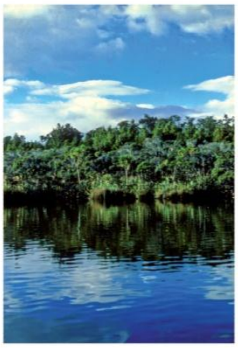
Review of Northland Soil Quality Sampling



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Review of Northland Soil Quality Sampling

Bryan A Stevenson, Research Soil Scientist

Landcare Research

Prepared for:

Northland Regional Council

Private Bag 9021

Whangarei 0148

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Landcare Research, Gate 10 Silverdale Road, University of Waikato Campus, Private Bag 3127, Hamilton 3240, New Zealand, Ph +64 7 859 3700, Fax +64 7 859 3701, www.landcareresearch.co.nz

Reviewed by:	*Approved for release by:*
Dr Scott Fraser Soil Scientist Landcare Research	Dr Craig Ross Programme Leader Commercial Soil Services
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Summary

Project and Client

- 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". Section 30(1) of the Resource Management Act has as a function of the Regional Council the control of land use for the purpose of soil conservation, the maintenance and enhancement of the quality of water in water bodies and coastal waters, and the maintenance of the quantity of water in water bodies and coastal waters. Pursuant to Section 126 of the Soil Conservation and Rivers Control Act 1941 it is the duty of regional councils as "catchment boards" to prevent or lessen erosion or the likelihood of erosion and to promote soil conservation. Adverse changes in some soil quality parameters are indicators of increasing risk of soil erosion while improvements in these parameters are measures of increased resilience to not only soil erosion and sediment discharge but also to climatic extremes, particularly drought.
- Northland Regional Council (NRC) participated in the Sustainable Management Fund project "Implementing Soil Quality Indicators for Land" in 2000–2001 when 25 sites were selected and sampled. NRC resampled the sites in 2006/2007 to determine whether any changes had occurred. NRC wishes to proceed with further sampling but desired a review of the sites that had been sampled, whether additional sites should be included in sampling, and advice on sampling strategy. Landcare Research was contracted (through a small advice Envirolink grant) to review the sites and provide recommendations for future sampling.

Objectives

- Summarise current NRC soil quality sites
- Evaluate land use and soil type distribution of current soil quality sites
- Comment on adequacy of distribution of current soil quality sites
- Propose alternatives to present sampling strategy

Recommendations

- NRC continues to sample current sites and add additional sites in the future to increase the total number of sites sampled.
    - Addition of a minimum of between five and ten sites would help to increase the ability to detect change between landuses and decrease the bias between land use area and number of sites sampled.
- NRC adopt a rotational plan to sample sites if all sites cannot be sampled in a single year (reporting can be done once the rotation gets through all sites).
    - Every effort, however, should be made to sample all sites of a given land use in a single year as this increases the statistical power to detect changes within land uses. Given the current number and land use distribution of sites, a 3-yr rotation would work best with all drystock sites sampled in yr 1, dairy + crop/hort sites in yr 2, and forestry and indigenous sites in yr 3 (or variation thereof).
- NRC considers the above recommendations in concert with specific concerns of the Northland region.

1 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". Section 30(1) of the Resource Management Act has as a function of the Regional Council the control of land use for the purpose of soil conservation, the maintenance and enhancement of the quality of water in water bodies and coastal waters, and the maintenance of the quantity of water in water bodies and coastal waters. Pursuant to Section 126 of the Soil Conservation and Rivers Control Act 1941 it is the duty of regional councils as "catchment boards" to prevent or lessen erosion or the likelihood of erosion and to promote soil conservation. Adverse changes in some soil quality parameters are indicators of increasing risk of soil erosion while improvements in these parameters are measures of increased resilience to not only soil erosion and sediment discharge but also to climatic extremes, particularly drought.

