CHANGES IN TOPSOIL QUALITIES OF DRYSTOCK PASTURE AND KIWIFRUIT ORCHARD SITES IN THE BAY OF PLENTY

Dani Guinto

Bay of Plenty Regional Council, P O Box 364, Whakatāne 3158

Abstract
Temporal changes in topsoil (0-10 cm) qualities of drystock (sheep/beef and deer) and kiwifruit orchard sites were monitored periodically over a 10-year period. Results indicate that for the land uses considered, many of the topsoil quality indicators were being maintained and these are within the provisional target values set by Landcare Research for production and/or environmental criterion. However, the current high level of anaerobically mineralisable N (close to 200 mg/kg) in the drystock sites will need to be monitored closely because further increase could lead to significantly higher nitrate leaching and subsequent eutrophication of water bodies. In the case of kiwifruit land use, there was an increasing temporal trend in Olsen P values. The current Olsen P mean value exceeded the 100 mg/kg target and is a cause of concern because high Olsen P levels could lead to P-laden sediment polluting streams and other water bodies. Since kiwifruit does not require high P input for high productivity, application of P fertilisers can be reduced significantly.

Introduction
As part of its Natural Environment Regional Monitoring Network (NERMN) programme, the Bay of Plenty Regional Council (BOPRC) has been collecting soil quality or soil health data since the late 1990's when it participated in the 500 Soils Project involving various regional councils in New Zealand (Sparling and Schipper 2002; 2004). Over the years, a total of more than 70 soil quality sites have been progressively established under various land uses. The sites were categorised by land use which include: cropping (maize), dairy, sheep and beef, deer, kiwifruit and forests (indigenous and plantation). Sampling frequencies differ and depend on the degree of soil disturbance or cultivation. Thus, cropping sites are sampled every three years, dairy, sheep and beef, deer, and kiwifruit sites every five years, and forest sites every 10 years. The status of soil quality in the region has been reported periodically by Landcare Research (Sparling 2001; Sparling and Rijkse 2003; Sparling 2004; Sparling 2005; Sparling 2006a; Sparling 2006b) for all land uses and more recently by Guinto (2009) for dairy pasture and maize cropping sites. This report focuses on the results of the 2010 soil quality sampling which covered drystock (sheep/beef and deer pastures) and kiwifruit orchard sites.

Materials and Methods
Soil sampling and analyses
The standard protocol for New Zealand soil quality sampling was followed (Hill and Sparling 2009). A 50 m transect was established in each site. For chemical analyses, topsoil samples (0-10 cm) were collected with a step-on soil sampler at 2 m intervals along the 50 m transect. The individual samples collected were bulked and mixed thoroughly in a plastic bag. For physical analyses, three stainless steel soil cores (10 cm diameter, 7.5 cm high) were taken at 15, 30 and 45 m along the transect. It should be noted that the standard 0-10 cm topsoil

sampling depth represents a compromise for pasture and horticultural land uses since pasture soils are normally sampled at 0-7.5 cm while kiwifruit soils are sampled at 0-15 cm.

In samplings previously conducted by Landcare Research on these three land uses (Sparling 2001; 2005), there were a total 19 soil quality sites consisting of 10 sheep/beef pasture sites, four deer pasture sites and five kiwifruit orchard sites (Figure 1). However, for the 2010 resampling, one sheep/beef landowner and one deer farm landowner did not allow access to their farms which reduced the total number of sites sampled to 17.

The samples were submitted to Landcare Research laboratories (Hamilton for physical analyses and Palmerston North for chemical analyses) for the analysis of seven standard soil quality indicators, namely: pH, total carbon (C), total nitrogen (N), anaerobically mineralisable N, Olsen phosphorus (P), bulk density and macroporosity. The C/N ratio was obtained by dividing total C with total N (Hill and Sparling 2009).

Data analysis

Mean values of topsoil qualities by land use class were compared with the "target" or "desirable" qualities set as provisional soil quality target values for New Zealand (Sparling et al. 2008). These provisional standards have been adopted by many regional councils represented by the Land Monitoring Forum (LMF). The standards are grouped according to land use and/or soil classification. Previous results from drystock and kiwifruit sites sampled in 1999/2000 and 2004/2005 reported by Landcare Research (Sparling 2001; 2005) were also presented in order to show trends over time. For each land use, analysis of variance was employed to detect if there are statistically significant changes in topsoil qualities over time ($P<0.05$).

Results and Discussion

Temporal trends in topsoil qualities of sheep/beef sites

Table 1 shows the trends in topsoil qualities of sheep/beef sites over a ten-year period. Changes in all topsoil quality indicators were not statistically significant ($P>0.05$). Soil pH increased slightly over time. The mean pH values in each sampling year lie within the provisional target range of 5.0 to 6.6.

