Comparison of soil quality targets and background concentrations in soil of the Waikato Region, New Zealand

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Abstract
Current targets used for assessing soil quality in New Zealand were compared with 95% confidence intervals of measurements of background soils from the Waikato region, New Zealand. Indicators analysed included pH, total C and N, Olsen P, anaerobically mineralised N, bulk density, macroporosity, aggregate stability, As, Cd, Cr, Cu, Hg, Pb, Ni and Zn.

While background concentrations are easily applied to some measurements (metals), for other soil quality measurements (particularly those with optimum ranges rather than just maximum allowable limits such as bulk density and macroporosity) the concept is more difficult to apply. Background sites met the targets for pH, total C, aggregate stability, Zn, Cu, Pb, As, Cr Ni, Cd and Hg. Some background sites didn't meet the targets for Olsen P, as New Zealand soils are naturally low in phosphorous. Also, some sites didn't meet the targets for bulk density and macroporosity indicating an erosion risk. Targets for total N and anaerobically mineralised N on their own are inadequate to assess N status and the N leaching risk, and trends in these measurements may be more valuable than meeting an actual target.

Key Words
Background, soil quality, indicators.

Introduction

Regional environmental authorities in New Zealand have been monitoring soil quality since 1995. A set of indicators was agreed upon and the majority of target values were set by "expert" opinion (or for metals, adoption of guidelines from NZWWA). Currently these target values are being reviewed. Expert opinion target values were based on a "fitness for use" standard and one concern has been the applicability of these target values to indigenous systems.

Background concentrations of soil properties provide a reference for assessing the impacts of anthropogenic activity, including changes in land uses. The Ministry for the Environment's Contaminated Land Management Guideline number 4 (MfE 2006) defines background concentration as: "An estimate of the natural concentration of a substance (element, compound or mixture) that would exist in the absence of any anthropogenic input, usually on a regional, sub-regional or catchment basis". For chemical elements in soils, the background concentration is expected to show some broad-scale variation depending on the nature of the geochemical parent materials. Other factors that affect background levels are natural surface inputs (volcanic ash, dust, fluvial deposition and atmospheric aerosol deposition) and disturbances such as a tree turnover. Consequently, background soil properties can vary widely. A site is considered to be above background concentrations when the concentration of a contaminant is clearly higher than its background concentration. Factors such as the confidence limit (95% CL) of the background concentration, the number of samples collected and their representativeness, observed or expected variability associated with sampling and analysis, and applicable guideline values are considered in the assessment. In this study, background levels for soil quality indicators from indigenous sites throughout the Waikato region were assessed and compared with suggested target values.

Methods

Background sites were identified on the basis of their current land use and what is known of their land use history. They were long-term forest or wetlands, with minimal influence from anthropogenic activities for the life of the vegetation or longer. Some of these sites may have been logged or cleared by early generations, but atmospheric inputs in New Zealand soils are relatively low, and for the most part these sites are regarded as being close enough to background to serve as a useful point of comparison. Sampling for chemical and biochemical indicators consisted of 25 soil cores (0-100 mm, 25mm diameter) over a 50 m transect, which are combined to form composites for analysis (Sparling *et al*. 2002). Sampling for physical

indicators consisted of 3 soil cores (10-90 mm, 100mm diameter), which are individually analysed and the results averaged for each site.

Samples are analysed for an established set of soil quality chemical and physical parameters following Sparling *et al*. (2002) and for trace elements following EPA 200.2 (total recoverable metals hydrochloric/nitric acid digestion). Measurements were made at IANZ-accredited laboratories (soil quality chemistry at Landcare Research, Palmerston North, soil quality physical parameters at Landcare Research, Hamilton, aggregate analysis at Plant & Food Research, Lincoln and elemental analysis by ICP-MS at Hill Laboratories, Hamilton).

Results and discussion

Background measurements of soil chemical and physical soil quality indicators found in the Waikato region were identified and 95% confidence limits fitted (Table 1). The 95% confidence limits of pH, aggregate stability, Zn, Cu, Pb, As, Cr Ni, Cd and Hg fitted into clear categories when compared with current targets for soil quality parameters for forests.

Table 1. Average background concentrations of soil quality indicators in Waikato mineral soils.

Element	Average	95% CL	n	Current target rating
pH	5.2	4.5-5.7	36	Optimal[1]
Total C (%)	8.3	3.5-16.0	36	Normal to ample[1]
Total N (%)	0.45	0.18-0.91	36	Depleted to high[1]
Olsen P (mg/kg)	6.6	1.1-14.9	36	Very low to adequate[1]
Anaerobically mineralised N (mg/kg)	117	46-225	35	Adequate to excessive[1]
Bulk Density (t/ha)	0.69	0.41-1.01	35	Very loose to adequate[1]
Macroporosity (% at -10 kPa)	22	8-39	35	Low to high[1]
Aggregate stability (MWD, mm)	2.21	1.96-2.62	13	Optimal[2]
Zn (mg/kg)	29.9	11.2-57.4	26	Below guidelines[3]
Cu (mg/kg)	13.8	5.1-27.3	26	Below guidelines[3]
Pb (mg/kg)	10.3	3.1-25.6	25	Below guidelines[3]
As (mg/kg)	4.9	0.70-9.0	26	Below guidelines[3]
Cr (mg/kg)	4.56	0.75-10.7	26	Below guidelines[3]
Ni (mg/kg)	3.18	0.69-9.19	25	Below guidelines[3]
Cd (mg/kg)	0.12	0.04-.28	26	Below guidelines[3]
Hg (mg/kg)	0.11	0.05-0.27	26	Below guidelines[3]

[1] Sparling *et al*. (2003)
[2] Beare *et al*. (2006)
[3] NZWWA (2003)

Total carbon fitted across two categories but both these are considered as meeting soil quality targets.