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2 Background and Methods

Many Regional Councils monitor soil quality using the sampling protocol developed by the 500 Soils Project (Hill et al. 2003). The various properties monitored target the dynamic aspects of soil health, rather than land-use capability, contamination, or erosion, though some Regional Councils monitor additional parameters (such as heavy metals) for such purposes. The soil quality assessment is based on the fitness of the soil for its particular use, which depends on the match between the soil capability and its actual use. For each site, data from the seven key soil quality indicators (pH, total carbon and total nitrogen, Olsen P, anaerobically mineralisable nitrogen, bulk density, and macroporosity) are compared against target ranges (specific to soil order and land use) from the provisional values suggested by Sparling et al. (2003) and the number of times a value fails to meet the target ranges recorded. Comparison of soil properties at individual sites over time are also used to assess the extent and direction of change in soil quality characteristics.

One of the intentions in developing a soil quality monitoring programme was as a tool for State of the Environment (SOE) reporting. For SOE reporting at a regional level, soil quality data from the various sites must be extrapolated across the region (Sparling & Schipper 2004; Lilburne et al. 2004). Overall soil quality can be calculated in several ways: by the proportion of all indicators that met the target range or by the total number of sites where all indicators met the specified the target range. The data, however, are biased towards particular land uses, and this bias needs to be considered.

Reporting on an area basis for each land use is another way to report on soil quality. Data are grouped by land-use category, and the proportion of sites meeting or not meeting soil quality targets 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 not meeting the target range on one or more indicators, and *N* is the total number of sites sampled.

The proportion of the area within each region for the five land-use categories (dairy pasture, sheep-beef pasture, horticulture and cropping, plantation forests, and indigenous vegetation) is also calculated using regional or national data. The proportion of concern can then be calculated by multiplying by P derived as above. Extrapolation to the land area of concern can be calculated using the formula

$$Ac = P \times At,$$

where *Ac* is the area of concern, *P* is the proportion of sites of concern, and *At* is the total area. The calculation can be completed for each land use individually, and also using all land uses combined to obtain a figure for the whole region. The original intent was to apply these proportions to land-use/soil-type combinations, but accurate information on the area of soil type under each land use is lacking (land-use changes are frequent and difficult to predict by soil type), so land use alone has been used.

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 seven indicators can be 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.

Ideally, assuming that the variances for soil quality parameter are the same for all land uses, the number of sites selected for each land use should be representative of the land area for each land use (e.g., land uses that occupy the largest area within a region should have the most sites sampled). This is not always feasible, however, and there are valid reasons for biasing sampling towards specific land uses. For instance, cropping and horticulture generally occupy a small total area, but as the most intensive land uses they could potentially have larger impacts than lower intensity land uses.

Indigenous sites were originally included in proportional representation of total land area of concern; however, target values for indigenous systems have not been well defined, and therefore calculation for the proportion of sites and areas of concern is currently calculated for managed land uses only. Indigenous sites, however, provide valuable baseline information on how land use change affects soil characteristics. Additionally, changes in soil parameters over time in indigenous systems can indicate the extent that these systems are being influenced by human activity; therefore sampling of indigenous sites is still encouraged.

The 25 sites selected for soil quality monitoring (Sparling et al. 2000) and later resampled (Stevenson 2007) were assessed against area estimates of the different land uses in the Northland region (obtained from the NRC SOE report and Landcare Research's LUNZ database). The results of this assessment and discussion of sampling strategy follow.

3 Results

Table 1 presents site information for the 25 sites chosen across Northland in 2000 and resampled in 2007 (land use refers to the 2007 sampling date). The area for each land use and the sampling bias (based on the ratio of the percentage area that land use occupies to the percentage of sites sampled for that land use) are shown in Table 2. A bias greater than one indicates that land use is under-represented against the amount of area it occupies, and less than one that the land use is over-represented. The greater the distance away from one, the greater that land use is under- or over-represented.

The original (2000) distribution of land uses was nine dairy, five drystock, one cropping, one horticulture, five forestry, and four indigenous forests. By 2007, five of the sites (20%) had changed land use, and the distribution was seven dairy, eight drystock, one horticulture, five forestry, and four indigenous forests. The area percentages for managed land uses (Table 2) are: dairy (22%), drystock (54%), Cropping and horticulture (1%), and exotic forestry (23%). On an area basis (from the 2007 sampling), drystock sites are somewhat under-represented, dairy somewhat over-represented, cropping and horticulture highly over-represented, and forestry proportional to area. In the original 2000 site selection dairy and cropping were even more over-represented and drystock more under-represented.

