Soil Quality of Cropping Soils in Hawke's Bay – 2013/2014

Prepared for

Hawke's Bay Regional Council

Prepared by

L E W E
Environmental
Impact

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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 for State of the Environment (SoE) reporting. HBRC reviewed their soil monitoring programme in 2006 (Pearson & Reid, 2006). This provided a framework on which to base a selection process for sites that represent Hawke's Bay based on land form, soil order, soil types and land use. It also prioritized the soil quality indicators to be used in this programme.

In 2009 the National Land Monitoring Forum (NLMF) produced robust guidelines from which councils can produce nationally consistent land monitoring procedures and reporting. In accordance with the identified reporting requirements HBRC have engaged LEI to assist with field work and report on soil quality parameters. Information presented in this report examines the soil quality of cropping land in the Hawke's Bay. Soil quality is assessed in accordance with the recommendations of Pearson and Reid (2006) and the NLMF guidelines.

Cropping refers to the practice of cultivating, sowing or planting, weeding and harvesting a crop, usually within a single growing season. The crops are grown for human or stock consumption. The cropping practice is the predominant land use and land which is cropped as part of a pastoral rotation is not included. The land is intensively managed.

Soil sampling for the cropping sampling round occurred in January 2014. Sites were visited by LEI staff and HBRC staff. Where possible sites were chosen where the crop was either nearing maturity or recently harvested but not cultivated.

Fifteen sites were sampled from cropping properties used for a range of crops throughout Hawke's 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 cropping sites is good.
- Soil fertility is expected to be adequate for cropping sites due to fertilisation, and to vary rapidly due to the cultivation cycle i.e. plant uptake during active growth, oxidation due to ploughing. While every attempt to sample immediately prior to harvest was made, some variance may be expected which can be accounted for by the crop's growth phase.
- Soil physical condition is a concern for cropping, in particular those sites with fine textured soils or Organic soils.
- Aggregate stability and carbon reserves are considered to be the key issues for soil quality and sustainability of cropping land use in the Hawke's Bay.
- Reduced nutrient retention resulting from low carbon may increase potential leaching from these sites.
- A reduction in ground level may be an indicator of sustainability limitations of cropping on Organic soils where, a reducing ground level elevation may indicate that the land use is unsustainable on that soil or at that location.

Recommended actions coming from this report include:

- 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.
- Wider monitoring of the receiving environment around cropping sites may be needed to quantify the sustainability of existing practices. This may include groundwater monitoring

near sites with low carbon, ground level monitoring of organic soils and potentially, evaluation of soil loss by wind and sheet erosion in areas where conventional tillage is practiced.

- 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.

2 INTRODUCTION

2.1 Purpose

This report provides Hawke's 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 council's State of the Environment reporting obligations.

2.2 Background

The HBRC is developing a database of soil condition from different land uses representative of the Hawke's 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 on which to base a selection process for sites that represent Hawke's Bay based on land form, soil order, soil types and land use. It also prioritized the soil quality indicators. The current report focuses solely on cropping soils.

In 2009 the National Land Monitoring Forum (NLMF) produced robust guidelines from which councils can produce nationally consistent land monitoring procedures and reporting. In accordance with the identified reporting requirements HBRC have engaged LEI to assist with field work and report on soil quality parameters. Information presented here examines soil quality of cropping 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

This report follows on from previous soil quality reports produced for extensive pastoralism (2011) and intensive pastoralism (2013) in the Hawke's Bay. For consistency this report maintains a similar format and methodology for assessing soil quality as that used in the previous reports. The scope of this report is to describe the soil quality of land used for cropping in the Hawkes Bay region. In particular it details:

- Section 3: Discusses the soil quality monitoring framework;
- Section 4: Methods used to collect data;
- Section 5: Results from data collected with brief written interpretation;
- Section 6: Discussion;
- Section 7: Conclusion; and
- Section 8: Recommendations.

To enable the report to be a stand-alone document which is able to be read without the previous reports, some information is repeated from previous reports – particularly as regards the framework and methodology.

