Soil quality in the Bay of Plenty 2014 - update of dairy farm sites

Bay of Plenty Regional Council
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Executive summary

Temporal changes in topsoil qualities of dairy pasture were monitored 5 yearly over a 15 year period. Results indicate that in most areas, many of the topsoil parameters are being maintained and these are within the provisional target values set by Landcare Research, New Zealand for production and/or environmental criterion. Samples were taken in a very small area of the farm only. However, a continuous steady increase in levels of mineralisable N and high values of Olsen P (although in few places due to recent topdressing) could lead to sub-surface leaching or runoff of phosphate entering water bodies. Dairy farmers should therefore exercise judicious use of P and N fertilisers through periodic soils testing and farm nutrient budgeting.

The soil quality monitoring programme, which also encompasses dry stock farming, cropping, horticulture and forestry, is invaluable in keeping farmers informed of soil quality of their properties over time. This especially when there are clear indications of looming problems with some properties of their soils and remedial measures can be promptly taken.

It is therefore essential that soil monitoring should continue and in future include areas of soil-use changes and inclusion of trace elements. Including soil microbial biodiversity such as earthworms, microbiological activity, respiration, soil enzyme activity etc. to monitor soil wellbeing would bolster the programme.

Contents

Part 1: Introduction

Healthy productive soils underpin the Bay of Plenty economy. Agriculture, fishing and forestry were the largest industries in the Bay of Plenty in 2010 accounting for 16.2% of GDP (Infometrics, 2012). Deterioration of soil quality as a result of intensification of land and land use change can occur gradually and if not done sustainably can impact on the environment and its ability to produce in the future.

It is because of the potential gradual decline in soil quality that a methodology was developed by Landcare Research to identify changes in soils. In 1998 the Ministry for the Environment (MfE) contracted Landcare Research to trial a series of soil quality indicators. Following this trial MfE partially funded a three year project called the '500 Soils Project' which aimed to establish sites to measure these indicators on 500 soils throughout New Zealand (Sparling and Schipper 2002; 2004) Bay of Plenty Regional Council was one of the five inaugural regional councils that participated in this project and by completion of this project in 2001, ten regional councils had joined. In the Bay of Plenty 75 sample sites were established in this period.

Bay of Plenty Regional Council's current Natural Environment Regional Monitoring Network (NERMN) programme for soil quality monitoring continues the sampling from the 500 soils project to provide long term trends in soil health. .

This review continues monitoring of 75 established sites and this year 18 dairy sites throughout the Bay of Plenty were resampled for chemical and soil physical properties. In the past the status of soil quality in the Bay of Plenty has been reported periodically by Landcare Research (Sparling 2001; Sparling and Rijkse 2003, Sparling 2004; Sparling 2005; Sparling 2006a; Sparling 2006b). This short report focuses on the results of 2014 soil quality sampling which covers dairy pasture sites.

Part 2: Materials and methods

2.1 Soil types within sampling program

Table 1 outlines the soil types that were tested as part of this monitoring program. The majority of soils sand / loam and well drained. P retention is generally medium to high.

Table 1 Soil types analysed in this sampling program.

Soil type	NZ Soil Classification (Order Level)	Texture	Drainage	P Retention
Rotomahana sandy loam	Recent	Loam	Rapid	Medium (32%)
Horomanga sand	Recent	Sand	Rapid	Medium (32%)
Galatea sand	Pumice	Sand over loam	Rapid	Medium (51%)
Oropi loamy coarse sand	Pumice	Sand	Rapid	Medium (51%)
Kawhatiwhati sand	Pumice	Sand	Rapid	Medium (51%)
Opouriao fine sandy loam	Recent	Loam	Rapid	Medium (38%)
Kaingaroa gravelly sand	Pumice	Sand	Rapid	High (62%)
Otara silt loam	Recent			
Oturoa loam	Allophanic	Sand	Rapid	High (87%)
Katikati sandy loam	Allophanic	Loam	Rapid	High (83%)
Paroa silt loam on peat	Gley	Loam over peat	Poor	Medium (35%)

2.2 Soil sampling and analyses

Eighteen dairy pasture soil quality sites were resampled in March 2014 following previous sampling in 1999, 2004 and 2009. The standard method for soil quality sampling was followed (Sparling and Schipper 2002, 2004). A 50 m transect was established on each site. For chemical analyses topsoil samples (0 – 10 cm) were collected along a 50 m transect at 2 m intervals. The samples were collected in a plastic sample bag and bulked. Three physical samples were taken using three stainless steel corers (10 cm diameter and 7.5 cm high) and taken at 0, 15 and 30 m interval along the transect.

