystock	5.76	71.3	5.88	159	50	0.95	5.6
ARC99_24	Granular	Drystock	5.46	73.8	5.97	171	9	1.00	2.9
ARC00_07	Granular	Drystock	6.05	67.9	6.11	227	10	0.84	12.3
ARC00_22	Granular	Drystock	6.50	73.4	5.58	256	11	0.95	4.6
ARC98_18	Recent	Drystock	5.67	60.3	5.55	138	33	0.92	12.3
ARC96_01	Ultic	Drystock	5.85	50.8	4.42	139	6	0.78	9.8
ARC98_06	Ultic	Drystock	5.86	55.4	4.33	107	10	1.09	14.1
ARC98_15	Ultic	Drystock	5.64	54.6	4.92	137	9	0.64	11.2
ARC00_16	Ultic	Drystock	6.38	46.2	3.79	207	14	0.85	10.3
ARC98_10	Brown	Forestry	5.27	40.6	3.69	60	17	0.76	34.7
ARC98_11	Brown	Forestry	4.90	99.8	6.88	81	70	0.91	17.6
ARC98_12	Brown	Forestry	5.53	60.0	5.49	109	9	0.64	23.4
ARC00_10	Brown	Forestry	5.08	49.4	1.95	59	6	1.05	18.4
ARC99_22	Raw	Forestry	6.07	7.90	0.39	na[1]	13	1.44	31.9
ARC99_23	Raw	Forestry	5.89	9.40	0.42	9	6	1.02	42.9
ARC99_21	Recent	Forestry	5.72	37.4	2.35	55	5	0.89	27.6
ARC96_02	Ultic	Forestry	4.67	47.9	3.29	42	34	1.05	12.6
ARC96_03	Ultic	Forestry	4.93	46.9	2.85	55	13	0.84	7.4
ARC98_01	Allophanic	Indigenous	5.44	72.2	5.98	98	2	0.52	20.7

			pH	Total C	Total N	AMN	Olsen P	Bulk Density	Macropores
ARC99_02	Allophanic	Indigenous	5.93	56.7	3.25	94	2	0.68	31
ARC99_03	Brown	Indigenous	5.56	60.9	2.90	107	2	0.65	30.7
ARC99_12	Brown	Indigenous	6.26	62.4	4.36	116	13	1.06	12.5
ARC99_15	Brown	Indigenous	5.31	38.6	1.97	63	5	0.99	27.4
ARC00_21	Brown	Indigenous	5.72	57.8	2.91	130	37	1.05	10.3
ARC00_23	Brown	Indigenous	4.54	61.9	2.84	61	2	1.07	10.2
ARC97_03	Granular	Indigenous	5.35	62.1	4.03	111	3	0.82	19.2
ARC99_08	Granular	Indigenous	4.13	114.5	5.66	85	35	0.88	11.9
ARC99_19	Granular	Indigenous	6.55	82.8	4.66	167	7	0.71	15.2
ARC99_20	Granular	Indigenous	5.44	77.2	3.28	91	1	0.83	5.1
ARC99_07	Organic	Indigenous	4.91	124.9	6.82	96	51	0.41	10.2
ARC98_17	Recent	Indigenous	5.66	55.7	3.67	106	9	0.94	5.3
ARC98_24	Recent	Indigenous	5.18	59.2	3.78	93	21	0.86	13
ARC96_04	Ultic	Indigenous	5.32	52.9	3.16	110	5	0.78	9.6
ARC98_05	Ultic	Indigenous	4.83	56.1	2.80	113	5	1.18	6.6
ARC98_07	Ultic	Indigenous	5.17	50.8	2.96	101	3	0.86	13.4
ARC98_14	Ultic	Indigenous	5.51	55.8	4.17	123	6	0.87	7.4
ARC98_20	Ultic	Indigenous	5.50	45.6	3.15	114	6	0.92	13.2
ARC99_17	Ultic	Indigenous	5.64	90.3	5.06	139	4	0.83	9.8

[1]na Data used to assess soil quality in the Auckland region, compiled from annual reports 1995–2001 for the 500 Soils Project.

Figures in bold (orange) exceeded the suggested range; figures in bold (blue) were less than the suggested range, for that soil order and land use combination.