Soil Quality in Hawke's Bay 2011

Extensive Pasture

Prepared for

Hawke's Bay Regional Council

Prepared by

LOWE Environmental Impact

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EMT 12/09
HBRC Plan No. 4361

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Quality Assurance Statement		
Task	Responsibility	Signature
Project Manager:	Katie Beecroft	
Prepared by:	Sian Cass, Katie Beecroft	
Reviewed by:	Barry Lynch	
Approved for Issue by:	Hamish Lowe	
Status:	Final	

Prepared by:

Lowe Environmental Impact
P O Box 4467
Palmerston North 4462

| T | [+64] 6 359 3099
| E | office@lei.co.nz
| W| www.lei.co.nz

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1 EXECUTIVE SUMMARY

Hawke's Bay Regional Council (HBRC) are responsible for monitoring the soil quality of the Hawke's Bay region as part of their obligations under the State of the Environment (SoE) reporting. HBRC reviewed their soil monitoring programme in 2006 (Pearson & Reid, 2006). This provided a framework to selection process for sites to represent Hawkes Bay based on land form, soil order, soil types and land use. It also prioritized the soil quality indicators.

In 2009 the National Land Monitoring Forum (NLMF) produced robust guidelines from which councils can produce nationally consistent land monitoring procedures and reporting. This report examines soil quality of extensive pastoral land use in the Hawke's Bay. Soil quality is assessed in accordance with the recommendations of Pearson and Reid (2006) and the NLMF guidelines.

Extensive pastoral land use can be defined as land under low producing exotic grassland. The land has been modified by development of a pastoral system and establishment of exotic grass cover, often ryegrass. However it is distinguished from high producing pasture by lower inputs of fertiliser and little pasture improvement. Stocking rates are low and stock types (sheep, beef and deer) have a low management input. It should be noted that beef finishing and intensive beef production is not included in the extensive pastoral group.

Sampling for soil quality monitoring was delayed for 2011 due to an exceptionally wet autumn. During this period the Hawke's Bay and in particular the Eastern (coastward) Hawke's Bay experienced extensive land movement on rolling and steep country. Flooding and deposition occurred in some low lying areas. Land that is most vulnerable to slipping or inundation is typically managed extensively and so many sites visited in this sampling round had been affected by land movement.

Nineteen sites were sampled from extensive pastoral properties used for dry stock throughout Hawkes Bay. Results from the analysis of soil from each site enabled the following conclusions to be made:

- In general soil quality in the Hawke's Bay extensive pasture sites is good, although some care should be taken in interpretation of the results since sampled areas excluded sites of recent mass movement and likely future instability.
- Extensive pasture sites are expected to have low C, N and fertility status compared to other land uses (cropping, intensive pasture) and so changes over time are likely to be more important than a point in time review.
- Compared to previous soil physical condition of sampled soils the extensive pasture soils sampled in this round were within the target range for soil physical parameters. This is most likely due to lower instance of animal and machine tracking on extensive pasture sites.
- A high number of sites had P status outside of the target range. This indicates that low P status may be wide spread in the Hawke's Bay.
- Low P status should be addressed to avoid "knock-on" effects due to poor pasture cover and resulting risk of further loss of shallow soil (NB this does not address issues due to deeper failure of hillslopes).

Recommended actions coming from this report include:

- Further information and assistance to farmers is needed to maintain hill country soil cover.

- Managers of the properties sampled should be informed of the soil quality on their properties and where remedial activity is recommended HBRC may provide advice on potential management strategies.
- Land managers and advisors, including fertilizer representatives, may require information regarding the management of P on hill country soils. Specifically, the adoption of P forms best suited to soil type and land slope, and application regimes designed to optimise P use.
- The same sites should be resampled within 5 years and at ongoing intervals to develop a long term record of soil quality indicator performance over time.
- Comparison of soil quality under different land uses with the same soil type is recommended.

2 INTRODUCTION

2.1 Purpose

The purpose of this report is to provide Hawkes Bay Regional Council (HBRC) with an interpretive soil quality report based on laboratory and field data collected. This information is intended to contribute to the State of the Environment document. The data is collected from representative extensive pastoralism properties in the region and compared to interpretative frameworks developed by an expert panel and compared to data collected from previous sampling. These comparisons will help to identify changes and provide general statements on the regions soil condition.

2.2 Background

The HBRC is developing a database of soil condition from different land uses representative of the Hawkes Bay region. This database began with the "500 Soils Project" cofounded with the Ministry for the Environment (MfE) during 1999-2000. The MfE ceased involvement in the project in 2001 with the understanding that regions would continue monitoring and at a future date the 500 Soils Project sites would be resampled.

The HBRC reviewed their soil monitoring programme in 2006 (Pearson & Reid, 2006). This provided a framework to selection process for sites to represent Hawkes Bay based on land form, soil order, soil types and land use. It also prioritized the soil quality indicators. Previously sampled land uses were divided into intensive cropping, dairying and bull beef land use. The current report focuses solely on extensive pastoralism and is compared to data identified for bull beef properties in the 2007 report.

The Land Monitoring Forum that took place in 2009 produced robust guidelines from which councils can produce nationally consistent land monitoring procedures and reporting. This report examines soil quality of extensive pastoral land use in the Hawke's Bay. Soil quality is assessed in accordance with the recommendations of Pearson and Reid (2006) and the NLMF guidelines.

2.3 Scope

The scope of this report is to describe soils used for extensive pastoralism in the Hawkes Bay region.

- Section 3: Methods used to collect data.
- Section 4: Results from data collected with brief written interpretation.
- Section 5: Discussion
- Section 6: Conclusion
- Section 7: Recommendations

3 SOIL QUALITY AND LAND USE

3.1 Soil Quality Monitoring in the Hawke's Bay

Soil quality and land use impacts on soil quality are important indicators of the state of the environment. A clear procedure for the investigation of soil quality in New Zealand has been established. This report uses guidelines prepared by the National Land Monitoring Forum (2009) for the measurement and interpretation of soil quality. In addition, previous reports into soil quality in the Hawke's Bay have been reviewed and referenced through this report.

3.2 Land Use Definition

Extensive pasture land use has not been categorised as a land use group in previous sampling periods. The adoption of extensive pasture as a land use is in line with the NLMF guidelines which group pastoral land stocked with sheep/beef and deer as extensive pastoralism. The land use categories are defined so that they can be aggregated back to the New Zealand Land Cover Database.

Extensive pastoral land use can be defined as land under low producing exotic grassland. The land has been modified by development of a pastoral system and establishment of exotic grass cover, often ryegrass. However it is distinguished from high producing pasture by lower inputs of fertiliser and little pasture improvement. Stocking rates are low and stock types (sheep, beef and deer) have a low management input. It should be noted that beef finishing and intensive beef production is not included in the extensive pastoral group.

3.3 Soil Quality Indicators

Much investigation has been undertaken into the measurement of soil quality. In line with the recommendations of the Pearson and Reid (2006) the adopted indicators for the Hawke's Bay region follow the convention of the "500 Soils Project" (Sparling, *et al.*, 2001). The identified soil quality indicators are as follows:

Priority One: The Minimum Data Set

- Soil pH or soil acidity;
- Olsen P;
- Total C and N;
- Potentially mineralisable N;
- Bulk density;
- Macroporosity; and
- Aggregate stability (not analysed in this study).

Priority Two: Visual Soil Assessment (VSA; Shepard, 2000)

- % bare ground;
- % area of crusted soil and crust thickness;
- % area damaged soil surface; and
- Thickness of organic matter thatch.

Priority Three: Extra Measurements

- Exchangeable cations and cation exchange capacity;
- Heavy metals (As, Cd, Cr, Cu, Pb, Hg, Ni);
- DDT; and
- Hot water extractable C.