The samples were submitted to Landcare Research laboratories (Palmerston North) for analyses (pH; organic carbon; total N; C/N ratio; Olsen phosphorus (P); phosphate retention; exchangeable calcium (Ca); exchangeable magnesium (Mg); exchangeable potassium (K); and exchangeable sodium (Na), Cation exchange capacity (CEC) and base saturation (Bs)).

Dry bulk density, particle density, total porosity, macro porosity and total water-holding capacity were determined in the Landcare Research's Hamilton laboratory (for description of terms see Appendix 2).

2.3 Data analyses

Mean values of topsoil qualities by land use class were compared with the 'target' or 'desirable' qualities set as Provisional Targets for Soil Quality Indicators in New Zealand (Sparling et al. 2008).The results are grouped according to land use and/or soil classification.

Part 3: Results and discussion

3.1 Topsoil qualities of dairy sites

Table 2 shows the mean topsoil qualities of dairy sites sampled in 2014. Mean soil pH (5.9) was within the 5.0 – 6.6 soil quality target. All sites met this target, so soil acidity is not deemed to be a problem on the dairy sites.

The mean total carbon (C) was 8.0% and all sites met the >2.5% total C target. For total nitrogen (N) the mean value of 0.76 slightly exceeds the target range of 0.25 - 0.70. However, 12 out of 18 sites exceed the target (> 0.70%). The number of sites exceeding the sampling target has also increased across every reporting period since 1999.

Generally speaking high total N concentrations are desirable from a productivity standpoint but very high total N levels (>0.70%) have potential to contribute to excessive nitrate levels in the soil and to increase leaching losses and eutrophication of receiving waters (Sparling et al. 2008).

The mean C/N ratio of 10.3 was within the 8 - 12 target range from a production standpoint. All sites were within the target of 8 - 12. The mean C/N has remained consistent with the previous sampling in 2009 (10.2), but has been narrowing over the programme duration. Generally a C/N ratio of 10 to 12 occurs in well decomposed humus of arable soils (weakly decomposed material has a C/N ratio of > 15).

The mean Olsen P concentration of 99.8 mg/kg is high compared with guideline values of 25 – 40 for volcanic soils. Any concentration above 100 mg/kg is deemed excessive and likely to cause significant loses to the receiving environment. Landcare Research’s SINDI analyser shows that an Olsen P greater than 100 is excessive. 41% of sites sampled have Olsen P values above the 100 mg/kg upper limit. This is a slight increase (2%) compared with the 2009 sampling and a 25% increase from the 2004 sampling. Applying phosphate fertilisers in excess of plant requirements represents a monetary loss to farmers and contributes to eutrophication of rivers, streams and lakes when P is carried in sediment during runoff events.

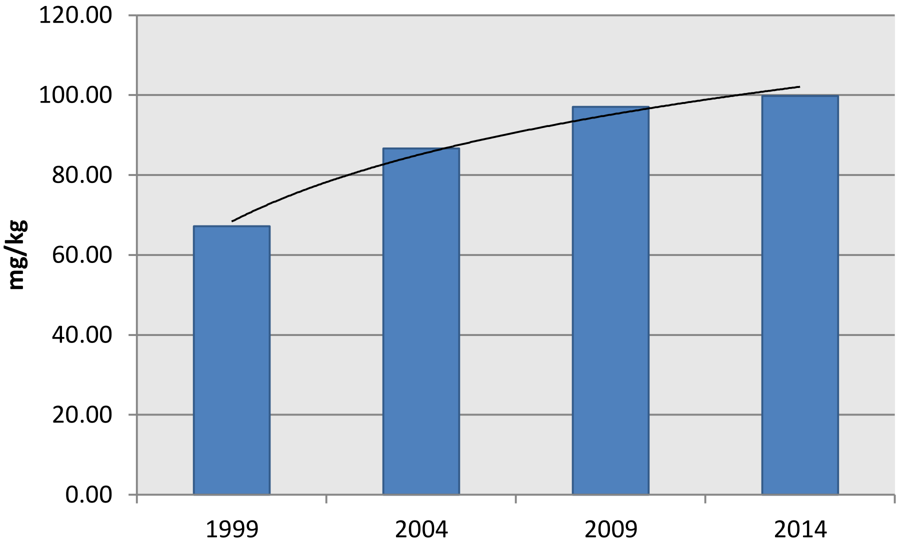


Figure 2 Mean Olsen P concentrations over consecutive reporting periods.