4 Discussion and Conclusions

General Trends

Land-use change has occurred more frequently than was anticipated and sites initially chosen for one land use are often found to be a different land use when resampled. There has been no set procedure across Regional Councils to deal with such contingencies, but the reality is that even sites chosen for long term stability (such as research trial sites) have undergone some land use change and there is little that can be done other than to re-evaluate site selection over time. Following sites as land uses change can provide data on how sites react to change but with limited sites, land-use changes can also increase or decrease the bias of land-use sampling.

Soil quality concerns often vary by region throughout New Zealand and the soil quality monitoring programme was designed to create a flexible system in which regional concerns could be addressed. Nevertheless, some general trends have emerged from soil quality sampling across regions (Sparling & Schipper 2004; Stevenson 2009). Soil quality trends in dairy sites have been the most consistent. Many dairy sites (regardless of region) have shown significant downward trends in macroporosity – an indication of compaction. Additionally, in many dairy sites, soil nutrient status (primarily total N and Olsen P) is high, though high Olsen P has appeared to be less of a problem in recent samplings (possibly due to better nutrient management practices, but also could simply reflect increased fertilizer costs).

Trends in the drystock land use have shown divergent pathways – intensive drystock (particularly intensive beef) generally have many of the same issues that are associated with dairy (e.g., low macroporosity and high nutrient status), whereas hill country and marginal lands can often have low nutrient status and thus in the long term may be susceptible to impacts from overgrazing.

For cropping sites, nutrient levels can be high and loss of soil carbon has been observed with long-term tillage. Aggregate stability has also been noted as being low on cropping sites (cropping and horticulture are the only land uses where this method is normally used), but not all Regional councils currently analyse for aggregate stability. Horticultural sites vary greatly but often have the overall best percentage of sites meeting target values. Compaction and fertility (high or low P status) are generally the issues of concern. Horticultural sites, though, can have other environmental issues (such as heavy metal contamination) that are not addressed by the seven core soil quality indicators, though many regional councils also test for heavy metals.

Forestry sites also receive generally high soil quality ratings, with low bulk density and high macroporosity the indicators most of concern. However, most adverse environmental effects for forestry generally occur during tree harvest and the first several years after planting when canopy cover is incomplete.

Number of Sites and Site Selection

The 500 soils sampling program was set up to achieve a statistical representation of soil quality over New Zealand. Hill and Sparling (2009) stated:

> *Hill et al. (2003) determined that about 500 samples nationally was sufficient when samples were stratified using the six Land Use Type classes in Table 3.2 (Level 1 classes). In theory, this provides some guidance for sampling requirements at a regional level (i.e. a similar number of samples would be needed at a regional level if the same range of Land Use Types and soil indicator variability were expected (pers.comm., C. Frampton)). However, given most regions are likely to be less variable in terms of soil quality and Land Use Types they will require a smaller sample size to represent the true population. In practice, a sample size for each Land Use Type should contain more than 30 samples (pers. comm., G. Sparling). In addition, samples within Land Use Type strata should be weighted according to the most common Soil Order (by area) for the particular Land Use Type. In a statistical sense the sample size for each Land Use Type should aim to be confident of estimating the most variable soil indicator (e.g. bulk density) to a predetermined confidence and variance about its mean value e.g. 95% confident that the mean level +/-20% is achieved.*

To date, there has not been a review of the degree of variation present to adequately state the number of sites needed for robust sampling within regions. If the above recommendations are not feasible, a smaller number of sites (a minimum of five to 10) could be added to balance sampling bias and increase statistical power to detect changes within land use. In practice, we have found that in comparing data from resampled sites, grouping similar land uses together in one sampling (ideally with a minimum of approximately seven sites) provides sufficient statistical power to determine broad changes in most soil quality indicators. Since the original sites have been sampled twice (and we consider sites sampled three or more times to be valuable in gauging temporal trends), we would recommend that these sites continue to be monitored.