3.4 Trace Element & Organochlorine Pesticide Monitoring

Trace element and organochlorine pesticide measurement corresponds to the Priority Three indicators. While not considered fundamental to the measurement of soil quality they give important information about soil health on an individual property, and may identify sites where previous land use has had a detrimental effect on soil quality. If data from several properties exceeds guidelines for heavy metals it is recommended to pursue further investigation (Chapter 5: NLMF, 2009). Organochlorines are an indicator of land use impacts since they do not occur naturally. In addition the presence of elevated levels of organochlorine pesticides and trace elements indicates a limitation to land uses on the site.

Particular attention will be given to cadmium, fluorine and uranium that are known to accumulate in the soil when superphosphate has been applied. Use of a range of zinc containing products such as in antibiotics and fungicides are also common practice on pastoral farms, particularly facial excema preventative remedies (Kim & Taylor, 2009).

3.5 Historical State of Hawke's Bay Soils

The key concerns of Hawke's Bay soils that emerged from previous sampling were the physical conditions. Low macroporosity occurred under bull beef and dairy farming, with bull beef farms in particular falling below the target range in the 2007 sampling (Sparling & Stevens). Poor aggregate stability occurred in all land uses and soils, with many falling below the target range. This is consistent with half the sites in New Zealand used for dairying and nearly a third of drystock sites which have been described in the New Zealand Soil Health Report Card (NZSHRC) with compacted soils (MOE, 2010). The NZSHRC also states the organic reserves are above target ranges on a quarter of dairy and drystock sites, however in the Hawke's Bay organic reserves of cropping soils are often low not high. Fertility is below the target range for many drystock sites in New Zealand(MOE, 2010), and is also of concern on some Hawke' Bay soils. Low phosphorus levels have occurred and but also excess nitrogen.

The key objectives for soil quality monitoring is to determine if the soils are improving or declining over time and if the current state is good or bad. Hawke's Bay soils natural characteristics vary with the seven different soil orders sampled that have both high and low natural nutrient levels and both high and low macroporosity between them. Fertility can be managed and therefore low or excess levels sampled can be adjusted. The stability is more difficult but again careful farm management can minimize the impact of compaction although the Pallic and Brown soils that occupy half of the sites sampled have a naturally moderate to low macroporosity. Pallic soils can have a weak structure that is easily damaged.

Extensive pastoralism monitored for this report is best compared to soils used for bull beef production that were monitored in the 2007 report. Drystock typically farmed on extensive pastoralism would normally cater for sheep and or beef. Sheep farms sampled in this report may have the advantage of less compaction with smaller animals but more likely related to farm management.

The 2007 soil quality report (Sparling & Stevenson) highlighted distinct differences between land use for cropping, bull beef and dairy farming. Loss of organic matter was the key concern of cropped soil by comparison to low macroporosity in bull beef and dairy farmed soils.

4 METHODOLOGY

4.1 Site Selection

The method for site selection follows the recommendation of NLMF (2009). The selection of sites follows the recommendation of Pearson and Reid (2006). The report identified that extensive pastoral land use occurred on 8 soil orders across the Hawke's Bay Region (Table 1). A total of 22 soil types were considered to be representative of extensive pasture in the region.

In order to determine locations for the establishment of soil quality monitoring sites HBRC utilized existing soil and land use maps of the region. Overlays of land use and soil type were applied to property boundaries. Sites that were visited in the 2007 study (Sparling, 2007) were given preference where detail for relocating those sites was known. The 2007 study sampled site land use were not identified as extensive pasture, however, site land use identified as Bull Beef were taken as equivalent to extensive pasture.

For the soil types not previously sampled, and where information was insufficient to relocate a previously sampled site, HBRC adjudged a representative property for each soil type. An approach was made to the property owner followed by a land management questionnaire as given in Appendix B.

Where the property was deemed to have met criteria for the establishment of a soil quality monitoring site (e.g. Section 5.1; Pearson And Reid, 2006), the site was selected for monitoring site establishment.

4.2 Establishment of a Monitoring Site

Monitoring sites were established in accordance with NLMF (2009) procedures and Section 5.2 of Pearson and Reid (2006). In brief, the site was located so that no part of the sampling transect was affected by tracks, fence lines, shelter belts, stock camps, water troughs, streams, drainage ditches, buildings, fire sites, erosion scars or other disturbed areas.

A 50 m transect was marked out. GPS co-ordinates were taken at 0 m, 25 m and 50 m. Soil pits were excavated at approximately 0 m, 25 m and 50 m along the transect. Soil was described to a depth of not less than 50 cm for all three pits and to around 100 cm at one pit. Details of each site are given in Appendix A.

4.3 Observations on Site Selection and Site Establishment

Sampling for soil quality monitoring was delayed for 2011 due to an exceptionally wet autumn. During this period the Hawke's Bay and in particular the Eastern (coastward) Hawke's Bay experienced extensive land movement on rolling and steep country. Flooding and deposition occurred in some low lying areas.

Land that is most vulnerable to slipping or inundation is typically managed extensively and so many sites visited in this sampling round had been affected by land movement. The procedure for establishment of sites requires that areas subject to movement are considered atypical and avoided. In order to meet this requirement transects were typically located in the most stable landforms. There is potential that these are not the most representative profile of some of the soil types. It is noted that this may cause overestimation of some parameters, most likely those associated with organic matter accumulation. However these landforms are likely to be able to be revisited more easily over time.

4.4 Sampling and Analysis

Soil sampling and analyses followed the guidelines prepared by the National Land Monitoring Forum (NLMF) (2009). The draft guidelines of this forum were the basis for sampling and analysis in 2007, however the assumption made for the 2007 report was that procedures followed the protocols established by the 500 Soils Project (Hill et al., 2003). These protocols formed the basis for the NLMF guidelines. A summary of the procedure is as follows.

4.4.1 Sampling for Soil Physical Indicators

An intact core of approximate dimensions 100 mm ∅ x 75 mm L was taken from three locations at each transect. The sampling locations corresponded to the soil pits at 0 m, 25 m and 50 m.

4.4.2 Sampling for Soil Chemical and Microbiological Indicators

A foot corer of dimensions 20 mm ∅ x 100 mm L was used to obtain one soil core every approximately 2 m along the transect. The cores were combined to provide a composite sample for analysis.

The procedure above was repeated to provide a second composite sample. This sample was used for analysis of heavy metals and persistent organic contaminants.

4.4.3 Sample Handling and Transport

Sealed samples were packed in chilly bins where necessary and transferred to a storage fridge if not conveyed immediately to a laboratory for analysis. Intact cores were stored and transported in padded crates.

Intact cores for soil physical indicators were sent to the Landcare Research Laboratory in Palmerston North for analysis. Composite samples were sent to Hill Laboratories in Hamilton.

4.4.1 Sample Analysis

As indicated above samples were sent to Hill Laboratories for chemical analyses, being:

- Basic soil test: pH, Olsen P, exchangeable cations, CEC, base saturation;
- Organic soil profile: Available N, anaerobically mineralisable N (AmN), organic matter, total C, total N, C/N ratio, AmN/N ratio;
- Heavy metal screen: As, Cd, Cr, Cu, Ni, Pb, Zn, Hg;
- Organochlorine pesticide screen;
- Total uranium (Ur); and
- Total fluoride (Fl^-).

Analyses conducted at the Landcare Research laboratory were:

- Bulk density;
- Macroporosity;
- Particle density;
- Total porosity;
- Field capacity: soil moisture content when all macropores have drained; and
- Available water capacity (AWC).

4.5 Data Presentation

All data is expressed as received from Hills Laboratories. Where necessary, recalculation of data to different units was made to enable comparison to historical data. Percent carbon and nitrogen was multiplied by 10 and the bulk density to change units from percentage to mg/cm^3.