Many soils in the Bay of Plenty have an amount of weathered volcanic ash in their makeup. The clay-type that weathers from the ash is called allophane and it ‘binds’ phosphate making it unavailable to plants. The measure of that process is phosphate retention. The mean phosphate retention of the 18 dairy soils is 49.6%, which includes soils primarily comprised of volcanic ash to weakly weathered pumice and recent soils. The target range of 30 – 60% is classed as medium.

Macroporosity is a measure of the number of large pores (diam. 60 µm) in soil. Macropores are important for soil aeration and are the first pores to be lost when the soil is compacted. Therefore macroporosity is a more sensitive indicator of soil compaction than bulk density. Low macroporosity reduces soil aeration, resulting in less clover growth, N-fixation and decreased pasture yields (Sparling et al. 2008).The mean value of macroporosity was 12.2% well within the target of 6-30%. The majority of the sites (94%) were within the target range, but implies that some degree of compaction can occur in dairy farm pastures. It should be noted that the majority of the soil types sampled are resistant to structural issues such as compaction.

The mean bulk density of 0.81t/m^3 was within the target range of 0.5 – 1.4 t/m^3. All sites were within this target range, which is consistent with previous monitoring periods. This shows that there is no significant trend in soil health as far as physical soil quality is concerned.

The number of exceedances of soil targets for Olsen P and Total Nitrogen (TN) has increased across each sampling period. This is consistent with the noted increases in total nitrogen, ANM and Olsen P concentrations.

Table 2 Topsoil qualities of dairy pasture sites sampled in 2014 and their comparison with the provisional target soil qualities for pasture soils.

	pH	Total C%	Total N%	C/N ratio	Olsen P (mg/kg)	Phosphate retention %	Bulk density (t/m^3)	Macro-porosity (%)
Pasture soil quality targets	5.0-6-6	>2.6	0.25-0.70	8-12	20-50	10-90	0.5-1.4	6-30
Mean	5.9	8.0	0.76	10.3	99.8	49.6	0.81	12.2
Total no. of dairy sites	18	18	18	18	18	18	18	18
No. of sites meeting target	18	18	6	18	11	18	18	17
No. of sites not meeting target	0	0	12	0	7	0	0	1
No. of sites below target	0	0	0	0	0	0	0	1
No. of sites above target	0	0	12	0	7	0	0	0
Percentages of sites meeting target	100	100	33.3	100	61	100	100	94

Note: Where target is not a range (e.g. >2.5%) number and percentage of sites above target are set to 'not applicable' (na) since there is no set upper limit.

3.2 Exchangeable cations

Exchangeable calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) are analysed for all sites.

Cation exchange (CEC) provides a measure of the number of cation-exchange sites available. As it is essentially a surface reaction it is a function of the amount and type of the small particle size fractions present, such as clay and organic matter. This can be misleadingly high because of pH-dependent charge effects of the amorphous clay minerals present in soils containing much volcanic ash. All sites sampled meet the set targets.

Base saturation (%BS) provides a measure of the state of leaching of the soil (e.g. %BS of less than 30% indicates strong leaching). It provides a useful indicator of fertility in that it gives a measure of the base status of the soils. However, BS may be abnormally low in soils which contain volcanic ash because of the effect of the amorphous clay (allophane) on the CEC.

Table 3 shows that three weakly leached sites are above the set target.

Exchangeable calcium (Ca) is not normally a limiting plant nutrient, but it is usually the most abundant exchangeable base in the soil. It largely controls the base status and thus the pH. Table 2 shows that the majority of sites (14 of the 18 sites) exceed the target of 10 cmol/kg).

Exchangeable magnesium (Mg) levels are high to medium and two sites have low levels. However all sites are above 0.5 cmol/kg and have exchangeable magnesium levels within the target.

Almost half the pastures (8 out of 18) have somewhat excessively high exchangeable potassium (K) levels. 10 out of 18 sites had adequate exchangeable potassium levels

Exchangeable sodium (Na) levels tend to be low (between 0.1 and 0.3 cmol/kg) but all sites are within target. Only three out of 18 sites were above 0.3cmol/kg.

Table 3 Exchangeable cations values of dairy soils sampled in 2014 and their comparison with the provisional target soil qualities for pasture soils.