The increases in total C and total N were not significant (ns) as is the decrease in C/N ratio. Mean values for each year for these three indicators were all within their respective provisional targets.

Mean anaerobically mineralisable N was high (193 mg/kg) during the initial sampling in 2000, declined in the 2005 sampling (137 mg/kg), and increased again in 2010 close to the initial mean value (189 mg/kg). These changes, however, were not statistically significant ($P=0.084$) and the mean values lie within the 50-250 mg/kg provisional target for pasture soils. In the soil quality monitoring results obtained under dairy farming (Guinto 2009), the initial and intermediate mean mineralisable N values were much lower (72 mg/kg in 1999/2000 and 155 mg/kg in 2004) relative to the sheep/beef results. However, in the latest sampling in 2009, it jumped to 256 mg/kg which exceeded the upper limit of the target range so that concern for increased nitrate leaching is a more significant issue in dairy farming compared with sheep/beef farming.

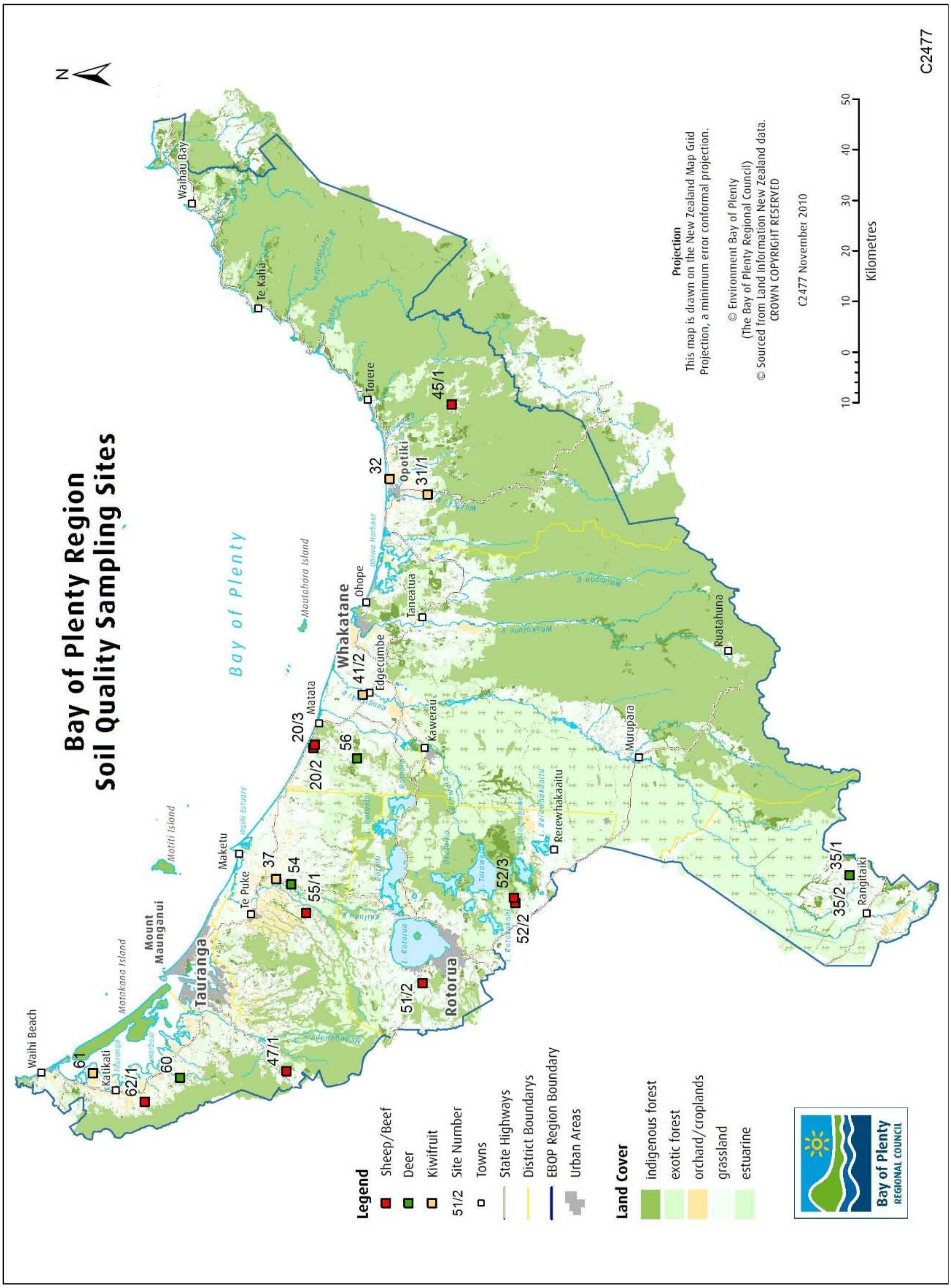

Figure 1. Soil quality sampling sites by land use.