5 RESULTS

5.1 Soils & Sites

Nineteen sites were sampled from extensive pastoral properties used for dry stock throughout Hawkes Bay. Table 1 lists the soil types at each sample site and the soil order/group to which they belong. Two properties had two sample sites because of two different soil types, 13 & 14, 17 & 18.

Of the 8 soil orders chosen to represent the region only organic soils are not represented in this analysis. While initially the Poukawa soil was identified as an Organic Soil used for extensive pastoralism it was noted that most of the area of Poukawa soil is managed as cropping soil and was therefore not considered to be representative of extensive pasture. The order listed is that identified for the soil type by Pearson & Reid (2006). The observed properties conform to the descriptions of Pohlen *et al.* (1947). The different allocated soil order identifies recent soils for Ruahine and Awamate. Differences of the allocated soil order also occurred in the 2007 monitoring report of soil quality (Sparling & Stevenson, 2008).

Table 1: Soil Quality Monitoring Sites

Site No	Soil Type	Order
1	Te Apiti	Pallic
2	Okawa	Gley
3	Mokapeka	Brown
4	Atua	Pallic
5	Crownthorpe	Pallic
6	Waipawa	Pallic
7	Matamau	Brown
8	Hastings	Gley
9	Matapiro	Pallic
10	Ruahine	Brown
11	Gisborne	Pumice
12	Taupo	Pumice
13	Hangaroa	Pumice
14	Awamate	Gley
15	Mahoenui	Pallic
16	Tiniroto	Pumice
17	Takapau	Allophanic
18	Gwavas	Brown
19	Te Onepu	Mellanic

Soil profile and site descriptions are provided in Appendix A. Soil chemistry, physical data, heavy metal levels and agrichemical contaminants are shown in Tables 2 to 5 below. Analysis results as received from the analysing laboratories are given in Appendix C.

Table 2: Soil chemical characteristics of Hawke's Bay sites sampled in 2011

Site	Soil Type	pH	CEC	Total Carbon	Total Nitrogen	C/N	Olsen P	Base Saturation	Mineral-isable N	Potassium	Calcium	Magnesium	Sodium
			me/100g	mg/cm³	mg/cm³	ratio	mg/L	%	µg/cm³	Exchangeable cations me/100g			
01-11-10cm	Te Apiti	5.8	35	76.2	7.17	10.7	21	74	446	1.04	21.8	2.59	0.23
02-11-10cm	Okawa	5.6	13	37.0	3.58	10.4	11	49	186	0.28	4.6	1.45	0.26
03-11-10cm	Mokapeka	5.6	16	48.8	4.27	11.6	6	45	138	0.37	5.4	1.05	0.12
04-11-10cm	Atua	5.4	15	41.1	4.00	10.1	15	40	129	0.51	4.1	1.25	0.12
05-11-10cm	Crownthorpe	5.7	18	45.9	4.73	9.9	29	65	143	0.81	9.4	1.28	0.15
06-11-10cm	Waipawa	5.5	19	55.6	4.94	11.2	10	54	127	0.41	8.1	1.8	0.14
07-11-10cm	Matamau	5.6	21	59.4	5.61	10.5	30	53	326	0.68	9.0	1.55	0.13
08-11-10cm	Hastings	6.6	24	62.7	6.61	9.6	42	87	178	1.29	17.9	1.57	0.08
09-11-10cm	Matapiro	6.0	26	57.8	5.78	10.0	23	71	314	0.86	13.6	3.77	0.56
10-11-10cm	Ruahine	5.9	31	76.8	7.36	10.4	27	52	255	1.12	12.4	2.31	0.2
11-11-10cm	Gisborne	6.0	21	54.8	4.73	11.5	5	46	104	0.23	8.4	0.77	0.13
12-11-10cm	Taupo	5.7	26	55.4	4.85	11.4	6	28	135	0.51	5.6	1.01	0.23
13-11-10cm	Hangaroa	5.6	16	42.2	3.87	11.0	6	31	114	0.42	3.2	1.13	0.2
14-11-10cm	Awamate	5.9	14	24.5	2.97	8.1	27	67	157	0.47	7.1	1.63	0.12
15-11-10cm	Mahoenui	5.6	18	36.6	3.66	9.9	13	42	156	0..35	5.3	1.70	0.38
16-11-10cm	Tiniroto	5.5	16	38.2	3.63	10.5	15	37	110	0.45	4.6	0.77	0.17
17-11-10cm	Takapau	6.0	18	48.3	5.06	9.6	13	60	105	0.24	9.5	0.99	0.21
18-11-10cm	Gwavas	5.9	19	48.8	4.76	10.2	22	62	139	0.71	9.7	1.43	0.08
19-11-10cm	TeOnepu	6.6	31	71.8	7.76	9.3	42	100	262	1.83	27.8	1.72	0.11

Table 3: Soil chemical characteristics of Hawke's Bay sites sampled in 2011(units utilised for target range)

Site	Soil Type	pH	CEC	Total Carbon	Total Nitrogen	C/N	Olsen P	Base Saturation	Mineral-isable N	Potassium	Calcium	Magnesium	Sodium
			me/100 g	%	%	ratio	mg/L	%	µg/cm³	Exchangeable cations me/100g			
01-11-10cm	Te Apiti	5.8	35	6.8	0.64	10.7	21	74	**446**	1.04	21.8	2.59	0.23
02-11-10cm	Okawa	5.6	13	3.3	0.32	10.4	**11**	49	186	0.28	4.6	1.45	0.26
03-11-10cm	Mokapeka	5.6	16	4	0.35	11.6	**6**	45	138	0.37	5.4	1.05	0.12
04-11-10cm	Atua	5.4	15	3.7	0.36	10.1	15	40	129	0.51	4.1	1.25	0.12
05-11-10cm	Crownthorpe	5.7	18	3.4	0.35	9.9	29	65	143	0.81	9.4	1.28	0.15
06-11-10cm	Waipawa	5.5	19	5.4	0.48	11.2	**10**	54	127	0.41	8.1	1.8	0.14
07-11-10cm	Matamau	5.6	21	5.4	0.51	10.5	30	53	**326**	0.68	9.0	1.55	0.13
08-11-10cm	Hastings	6.6	24	5.6	0.59	9.6	42	87	178	1.29	17.9	1.57	0.08
09-11-10cm	Matapiro	6.0	26	4.9	0.49	10.0	23	71	**314**	0.86	13.6	3.77	0.56
10-11-10cm	Ruahine	5.9	31	9.6	**0.92**	10.4	27	52	**255**	1.12	12.4	2.31	0.2
11-11-10cm	Gisborne	6.0	21	7.3	0.63	11.5	**5**	46	104	0.23	8.4	0.77	0.13
12-11-10cm	Taupo	5.7	26	8.8	**0.77**	11.4	**6**	28	135	0.51	5.6	1.01	0.23
13-11-10cm	Hangaroa	5.6	16	4.8	0.44	11.0	**6**	31	114	0.42	3.2	1.13	0.2
14-11-10cm	Awamate	5.9	14	**1.9**	**0.23**	8.1	27	67	157	0.47	7.1	1.63	0.12
15-11-10cm	Mahoenui	5.6	18	3.7	0.37	9.9	**13**	42	156	0..35	5.3	1.70	0.38
16-11-10cm	Tiniroto	5.5	16	3.9	0.37	10.5	15	37	110	0.45	4.6	0.77	0.17
17-11-10cm	Takapau	6.0	18	4.2	0.44	9.6	**13**	60	105	0.24	9.5	0.99	0.21
18-11-10cm	Gwavas	5.9	19	4.1	0.40	10.2	22	62	139	0.71	9.7	1.43	0.08
19-11-10cm	TeOnepu	6.6	31	7.4	**0.80**	9.3	42	100	**262**	1.83	27.8	1.72	0.11