Soil types for sites initially chosen are representative of several of the dominant regional soils (Waiotira, Marua) as well as four of the major New Zealand soil orders (Allophanic, Brown, Granular, and Ultic soils). One of the intents of the original sampling scheme was to compare/contrast land use affects on different soil types. The selection of soil-type/land-use combinations was based on local knowledge of dominant soils on managed land uses, and included properties on which Council land management staff had a good working relationship with the landowners. Several of the dominant soil orders present in the Northland region (Ultic and Recent soils in particular) are perhaps under represented. Wim Rijkse (pers. comm., 12 Oct 2010), one of the pedologists directly involved in the 500 Soil project, indicated that soils originally sampled were chiefly west of Whangarei and one of the plans for future sampling was soils further North (Bay of Islands and Kaitaia areas) where there are more Ultic and Oxic soils.

At a bare minimum, we recommend the addition of two to three drystock sites, one cropping site, one to three indigenous sites and possibly one additional dairy site. Ideally, to gauge the divergence in the drystock land use better, drystock sites could be apportioned so that approximately half the sites are intensive and the other half less intensive (e.g., on hill country or marginal farmland). Though one cropping site in itself is not sufficient for robust statistical analysis of the land use, it does provide some representation for this land use. The addition of several more indigenous sites would provide better statistical power to gauge direction of change in the indigenous systems (these could be added on an Ultic or other soil orders that is currently under represented). Dairy sites are currently well represented on an area basis; however, over much of New Zealand the dairy land use is expected to continue to grow, and the impacts of dairy expansion remain a concern for soil quality. Additionally, the original (2000) selection of sites contained replicate dairy sites on each of the Granular, Ultic, Allophanic, and Brown soil orders. An Allophanic dairy site was lost (in change to drystock), but Allophanic soils are generally well represented in the Taranaki, Waikato and Auckland regions so that if the dairy site is replace this could also be on a soil type that is currently not well represented.

Sampling Schedule

A rotational schedule for SQ monitoring is employed by several Regional Councils and is effective; however, the most analytically efficient sampling is for all sites of a similar land use (e.g., all dairy or all drystock sites) to be sampled concurrently. Ideally, a 3-yr rotation would work best with all drystock sites sampled in yr 1, dairy + cropping and horticulture sites in yr 2, and forestry and indigenous sites in yr 3 (or variation thereof). Reporting of all sites could then be done in conjunction with the third year sampling or in the fourth year to spread the sampling cost over a longer period of time.

5 Recommendations

- NRC continues to sample current sites and add additional sites in the future to increase the total number of sites sampled.
    - Addition of a minimum of between five and ten sites would help to increase the ability to detect change between landuses and decrease the bias between land use area and number of sites sampled.
- NRC adopt a rotational plan to sample sites if all sites cannot be sampled in a single year (reporting can be done once the rotation gets through all sites).
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- NRC considers the above recommendations in concert with specific concerns of the Northland region.

6 Acknowledgements

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7 References

Hill RB, Sparling G, Frampton C Cuff J 2003. National Soil Quality Review and Programme Design, Technical Paper 75, Land. Wellington, Ministry for the Environment.

Hill R, Sparling GP 2009. Chapter 3: Soil quality monitoring. In: Land and Soil monitoring: a guide for SoE and Regional Council reporting. Land Monintoring Forum, New Zealand.

Lilburne L, Sparling GP, Schipper LA 2004. Soil quality monitoring in New Zealand: development of an interpretative framework. Agriculture Ecosystem & Environment 104: 535–544.

NRC 2008. 2007 State of the Environment report. Northland Regional Council. Available online at http://www.nrc.govt.nz/Resource-Library-Summary Environmental-Monitoring/State-of-the-Environment-Monitoring/.

Sparling GP, Rijkse W, Wilde RH, van der Weerden T, Beare MH, Francis GS 2001. Implementing soil quality indicators for land. Research Report for 2000–2001 and Final Report for MfE Project Number 5089. Landcare Research Contract Report LC0102/015.

Sparling G, Lilburne L, Vojvodic-Vucovic M. 2003. Provisional targets for soil quality indicators in New Zealand. Lincoln, Landcare Research.

Sparling GP, Schipper LA 2004. Soil quality monitoring in New Zealand: Trends and issues arising from a broad-scale survey. Agriculture Ecosystem & Environment 104: 545–552.