Mean Olsen P values increased from 26 mg/kg in 1999/2000 to 44 mg/kg in 2010. This represents a 69% increase and reflects the continual application of phosphate fertilisers in these sheep/beef farms. However, this change was not statistically significant (*P*=0.430). This build up of P is also below the upper target Olsen P level of 100 mg/kg. However, if this increasing trend continues into the future, this would clearly be a more significant issue for this land use since excessive levels of phosphate in the soil may contribute to the eutrophication of rivers and lakes through sediment-laded runoff.

There was little change in bulk density with time. Mean bulk density values in each sampling year lie within the provisional target range of 0.5 to 1.4 t/m^3. Macroporosity decreased slightly in 2005 but recovered to just above the initial mean value in 2010. Mean values for each sampling year lie within the provisional target range of 6 to 30%.

Table 1. Temporal changes in topsoil qualities of sheep/beef pasture sites with respect to pH, total C, total N, C/N ratio, anaerobically mineralisable N, Olsen P, bulk density, and macroporosity (n=10 in 1999/2000 and 2005; n=9 in 2010)

Soil Quality	**Year**			
	1999/2000	**2005**	**2010**	***P* value**
pH	5.6	5.7	5.8	0.631 ns
Total C (%)	6.7	7.7	7.7	0.542 ns
Total N (%)	0.51	0.61	0.64	0.340 ns
C/N ratio	13.2	12.5	12.1	0.500 ns
Mineralisable N (mg/kg)	193	137	189	0.084 ns
Olsen P (mg/kg)	26	38	44	0.430 ns
Bulk Density (t/m^3)	0.79	0.81	0.77	0.905 ns
Macroporosity (%)	18.9	16.4	19.8	0.707 ns

ns = not significant

Temporal trends in topsoil qualities of deer sites

Table 2 shows the trends in topsoil qualities of deer sites over a ten-year period. Similar to the sheep/beef sites, changes in all topsoil quality indicators were not statistically significant (P>0.05). Soil pH remained stable over time. The mean pH values in each sampling year lie within the provisional target range of 5.0 to 6.6.

Relative to their initial mean values, both mean organic carbon and total nitrogen increased over time. However, the increases were not considered as statistically significant (*P*=0.086 for total C and *P*=0.055 for total N). Mean values for each year for both total C and total N were all within their respective provisional targets. The mean C/N ratios were all close to 12 and remained fairly constant through time (*P*=0.823).

Mean anaerobically mineralisable N was high (158 mg/kg) during the initial sampling, declined in the 2005 sampling (139 mg/kg) and increased again in 2010 exceeding the initial mean value (179 mg/kg). These changes, however, were not statistically significant (*P*=0.222).

Mean Olsen P values increased from 42 mg/kg in 2000 to 67 mg/kg in 2010 with percentage change similar to the sheep/beef sites (60% increase). This change was also not statistically significant (*P*=0.314). This build-up of P is still below the upper target Olsen P level of 100 mg/kg but if this trend continues, deer farming may potentially contribute more to the eutrophication of water bodies relative to sheep/beef farming due to the higher Olsen P values involved.

Like the sheep/beef sites, there was little change in bulk density over time on the deer sites (means ranged from 0.70 to 0.78 t/m^3) and these values lie within the provisional target range of 0.5 to 1.4 t/m^3. Macroporosity was also maintained close to 20% with mean values for each sampling year which are within the provisional target range of 6 to 30%.

Table 2. Temporal changes in topsoil qualities of deer pasture sites with respect to pH, total C, total N, C/N ratio, anaerobically mineralisable N, Olsen P, bulk density, and macroporosity (n=4 in 2000 and 2005; n=3 in 2010)

Soil Quality	**Year**			
	2000	**2004/2005**	**2010**	***P* value**
pH	5.8	5.8	5.7	0.892 ns
Total C (%)	5.9	8.6	7.8	0.086 ns
Total N (%)	0.48	0.72	0.65	0.055 ns
C/N ratio	12.4	12.0	11.9	0.823 ns
Mineralisable N (mg/kg)	158	139	179	0.222 ns
Olsen P (mg/kg)	42	50	67	0.314 ns
Bulk Density (t/m^3)	0.70	0.78	0.75	0.746 ns
Macroporosity (%)	22.7	20.0	24.1	0.772 ns

ns = not significant

Temporal trends in topsoil qualities of kiwifruit sites

Table 3 shows the trends in topsoil qualities of kiwifruit sites over a ten-year period. Similar to the sheep/beef and deer sites, there were no statistically significant changes in soil quality indicators with the exception of the C/N ratio and a nearly significant change in Olsen P.