* Items in bold fell outside the target range for that land use and soil order (Hill & Sparling, 2009)

Table 4: Soil physical characteristics of Hawke's Bay sites sampled in 2011

Site	Soil Type	Dry bulk density	Particle density	Porosity	Macro-porosity	Field capacity	AWC
		(g/ cm^3)	(g/cm^3)	(%)	(%)	(%)	(%)
01-11-10cm	Te Apiti	1.12	2.52	56	7	49	20
02-11-10cm	Okawa	1.12	2.49	55	11	44	26
03-11-10cm	Mokapeka	1.20	2.53	53	16	36	23
04-11-10cm	Atua	1.11	2.51	56	17	38	22
05-11-10cm	Crownthorpe	1.35	2.57	48	11	36	17
06-11-10cm	Waipawa	1.03	2.50	59	19	40	17
07-11-10cm	Matamau	1.10	2.50	56	11	45	24
08-11-10cm	Hastings	1.12	2.51	55	15	40	21
09-11-10cm	Matapiro	1.18	2.52	53	7	46	22
10-11-10cm	Ruahine	0.80	2.40	67	19	48	24
11-11-10cm	Gisborne	0.75	2.31	68	20	48	32
12-11-10cm	Taupo	**0.63**	2.22	72	22	49	34
13-11-10cm	Hangaroa	0.88	2.36	63	20	43	29
14-11-10cm	Awamate	1.29	2.63	51	**5**	46	26
15-11-10cm	Mahoenui	0.99	2.45	60	16	44	30
16-11-10cm	Tiniroto	0.98	2.36	59	12	46	32
17-11-10cm	Takapau	1.15	2.51	54	15	39	23
18-11-10cm	Gwavas	1.19	2.54	53	19	34	21
19-11-10cm	TeOnepu	0.97	2.46	60	14	47	25

***** Items in bold fell outside the target range for that land use and soil order (Hill & Sparling, 2009)

Table 5: Heavy metal levels of Hawke's Bay sites sampled in 2011

Site	Soil Type	Individual Tests		Heavy metals , screen As, Cd, Cr, Cu, Ni, Pb, Zn, Hg							
		Total Recoverable Uranium	Fluoride	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
01-11-10cm	Te Apiti	0.96	390	2	0.27	11	11	7.6	<0.10	8	51
02-11-10cm	Okawa	0.76	260	<2	0.11	7	4	7.4	<0.10	4	34
03-11-10cm	Mokapeka	0.45	196	<2	0.10	9	3	6.1	<0.10	4	41
04-11-10cm	Atua	0.57	240	2	0.21	8	4	8.2	<0.10	4	32
05-11-10cm	Crownthorpe	0.76	270	3	0.30	13	20	9.9	<0.10	9	48
06-11-10cm	Waipawa	0.63	240	2	0.32	6	7	5.3	<0.10	5	45
07-11-10cm	Matamau	0.73	260	2	0.27	10	9	7.5	<0.10	5	46
08-11-10cm	Hastings	0.8	300	2	0.46	12	14	8.9	<0.10	10	65
09-11-10cm	Matapiro	1.2	300	<2	0.35	11	9	9.1	<0.10	10	71
10-11-10cm	Ruahine	1.53	500	<2	0.59	12	20	6.8	<0.10	6	69
11-11-10cm	Gisborne	0.94	400	<2	0.53	7	5	5.4	<0.10	3	36
12-11-10cm	Taupo	0.66	360	<2	0.43	4	5	3.9	<0.10	2	25
13-11-10cm	Hangaroa	0.43	270	<2	0.10	5	3	5.8	<0.10	4	27
14-11-10cm	Awamate	1.02	340	2	0.15	15	7	8.8	<0.10	11	52
15-11-10cm	Mahoenui	0.8	340	<2	0.23	7	4	6.0	<0.10	5	36
16-11-10cm	Tiniroto	0.73	350	<2	0.32	5	4	5.1	<0.10	4	33
17-11-10cm	Takapau	0.97	310	2	0.34	14	9	9	<0.10	7	71
18-11-10cm	Gwavas	0.77	240	3	0.26	14	10	8.2	<0.10	6	48
19-11-10cm	TeOnepu	0.71	240	4	0.69	17	16	14.4	0.12	6	63

5.2 Priority One Indicators

The results from the soils analysed have been compared to the interpretative frameworks developed by expert panels (Hill & Sparling, 2009) (referred to in this report as the framework). The framework provides terms to categorise the results and target ranges or critical limits.

5.2.1 Soil pH

Soil pH results are shown in Figure 1. All the sampled soils were within the target range for soil pH. Two soils were near to the high limit corresponding to a Hastings soil (Site 8) and a Te Onepu Soil (Site 19). A high pH is expected for the Te Onepu soil as a result of the limestone stone parent material and likely elevated carbonate concentration in the soil. The Hastings soil was present in a catchment draining from limestone hills and so can be expected to have elevated carbonate concentrations also.

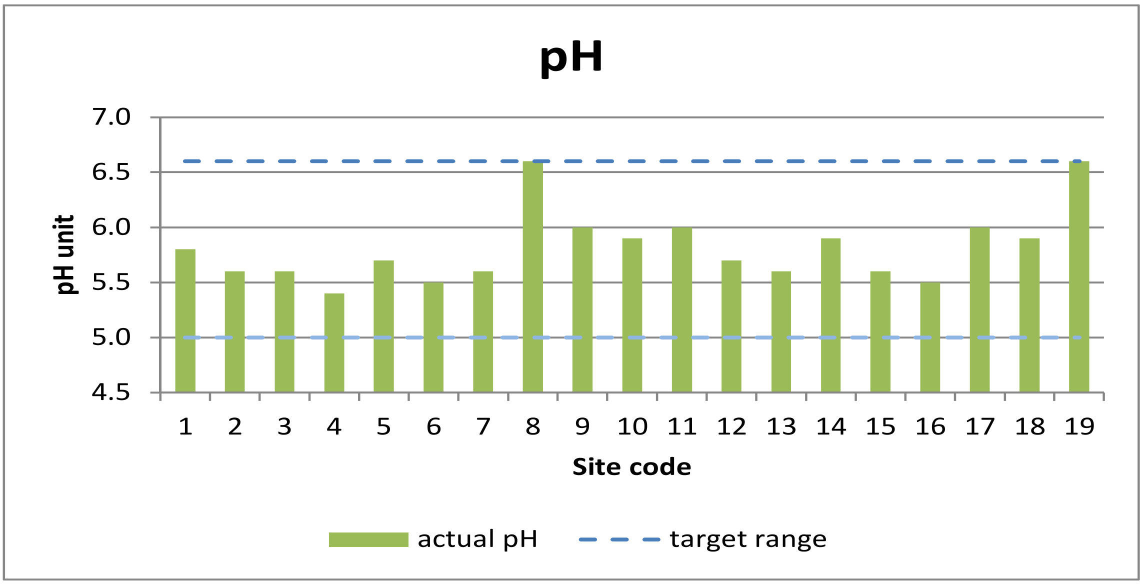

Figure 1: Soil pH for Hawke's Bay sites sampled in 2011

5.2.2 Total Carbon

The range recorded of total C (%w/w) is 1.9 to 9.6. For comparative purposes the results have been expressed on a weight per volume basis (mg/cm^3). Figure 2 shows the results that range from 24.5 to 76.8 mg/cm^3. Utilising the 2009 framework the Awamate soil (Site 14) is very depleted and below the critical limit, potentially due to "dilution" by low carbon sediment after recent flooding. All other sites are above the critical limit with the majority in the normal range.