Total N ranged from one extreme to the other. Too little total N in managed land uses restricts production due to N deficiency and too much increases the risk of N leaching. Too little labile N is not likely to be harmful in native systems as they are often adapted to low nutrient conditions. Too much available N however has been linked to forest degradation in northern hemisphere forests subjected to high atmospheric N deposition. Total N on its own appears inadequate to measure nitrogen status for soil quality assessment (Taylor 2009). Trends in total N may be more valuable than meeting an actual target.

Olsen P ranged from very low to adequate, supporting the view that New Zealand soils are regarded as being naturally low in P (McLaren & Cameron 1990). The very low rating is outside the soil quality target, but many indigenous forests are considered P limited (Parfitt *et al*. 2005) and it is possible that higher P levels could result in changes in competitive dynamics between species.

Anaerobically mineralised N ranged from adequate to excessive. Too little anaerobically mineralised N restricts production, while too much (excessive rating) indicates an increased risk of nitrogen transfer. However, anaerobically mineralised N was strongly positively correlated with total carbon (R=0.696,

p<0.0001), which reduces the N leaching risk due to sorption of N. This result supports the view that high anaerobically mineralised N on its own is inadequate to measure the risk of nitrogen transfer to water or the atmosphere (Taylor 2009). Trends in anaerobically mineralised N may be more valuable than meeting an actual target.

Bulk density ranged from very loose (low bulk density) to adequate and this property is strongly influenced by soil type (Table 2). The target range is met if bulk density is rated loose or adequate. Targets are not met if soils are rated very loose or compact (no background sites were rated compact). Soils of the Waikato region, generally, have low bulk density and these soils could have an increased erosion risk if cleared of vegetation. This risk is identified by the current soil quality targets for bulk density. However, it is debatable if low bulk density soils are non-desirable as these soils are in their natural state and have successfully supported the native vegetation for centuries. To say that these soils do not meet soil quality targets is, therefore, incorrect. The bulk density indicator is providing warning of the fragility of some of the soils of the Waikato region.

Table 2. Mean surface (0-100 mm) bulk density and macroporosity (-10kPa) measurements of different soil orders averaged over all land uses in Waikato soils

Soil Order[1]	Bulk density (t/ha)		Macroporosity (-10 kPa) (%)		n
	Average	95% CL	Average	95% CL	
Podzols	0.53	0.42-0.64	30	16-40	10
Pumice Soils	0.64	0.49-0.80	24	7-43	34
Allophanic Soils	0.70	0.49-0.88	16	4-36	56
Gley Soils	0.85	0.57-1.04	13	6-23	24
Recent Soils	0.87	0.71-1.04	17	6-47	9
Brown Soils	0.91	0.76-1.11	13	6-23	27
Granular Soils	0.97	0.72-1.32	15	2-28	17

[1] Hewitt 2002, New Zealand Soil Classification

Macroporosity had a very wide range of categories, from low to high. Also, like bulk density, macroporosity is strongly influenced by soil type (Table 2) and the two measurement are strongly negatively correlated (r=0.732, p=<0.0001). Targets are met if the macroporosity rating is low or adequate. Targets are not met if the rating is very low or high. Very low macroporosity inhibits soil aeration and plant root growth, while high macroporosity is indicative of an increased erosion risk, similar to low bulk density. A similar argument to that for bulk density applies. It is questionable if high macroporosity soils are non-desirable as these soils are in their natural state and have successfully supported the native vegetation for centuries. To say that these soils do not meet soil quality targets is, therefore, incorrect. Like bulk density, the macroporosity indicator is providing warning of the fragility of some of the soils of the Waikato region.

Conclusion

Background concentrations are easily applied to some measurements (e.g. metals) but for other soil quality measurements (e.g. bulk density and macroporosity) the concept is more difficult to apply. Background sites met the targets for pH, total C, aggregate stability, Zn, Cu, Pb, As, Cr Ni, Cd and Hg. Some background sites didn't meet the targets for Olsen P, as New Zealand soils are naturally low in phosphorous. Also, some sites didn't meet the targets for bulk density and macroporosity. However, it is questionable if these soils are non-desirable as they are in their natural state and have successfully supported the native vegetation for centuries. Targets for total N and anaerobically mineralised N on their own are inadequate to assess nitrogen status and risk of transfer to other parts of the environment. Trends in anaerobically mineralised N over time may be more valuable than meeting an actual target.

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