	Exch. Ca	**Exch. Mg**	**Exch. K**	**Exch. Na**	**CEC**	**BS**
Pasture soil quality targets.	5-10	0.5-7	0,3-1.2	0.1-2	4-40	20-80
Mean.	13.3	2.43	1.36	0.23	-	-
No of sites meeting target.	4	18	10	18	18	15
No of sites above target.	14	0	8	0	0	3
Percentages of sites meeting target (%).	22	100	56	100	100	83

Part 4: Conclusion and recommendations

Topsoil quality parameters of 18 dairy pasture sites were compared with the provisional target values set by Sparling *et al*, 2008. The steady increase in the levels of total N and Olsen P over the last 15 years that these sites have been sampled, are of concern. Although anaerobically mineralisable nitrogen was not analysed during this monitoring period, previous monitoring periods have shown a dramatic increase in the amount of nitrogen contained in soils on dairy farms. Increased N often leads to increased nitrate leaching and high values of Olsen P could lead to P-laden sediment increasing the risk of eutrophication of streams and other water bodies.

Very high levels of P and N from intensification are an unnecessary expense representing an economic loss to the land manager. Dairy farmers should therefore continue to exercise judicious use of fertilisers, especially P and N, through periodic soil testing and farm nutrient budgeting.

The NERMN soil quality monitoring programme is invaluable in informing land managers of changes in the soil quality of their properties over time, particularly when there are clear trends in declining soil health, so that remedial actions can be promptly undertaken. Generally changes in soil health occur over longer time periods, including for decline or improvement.

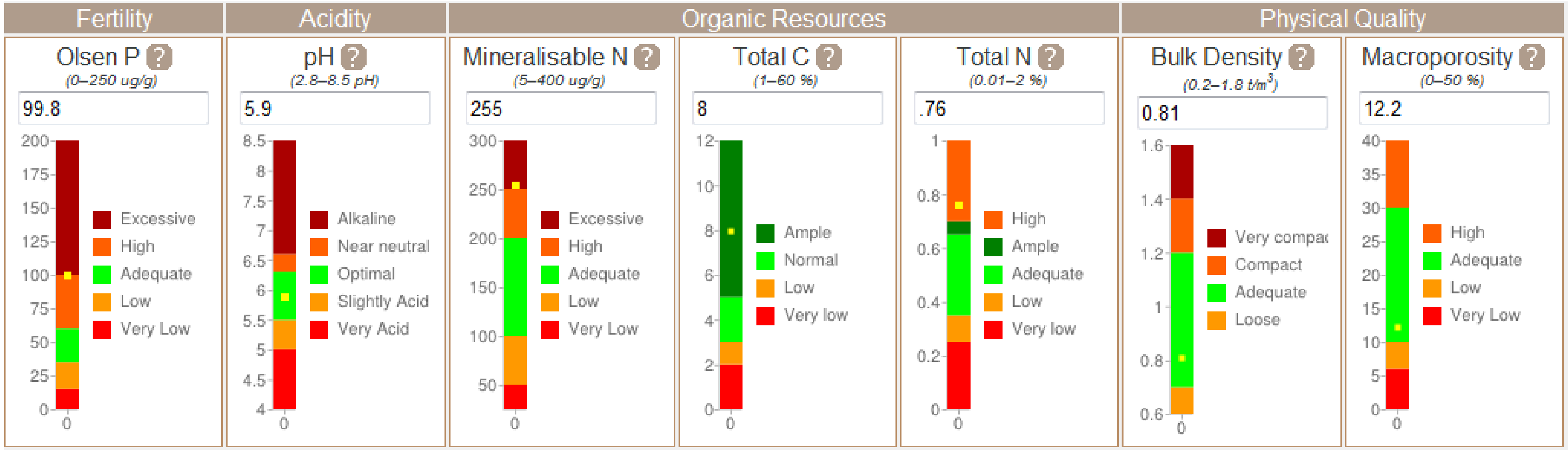
Soil quality monitoring should be continued with the following considered to improve the quality of the current monitoring program:

1. Continued inclusion of trace elements in the regular monitoring,
2. Expansion of the number of sites, specifically where there is a change of land use such as forests converted to pasture or where more details soil health information is required,
3. Inclusion of more biological measures of soil quality such as microbiological biodiversity (earthworms, microbiological activity), respiration, microbiological biomass, soil enzyme activity, etc. as an indication of soil well-being. The impacts of the long-term use of pesticides (especially herbicides) on soil microbial population and diversity may be assessed in this way.