In general, extensive pasture land use is expected to slowly accumulate carbon due to the low incidence of disturbance under this land use. Reduction in carbon concentration is most likely to be due to soil loss or sediment deposition.

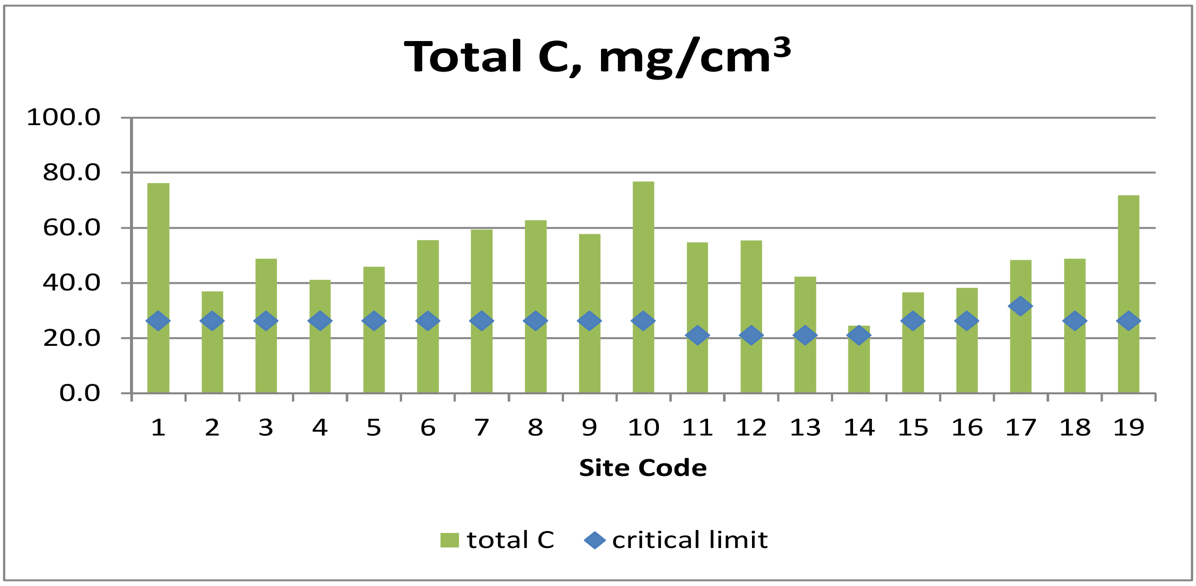

Figure 2: Total C for Hawke's Bay sites sampled in 2011

5.2.3 Total Nitrogen

There was a wide range of total N between sites from very depleted through to high. In general the trend for total N follows the total C observed. There is no clear trend based on soil order and it is likely that the total N status of the soils is related to land management practices such as fertilisation history, pasture development and tillage. Sites having total N towards the low end of the target range include the Awamate soil (Site 14) for reasons as outlined for total C. Figure 3 shows total N for the sites measured.

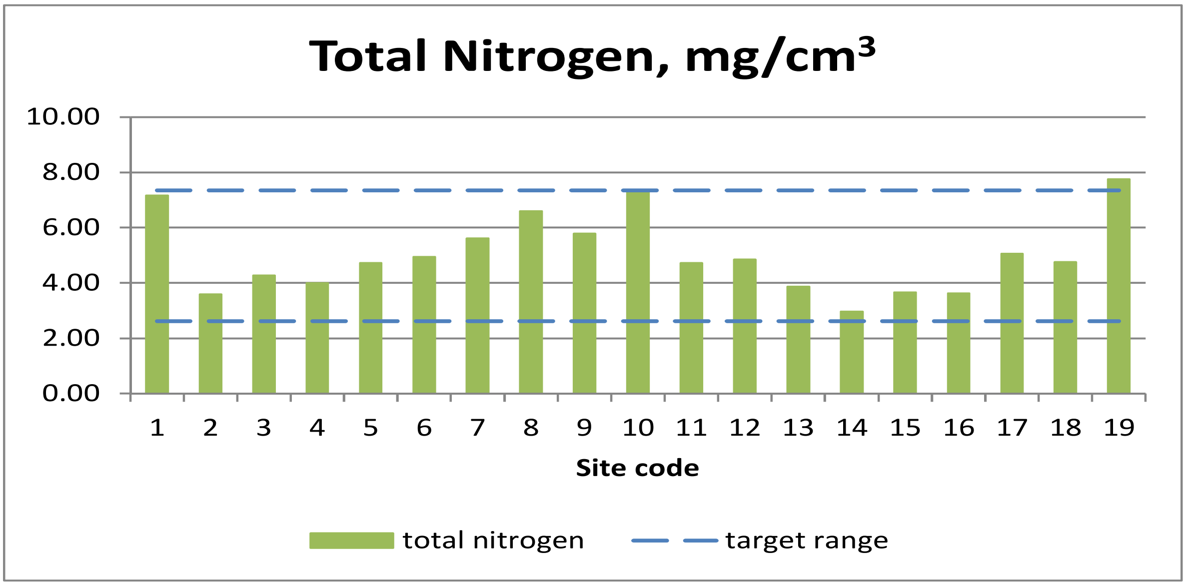

Figure 3: Total N for Hawke's Bay sites sampled in 2011

5.2.4 Anaerobically Mineralisable Nitrogen

The concentration of anaerobically mineralisable N (AmN) is a function of the C:N ratio. Some caution is advised in the interpretation of these results due to some concern for sample storage which may have caused elevated AmN. Figure 4 shows the AmN results. In general soils sampled were within the target range for AmN. Five sites had high AmN which is an indicator of nitrate leaching risk. Sites at the low end of the range may be at risk of limiting the potential for plant growth.

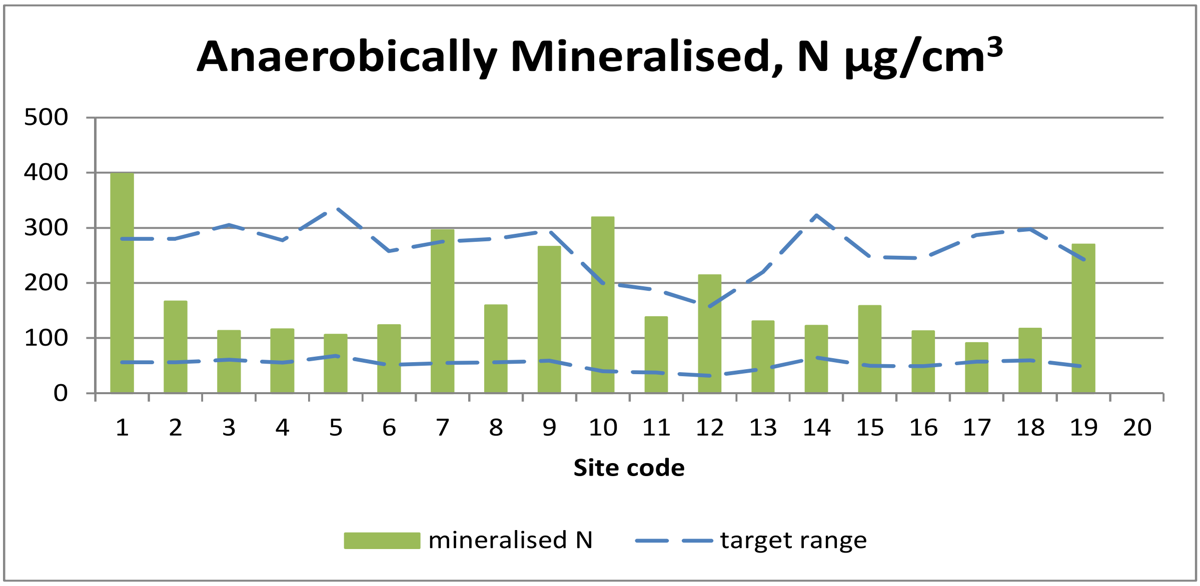

Figure 4: Mineralisable N content (µg/cm3) of Hawke's Bay soils sampled

5.2.5 Olsen Phosphorus

Ten sites showed very low levels from the Olsen P test, therefore operating below potential growth rate for the pasture and at or outside the target range. Levels are comparable to 2007 however 4 sites are below any recorded in 2007. Figure 5 gives the Olsen P results.