Soil pH was fairly stable (6.5-6.6) throughout the ten-year period and are within the provisional target range of 5.0-7.6. There was some decline in mean total C and total N values but the changes were not statistically significant. Both soil quality indicators remain high under kiwifruit land use.

There was a statistically significant decrease in the C/N ratio (*P*=0.026) indicating that N mineralisation is progressively dominating over N immobilisation (net N mineralisation). Nevertheless, the mean values for all sampling periods still lie within the provisional target range of 8 to 20 for cropping/horticulture soils (production criterion) and 7-30 (environmental criterion).

The changes in anaerobically mineralisable N were not statistically significant (*P*=0.150) with mean values ranging from 100-140 mg/kg. These values are within the 20-200 mg/kg provisional target for cropping/horticulture soils.

An increasing trend in mean Olsen P values was observed (71 to 106 mg/kg) which proved to be almost statistically significant (*P*=0.051). Further analysis using a linear polynomial contrast showed that the linear trend was significant (*P*=0.033) indicating a projected build-up of Olsen P into the future if kiwifruit growers continue to add superphosphate fertiliser. The 2010 mean Olsen P value already exceeds the 100 mg/kg upper limit of the provisional Olsen P target range. As noted earlier (Section 3.3), the inputs of P (and N and K) in many kiwifruit farms in New Zealand are excessive (Carey et al. 2009) and it would it would be in the growers' best interest to reduce fertiliser input for both economic and environmental reasons.

There were no statistically significant changes in bulk density (*P*=0.765). The bulk density values (0.85-0.90 t/m^3) lie within the 0.5-1.4 t/m^3 provisional target. The macroporosity values declined over the ten-year period (from 16.1% in 2000 to13.1% in 2010) but this reduction was not statistically significant (*P*=0.540).

Table 3. Temporal changes in topsoil qualities of kiwifruit orchard sites with respect to pH, total C, total N, C/N ratio, anaerobically mineralisable N, Olsen P, bulk density, and macroporosity (n=5)

Soil Quality	**Year**			
	2000	**2005**	**2010**	***P* value**
pH	6.5	6.6	6.6	0.341 ns
Total C (%)	8.9	6.1	6.4	0.088 ns
Total N (%)	0.60	0.57	0.58	0.719 ns
C/N ratio	14.6	11.2	11.2	0.026 *
Mineralisable N (mg/kg)	117	100	140	0.150 ns
Olsen P (mg/kg)	71	71	106	0.051 ns
Bulk Density (t/m^3)	0.85	0.89	0.90	0.765 ns
Macroporosity (%)	16.1	14.1	13.1	0.540 ns

* = significant at 5% level; ns = not significant

Conclusion and Recommendations

For the land uses considered (sheep/beef, deer and kiwifruit), many of the topsoil quality indicators were within the provisional target values set by Landcare Research for production and/or environmental criterion and have not changed significantly over the ten-year period. However, the current high level of anaerobically mineralisable N (close to 200 mg/kg) in the sheep/beef and deer sites will need to be monitored closely because further increase could lead to significantly higher nitrate leaching and subsequent eutrophication of water bodies. In the case of kiwifruit land use, the increasing trend in Olsen P and the current Olsen P mean value exceeding the 100 mg/kg target is a cause for concern because high Olsen P levels could lead to P-laden sediment polluting streams and other water bodies. A recent report on the water quality status of Bay of Plenty rivers and streams (Scholes and McIntosh 2009) has shown that while there are a number of significant improving trends, the water quality of many rivers and streams is deteriorating. Mention was made of the Rotorua and Central rivers having elevated nitrogen and phosphorus levels attributed to nitrate leaching on pumice soils and phosphorus leached from the underlying geology.

In all land uses, farmers should continue to periodically test their soil's fertility levels and employ farm nutrient budgeting to optimise fertiliser application in order to reduce input cost and minimise nutrient pollution impacts on the environment.

Where feasible, adoption of precision agriculture techniques to optimise water and nutrient application rates to realise savings in energy, water and nutrients particularly in intensive land uses such as kiwifruit should be considered.

Acknowledgments
Thanks to Wim Rijkse of Land Use Consultants Ltd for assistance during the field soil sampling and Simon Stokes (Manager, BOPRC Land Resources Section - Eastern) for helpful comments on the report. Many thanks to the farmers and landowners who allowed soil quality sampling on their properties.

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