Table 4: Soil health indicator status for dairy farm in the Bay of Plenty

Soil characteristic	Status
Fertility	Of concern
Acidity	Optimal
Organic Resources	High
Physical Quality	Optimal

Figure 3: Mean 2014[1] sampling results shown using Landcare Research's SINDI[2]



[1] Mineralisable N is from 2009 sampling period
[2] http://sindi.landcareresearch.co.nz/

Part 5: References

Blakemore, L.C.; Searle, P.L. and Daly, B.K. 1987: Methods for chemical analysis of soils New Zealand Soil bureau Scientific Report 80.

Guinto, D 2009: Soil Quality in the Bay of Plenty: 2009 Update. Environment Publication 2009/14. Environment Bay of Plenty.

Rijkse,W. and Guinto, D. 2010: Soils of the Bay of Plenty Volume 1, 2 and 3. Environment Bay of Plenty, Environmental Publication 2010/11-1; 11-2 and 11-3.

Sparling,G. 2001: Summary of sites, soil types, soil orders, land use, and laboratory analyses for soil quality characteristics of all sites sampled under the 500 Soils Project in the Bay of Plenty 1998-2001 (June 2001) Manaaki Whenua Landcare Research, Hamilton.

Sparling, G. and Rijkse,W. 2003. Implementing soil quality indicators for land: Arable sites in the Bay of Plenty, 2003. Landcare Research Contract Report LC0304/019 (September 2003) Manaaki Whenua Landcare Research, Hamilton.

Sparling, G. 2004: Soil quality in the Bay of Plenty Region in 2004: changes since 1998-2000. Landcare Research Contract Report 0405/002 (August 2004). Manaaki Whenua Landcare Research, Hamilton.

Sparling, G. 2005: Soil quality in the Bay of Plenty Region in 2004-2005: Changes since 1998-2000. Landcare Research Contract Report LCR0405/134 (June 2005). Manaaki Whenua Landcare Research, Hamilton.

Sparling, G. 2006a: Soil quality in the Bay of Plenty Region in 2006: Comparison with previous samplings in 1998-2000 revisited. Landcare Research Contract Report 0506/153 (November 2006) Manaaki Whenua Landcare Research, Hamilton.

Sparling, G. 2006b: An overview of soil quality in the Bay of Plenty 1998-2006: Comparison with data of other regions. Landcare Research Contract Report LC 0607/054 (December 2006) Manaaki Whenua Landcare Research, Hamilton.

Sparling, G. ; Lilburne, L. and Vojvodic-Vukovic, M. 2008: Provisional targets for soil quality indicators in New Zealand. Landcare Research Science Series No. 34. Manaaki Whenua Press, Lincoln, Canterbury, New Zealand.

Sparling, G. and Schipper, L. 2002: Soil quality at a national scale in New Zealand. Journal of Environmental Quality 31: 1848-1857.

Sparling, G. and Schipper, L. 2004: Soil quality monitoring in New Zealand: Trends and issues arising from a broad scale survey 1995-2001. Agriculture, Ecosystems and Environment 104: 545-552.

Appendices

Appendix 1 – Summary information for dairy sample sites

Site	Sample no.	Year establishment	Land use	Soil type	NZ Soil Classification (Order Level)
15	1	1999	Dairying	Rotomahana sandy loam.	Recent
16	1	1999	Dairying	Horomanga sand.	Pumice
17	1	1999	Dairying	Galatea sand.	Pumice
18	1	1999	Dairying	Oropi loamy coarse sand.	Pumice
18	2	1999	Dairying	Oropi hill soils.	Pumice
18	3	1999	Dairying	Kawhatiwhati sand.	Pumice
19	1	1999	Dairying	Opouriao fine sandy loam.	Recent
29	1	2000	Dairying effluent	Kaingaroa gravelly sand.	Pumice
29	2	2000	Dairying	Kaingaroa gravelly sand.	Pumice
31	2	2000	Dairying	Opouriao fine sandy loam.	Recent
33	1	2000	Dairying	Otara silt loam.	Recent
49	1	2000	Dairying effluent	Oturoa loam.	Allophanic
49	2	2000	Dairying	Oturoa loam.	Allophanic
50	1	2000	Dairying	Oturoa loam.	Allophanic
53	1	2000	Dairying	Katikati sandy loam.	Allophanic
57	1	2000	Dairying	Paroa silt loam on peat.	Gley
59	1	2000	Dairying	Paroa silt loam on peat.	Gley
63	1	2000	Dairying	Katikati sandy loam.	Allophanic

Appendix 2 – Glossary of some soil quality terms

Bulk density gives a measure of how densely a soil is packed (dry mass divided by total volume). Soils typically have about half of their volume comprised of voids (pore spaces). If these voids are lost through compaction, bulk density increases. The voids hold water and air and also allow water and air move through the soil. Compacted soils have poor aeration, are slow draining, and roots find it difficult to grow and push through such a soil. Bulk density is influenced by the amount of organic matter in soils, their texture constituent minerals and porosity. Soils with very low bulk density are open textured and porous, but may be so loose that they are susceptible to erosion, dry out quickly and roots find it difficult to absorb water and nutrients.