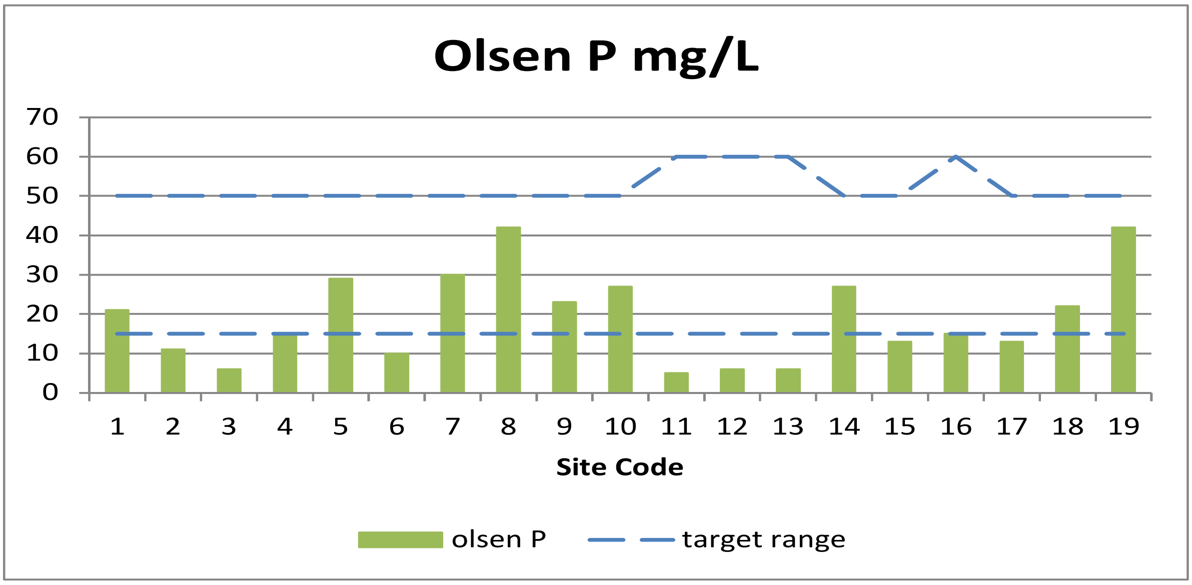

Figure 5: Olsen P content (mg/L) of Hawke's Bay soils sampled

5.2.6 Carbon : Nitrogen Ratio

The C/N ratio is consistent with the Total C and N measures. The Awamate soil (Site 14) is low by comparison to all other sites which range between 9.3 to 11.6. Below 9 is considered too low to store N in organic forms meaning that N may be limiting to pasture growth. Figure 6 gives the C/N ratio for each site.

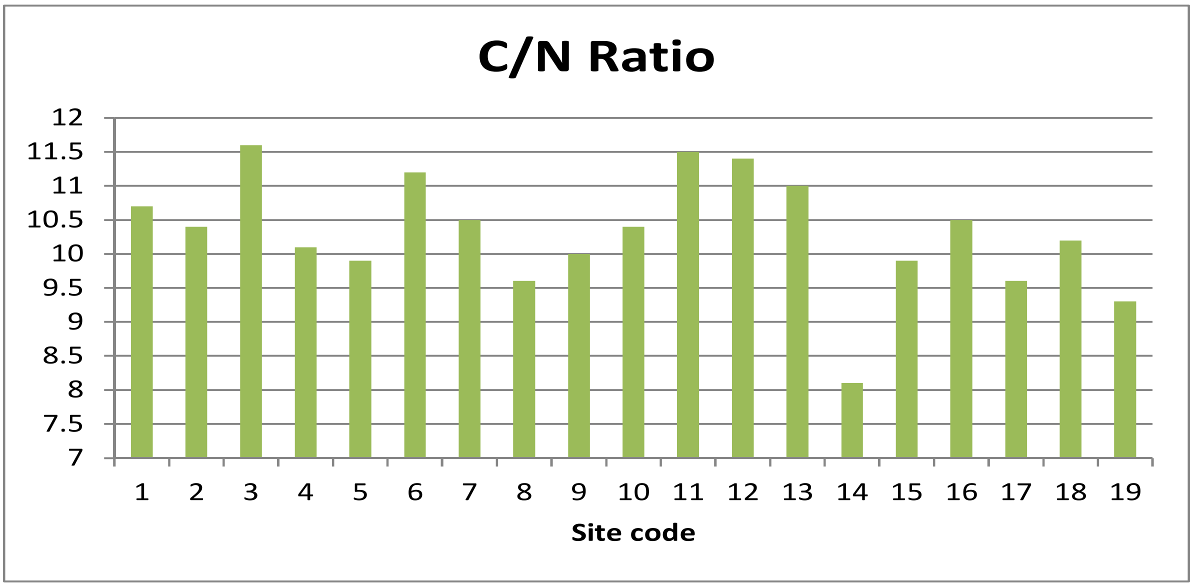

Figure 6: C/N ratio of Hawke's Bay soils sampled

5.2.7 Dry Bulk Density

All sites sat within the target range except a pumice soil with very low bulk density. Therefore no soil sampled should impede root growth from reduced aeration and drainage. Figure 7 shows the bulk density results. The Taupo soil (Site 12) with very low bulk density is at risk of increased water and nutrient loss. These results are generally consistent with 2007 results that indicated only one site showing signs of compaction outside the target range.

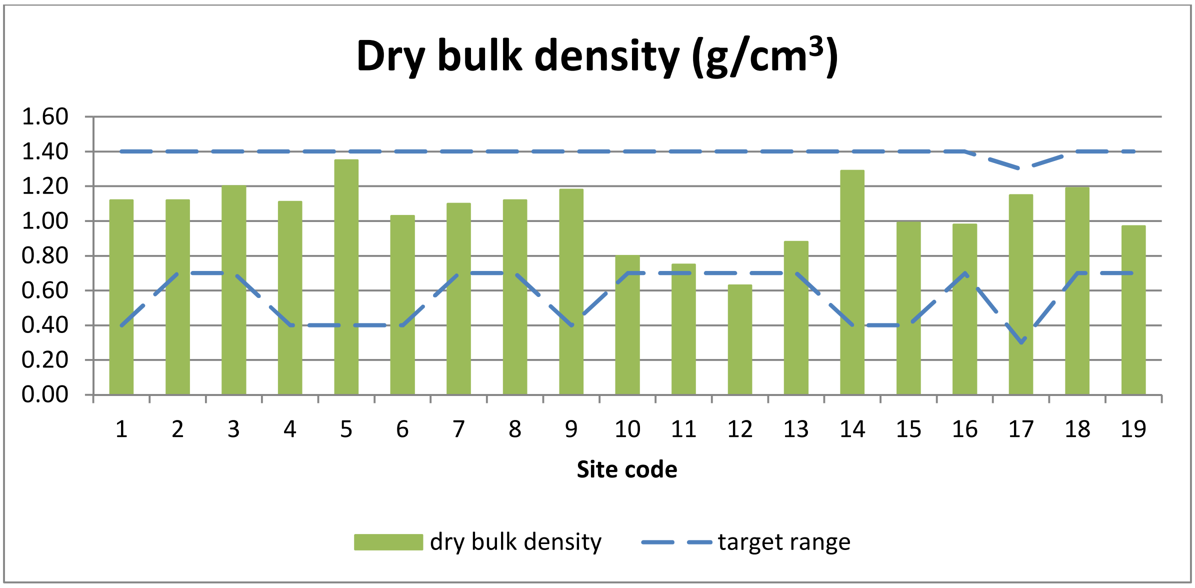

Figure 7: Dry bulk density (g/cm^3) of Hawkes Bay soils sampled

5.2.8 Macroporosity

Figure 8 shows macroporosity for the sampled soils. All sites except site 14 indicate macroporosity inside the target range that will contribute to adequate aeration and plant growth. Consistent with other data, site 14 macroporosity is very low. 2011 results contrast with 2007 that found most beef sites were below the target range.