Stevenson B 2009. Soil quality assessment – regional soil quality monitoring for State of the Environment reporting at a national scale. Report to Ministry for the Environment. Landcare Research Technical Report LCR 0910/042.

Stevenson B 2007. Soil quality in Northland 2007: comparison with previous sampling in 2001. Landcare Research Contract Report for Northland Regional Council LC0708/048.

Table 1 Site codes, soil types, soil orders and land uses resampled in April 2007

Site code	Soil type	Subgroup, Group, Order	Land use
NRC00_1	Marua clay	Typic Orthic Granular	Drystock for 2 yrs, previously dairy
NRC00_ 2	Marua clay	Typic Orthic Granular	Drystock
NRC00_ 3	Marua clay	Mottled Orthic Brown (?)	Drystock for 2 yrs, previously dairy (irrigated)
NRC00_ 4	Waiotira clay	Mottled Acid Brown	Dairy, non-irrigated
NRC00_ 5	Waiotira clay	Mottled Acid Brown	Dairying, irrigated
NRC00_ 6	Waiotira clay	Mottled Acid Brown	Indigenous forest (some stock browsing)
NRC00_ 7	Waiotira clay loam	Mottled Acid Brown	Drystock
NRC00_ 8	Waiotira clay loam	Mottled Acid Brown	Forestry, second rotation pine
NRC00_ 9	Waiotira clay	Mottled Acid Brown	Drystock
NRC00_ 10	Red Hill sandy loam	Typic Orthic Allophanic	Drystock for 18 mos, previously mixed cropping
NRC00_ 11	Red Hill sandy loam	Typic Orthic Allophanic	Forestry, second rotation pine
NRC00_ 12	Red Hill loamy sand	Typic Orthic Allophanic	Dairy, non-irrigated
NRC00_ 13	Red Hill loamy sand	Typic Orthic Allophanic	Drystock
NRC00_ 14	Wharekohe silt loam	Perch-gleyed Densipan Ultic	Dairy (less intensive), previously drystock
NRC00_ 15	Wharekohe silt loam	Perch-gleyed Densipan Ultic	Dairy (intensive), non-irrigated
NRC00_ 16	Wharekohe silt loam	Perch-gleyed Densipan Ultic	Forestry, first rotation pine after pasture
NRC00_ 17	Marua clay loam	Typic Orthic Brown	Forestry, first rotation pine after pasture
NRC00_ 18	Marua clay loam	Typic Orthic Brown	Indigenous forest, bush on previous pasture
NRC00_ 19	Awarua clay loam	Acidic Oxidic Granular	Dairying, non-irrigated
NRC00_ 20	Awarua clay loam	Acidic Oxidic Granular	Indigenous forest (evidence of stock access)
NRC00_ 21	Awarua clay loam	Acidic Oxidic Granular	Dairy, irrigated
NRC00_ 22	Awarua clay loam	Acidic Oxidic Granular	Forestry, first rotation, clear felled after pasture
NRC00_ 23	Kiripaka bouldery clay loam	Typic Orthic Allophanic	Drystock, previously dairy, non-irrigated
NRC00_ 24	Kiripaka bouldery clay loam	Typic Orthic Allophanic	Indigenous forest
NRC00_ 25	Kiripaka bouldery clay loam	Typic Orthic Allophanic	Citrus orchard

Table 2 Land Use Area, number of Soil Quality sites monitored (based on 2007 data) and bias in LU sampling for the Northland Region

Land use	**Area (km^2)**	**% Total Area**	**% of Managed LU Area**	**Number Sites Monitored**	**% of Managed LU Sites**	**Bias**
Dairy	174 534	14	22	7	33	0.67
Drystock	420 222	33	54	8	38	1.40
Crop/Hort	9265	1	1	1	5	0.25
Exotic Forestry	181 761	14	23	5	24	0.97
Indigenous Forest	273 434	22	-	4	-	
Indigenous (other)	118 501	9	-	-	-	
Miscellaneous	90 312	7	-	-	-	
Total						
(All)	1 268 029	100	-	25	-	
(Managed)	785 782	-	100	21	100	