C/N ratio Obtained by dividing the soil's total C with total N, this ratio provides a measure of organic matter quality. Soil organic matter is important as it is a reserve of soil nutrients, it holds moisture and helps stabilise soil aggregates and thus maintain good structure. The quantity of organic matter present in the soil, and its state of decomposition, depends on a balance between the addition of raw organic matter as plant or animal tissue, and its breakdown or mineralisation by organisms. Generally under cropping conditions organic matter will decrease but under continuous vegetation cover it will accumulate until equilibrium is reached. The state of decomposition is indicated by the C/N ratio. The raw or little decomposed material having a ratio greater than 15, and well decomposed humus of arable soils being about 10 to 12.

Macroporosity is a measure of the number of large pores in the soil. Large pores are defined having a diameter greater than 60 micrometers (um). Micropores are important for air penetration into soil, and are the first pores to be lost when soils are compacted. Low macroporosity reduces soil aeration, resulting in less clover growth and N-fixation and decreased pasture yields.

Olsen P is the standard method used in New Zealand to assess soil phosphorus (P) availability to plants. Phosphate is the only form of P taken up by plants. There is very little phosphate in the soil solution as most 'available' phosphate is adsorbed onto clays and organic matter. The Olsen extractant tries to mimic the ability of a plant to remove solution and adsorbed phosphates from soil, and hence get a measure of the P status for plant nutrition. Olsen P has been measured in many agronomic tests for crop production, and is used to calculate rates of fertiliser application.

Provisional (soil quality) targets refer to the numerical ranges of soil quality indicators deemed desirable either from a production or from an environmental protection standpoint as detailed in the Landcare Research publication "Provisional Targets for Soil Quality indicators in New Zealand" (Sparling et al. 2008).

Soil pH is an indication of the acidity or alkalinity of the soil. It is a measure of the number of hydrogen (H+) ions in the solution. A pH of 7 is termed neutral, below 7 is acidic, and above 7 is alkaline or basic. Most plants and animals have an optimum pH range for growth, and the pH of soil affects which species will grow best by influencing the availability of soil nutrients. Most forest soils in New Zealand are acidic, and indigenous forest species are generally tolerant of acidic soil conditions. Introduced exotic pasture and crop species require a more alkaline soil. Excess soil acidity is normally corrected by topdressing with lime (ground limestone) to raise the pH.

Soil quality (or soil health) is the capacity of a specific kind of soil to function within natural or managed ecosystems to sustain plant and animal productivity, or maintain or enhance water and air quality and support human health and habitation. Changes in the capacity of soil to function are reflected in the soil properties that changes in response to management or climate.

Total Carbon (C) measures the amount of carbon in the soil. This includes carbonates and soil organic matter C, but New Zealand soils typically contain very little carbonate, so total C is a good measure of organic matter C. Organic matter is important for soil quality because it helps soils retain moisture and nutrients, and gives good soil structure for water movement and root growth. Once depleted, organic matter takes many years to replace, and its careful conservation is recommended by agronomists and soil scientists.

Total Nitrogen (N) is a measure of the total amount of all forms of nitrogen in the soil. Typically in topsoils, organic matter N makes up more than 90% of the total N. Nitrogen is an essential major nutrient for plants and animals, and the store of organic matter N is an important measure of soil fertility. Organic N needs to be mineralised to inorganic forms (ammonium and nitrate) by soil-micro-organisms before it can be used by plants.

Exchangeable cations, which collectively determine the base status, are calcium, magnesium, potassium and sodium.

Exchangeable calcium (Ca) is not normally a limiting plant nutrient but as it is normally the most abundant exchangeable base in the soil it largely controls the base status and thus the pH.

Exchangeable magnesium (Mg) levels tend to be medium to high levels in weakly weathered and recent soils and low in the soils at higher altitude and rainfall.

Exchangeable potassium (K) levels are generally of medium to high levels.

Exchangeable sodium (Na) is low in most soils and medium in wet soils.