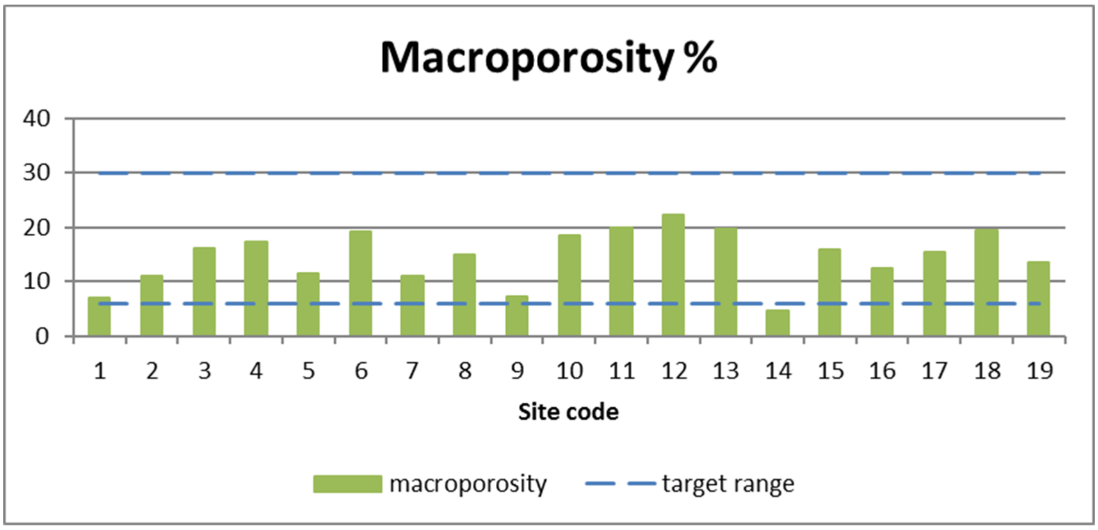

Figure 8: Macroporosity % of Hawkes Bay soils sampled

5.3 Priority Two Indicators

Where determined, results of the visual soil assessment (Shepard, 2000) are detailed in the soil descriptions given in Appendix A.

5.4 Priority Three Indicators

5.4.1 Organochlorine Pesticides

For most sites all measured organochlorine pesticides were below detectable limits. Of the measured organoclorine pesticides only DDT or it's metabolites (DDD, DDE) were measured. DDT/DDD/DDE was detected in soils at 5 sites, being:

- Site 7, Matamau series (0.581 mg/kg);
- Site 10, Ruahine series (0.027 mg/kg);
- Site 11, Gisborne series (0.020 mg/kg);
- Site 16, Tiniroto series (0.252 mg/kg); and
- Site 18, Gwavas series (0.019 mg/kg)].

In the absence of a New Zealand guideline for the protection of soil health the measured values were compared to the Canadian Council of Ministers of the Environment (CCME, 1999) guideline. The CCME guideline for soil quality for protection of environmental and human health is 0.7 mg/kg ΣDDT+DDE+DDD.

No sites exceeded the soil quality guideline adopted for agricultural soils. Presence of DDT is likely to be due to the coating of grass seed for protection against grass grub at pasture establishment prior to the 1970s. The value measured at Site 7 is close to the guideline value and further investigation may be warranted.

5.4.2 Trace Elements

Measured levels of As, Cd, Cr, Cu, Pb, Hg, Ni and Zn were below levels corresponding to risk to environmental or human health. Cd was considered to be the contaminant of most concern due its presence in phosphate rock used for superphosphate production. While Cd was detected in all samples the levels were below soil limits.

5.4.3 Fluoride

All measured values for fluoride were within the expected range for NZ soils (200-500 mg/kg, FLRC, 2009). As with P and Cd results this is likely to reflect low rates of phosphate fertiliser addition or loss of topsoil due to slipping.

5.4.4 Uranium

Measured U varied from 0.43 to 1.53 with the pattern of elevated values generally following the other indicators. This suggests that variance in U is likely to associated with the soil fertility as modified by land management. In general, levels are low and below the proposed Canadian soil limit of 23 mg/kg. Further information is required to determine a New Zealand limit (Taylor *et al.*, 2007).

5.5 Overall Soil Quality

The results from the soils analysed have been compared to the interpretative frameworks developed by expert panels (Hill & Sparling, 2009) (referred to in this report as the framework). The framework provides terms to categorise the results and target ranges or critical limits.

Five sites met all soil quality targets, 10 met all but one target seven of which was insufficient phosphorus levels. Three sites had two targets unmet and one property site 14 had three targets unsatisfied.

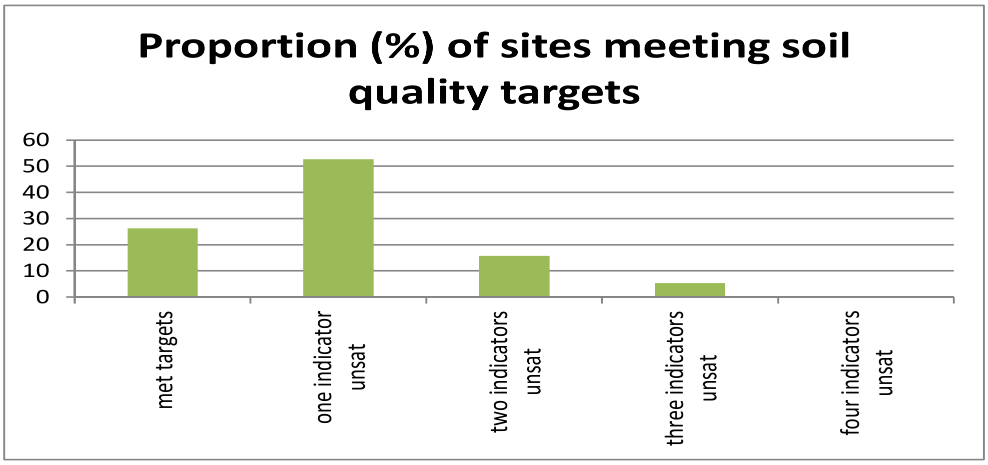

Figure 8: Proportion of Hawkes Bay soils not meeting soil quality targets for 7 quality indicators

As depicted in Figure 9 the main reason for sites failing one target was low phosphorus levels (52%). 26% of sites did not meet the mineralisable nitrogen target level. For beef properties analysed in 2007 two properties out of 10 met all targets, 4 had two unsatisfied and four had 3 targets unsatisfied. The main reason for unsatisfactory levels was for low macroporosity, whereas only 20% had Olsen P below target levels.

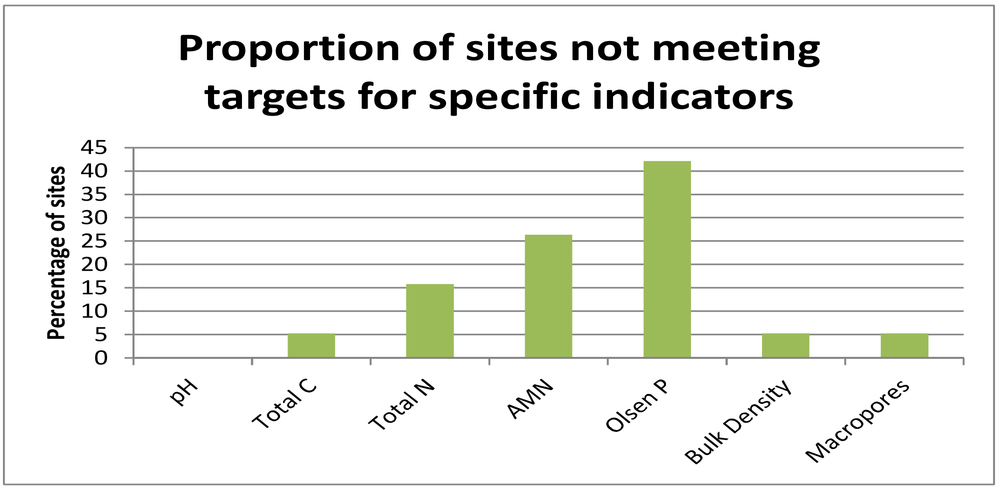

Figure 9: Proportion of Hawke's Bay soils not meeting suggested targets for specific soil quality indicators

5.6 Changes in Soil Quality Over Time

No sites previously sampled were sampled for the current data set. This is due to the extensive pastoral land use not previously being identified as a land use group. In addition, for the land use equivalent to extensive pasture, being bull beef, the details for relocating the sites were not available.

It is still considered appropriate to compare previously sampled bull beef sites in general with the current dataset. It should be noted that datasets prior to 2007 may not be directly comparable as described by Sparling and Stevenson (2008) which states:

> *"The current and archive data may not be directly comparable for all measured characteristics because analytical methods may have differed from those used previously. Two earlier sites had been sampled for the Crop and Food SQM project to a 15 cm depth, rather than the 10 cm depth of the 500 Soils protocol, which also causes problems when trying to compare soil characteristics that are strongly stratified with depth (i.e. properties that can be more or less concentrated in the surface soil). The depth of 10 cm is adequate for most non-tilled soils and is consistent with the IPCC recommendations for estimating C storage in surface soils."*

Some general observations regarding change over time in the soil quality observed for extensive pastoral land use can be made.

- pH is stable and within the target range;
- Total C was, in general, higher in 2011. The higher total C observed in 2011 is likely to be influenced by the choice of sampling location, whereby recent mass movement was avoided;
- Total N is similar for all sampling events when changes in sampling depth is considered;
- Olsen P has increased from 2007 results but is similar to earlier results. While Olsen P is typically low, it is relatively stable;
- A small increase in the mean value for anaerobically mineralisable N was seen, however it is considered to be within the bounds of experimental error and not significant; and
- Other measured parameters were not previously reported.

Data produced from the sites were generally similar between the two time periods. One or two sites fell outside of the target range for all measurements except pH which stayed within the target range. The main concern that arose for bull beef in 2007 was a large percentage of properties with low macroporosity indicating soil compaction whereas in 2011 this was only a concern for one property. However the concern in 2011 was low Olsen P values.

No targets have been specified and no data from previous years for comparative purposes is available for the following data collected: Porosity, particle density, field capacity, AWC and all heavy metal tests.

6 DISCUSSION

In previous soil quality monitoring for pasture soils the primary concern identified was low macroporosity, indicating soil compaction was occurring under pastoral land uses. The current dataset suggests that macroporosity is within the target range for all except one site. The Awamate soil which did not meet target macroporosity was subject to flooding and silt deposition within three months prior to sampling. This is likely to have influenced the soil macroporosity in the upper 10 cm and so the low macroporosity result is not considered to be a direct result of the land use at the site. In general the macroporosity of extensive pasture soils monitored was acceptable although at the low end of the scale. Further monitoring over time is warranted.

The current dataset represents land management practices, in particular stock types, which vary from the previously sampled bull beef sites. Both the different stock types including sheep and deer, and the low stocking rates and machine trafficking seen result in lower risk of soil compaction. It is considered that the broader application of the term extensive pasture to include farming regimes other than bull beef will assist to highlight differences in macroporosity due to higher stocking of heavier animals on marginal land, in particular in comparison to intensively managed sites which are to be sampled in the next 1-2 years.

The Olsen P status of the extensive pastoral sites monitored is the indicator of most concern for the current dataset. With over 40 % of sites falling below the target range for Olsen P. The range of soils which returned low Olsen P values span a number of soil groups including Pumice, Pallic, Gley and Brown. The soil groups represented include typically high P retaining soils (Pumice and Brown) and low P retaining soils (Pallic and Gley).

Olsen P is taken as a measure of the labile (plant available) P pool. For high P retention soils it is expected that P applied as fertiliser or other amendments will sorb to the soil, protecting it from loss of P as soluble phosphate. As a result P is typically higher in these soils where a history of fertiliser applications has occurred. If, however a significant time since P application has passed or a low rate of P is applied the P becomes occluded, meaning that it is no longer readily available. In this situation low Olsen P results may be returned. In soils with a low P retention the applied P is not strongly sorbed to the soil and is at risk of being lost predominantly via run-off. Again, this may result in low Olsen P measured.

For the sampled Hawke's Bay extensive pasture soils a further consideration for the low P status is the degree of soil loss that has occurred on the hill country which predominantly represents the land use, in particular, over the three months prior to sampling. Low P status may be an indicator of loss of the soil A horizon which is likely to contain the highest concentration of applied P. The soil Olsen P can be increased by the application of phosphate fertilisers or other P containing soil amendments.

A number of soil types sampled in the extensive pasture land use are known to be also under other land uses within the region. The collation of data from multiple land uses would enable a valuable comparison of soil quality under different land uses.

7 CONCLUSIONS

- In general soil quality in the Hawke's Bay extensive pasture sites is good, although some care should be taken in interpretation of the results since sampled areas excluded sites of recent mass movement and likely future instability.
- Extensive pasture sites are expected to have low C, N and fertility status compared to other land uses (cropping, intensive pasture) and so changes over time are likely to be more important than a point in time review.
- Compared to previous soil physical condition of sampled soils the extensive pasture soils sampled in this round were within the target range for soil physical parameters. This is most likely due to lower instance of animal and machine tracking on extensive pasture sites.
- A high number of sites had P status outside of the target range. This indicates that low P status may be wide spread in the Hawke's Bay.
- Low P status should be addressed to avoid "knock-on" effects due to poor pasture cover and resulting risk of further loss of shallow soil (NB this does not address issues due to deeper failure of hillslopes).

8 RECOMMENDATIONS

- Further information and assistance to farmers is needed to maintain hill country soil cover.
- Managers of the properties sampled should be informed of the soil quality on their properties and where remedial activity is recommended HBRC may provide advice on potential management strategies.
- Land managers and advisors, including fertilizer representatives, may require information regarding the management of P on hill country soils. Specifically, the adoption of P forms best suited to soil type and land slope, and application regimes designed to optimise P use.
- The same sites should be resampled within 5 years and at ongoing intervals to develop a long term record of soil quality indicator performance over time.
- Comparison of soil quality under different land uses with the same soil type is recommended.

9 REFERENCES

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10 APPENDICES

Appendix A: Soil Descriptions

Appendix B: Land Manager Questionnaire

Appendix C: Analytical Results

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