3 SOIL QUALITY AND LAND USE

3.1 Soil Quality Monitoring in the Hawke's Bay

As previously reported (LEI, 2011 and 2013), 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. It is complimented by information from previous reports on soil quality for the Hawke's Bay region, which have been reviewed and referenced through this report.

3.2 Land Use Definition

The adoption of cropping as a land use is in line with the NLMF guidelines. The land use categories are defined so that they can be aggregated back to the New Zealand Land Cover Database.

Cropping refers to the practice of cultivating, sowing or planting, weeding and harvesting a crop, usually within a single growing season. The crops are grown for human or stock consumption (potentially biofuel crops could be considered if they exist). The cropping practice is the predominant land use and land which is cropped as part of a pastoral rotation is not included. The land is intensively managed. Often land for cropping receives irrigation.

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.

The Priority One indicators are considered to represent the minimum parameters to be measured in order to assess soil health. These indicators are the focus of the monitoring programme described in this report regarding the health of cropping sites in the Hawke's Bay.

Priority Two: Extra Measurements - 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 Two indicators provide a qualitative assessment of soil condition. These measurements can indicate if soil quality is degraded. Priority Two indicators have not been evaluated for the 2014 cropping sites.

Priority Three: Extra Measurements

- Exchangeable cations and cation exchange capacity;
- Trace elements (As, Cd, Cr, Cu, Pb, Hg, Ni, Zn, U, F);
- DDT; and
- Hot water extractable C.

Priority Three indicators provide information which supports the Priority One indicators and adds detail about fertility and contamination. While Priority One indicators describe soil quality in general terms i.e. as relates to any land use, Priority Three indicators help to determine the soil quality as it relates to the specific site activity.

3.4 Trace Element and 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 the trace elements of particular concern (As, Cd, Cr, Cu, Ni, Pb, Zn, Hg, U, F) it is recommended to pursue further investigation (Chapter 5: NLMF, 2009). Organochlorines such as DDT and its metabolites 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.

Trace elements of concern which have the highest potential to be elevated are cadmium, fluorine and uranium. They are known to accumulate in the soil when superphosphate has been applied. Copper is used in anti-fungal treatments for food crops and is known to have detrimental effect on soil biota, and poses a risk if transported to the aquatic environment. Use of a range of zinc containing products such as in antibiotics and fungicides are also common practice on pastoral farms, particularly facial eczema preventative remedies (Kim & Taylor, 2009). While the sampling programme summarised in this report relates to cropping sites, some are likely to have had a pastoral history or may include a grazed phase in their rotation and so have the potential for elevated zinc levels.

3.5 Historical State of Hawke's Bay Soils

Previous reports and the New Zealand Soil Health Report Card (NZSHRC; MOE, 2010) have identified the soil management challenges for the Hawke's Bay region as:

- Poor aggregate stability (all land uses);
- Low macroporosity (intensive pasture);
- Low carbon reserves (cropping)
- General fertility (extensive pasture); and
- Phosphorus status (extensive pasture).

The above indicates that soil properties of concern for cropping sites are predominantly physical properties likely to be impacted by frequent cultivation or lack of vegetative cover (bare ground). Aggregate stability has not been assessed for the previous two sampling rounds however, it is considered an important soil quality indicator for cropping soils.

4 METHODOLOGY

4.1 Site Selection

The method for site selection follows the recommendation of NLMF (2009) for determining if a site is representative and, whether a site is suitable for establishment of a long term monitoring location. Pearson and Reid (2006) described locations which are considered to represent the range of soils and land use activities in the region. The sites identified by Pearson and Reid (2006) are considered to be aligned to the NLMF (2009) and so where these sites could be accessed they were sampled.

In order to confirm (where sites were identified by Pearson and Reid, 2006) or 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. To enable the detection of soil quality changes over time, sites that were visited in the 2007 study (Sparling, 2007) were given preference where detail for relocating those sites was known. Soil quality is not a static measure and so revisiting sites is important for the long term value of the soil quality monitoring programme.

For the soil types not previously sampled, and where information was insufficient to relocate a previously sampled site, HBRC identified 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 establishing a monitoring site.

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 around 50 cm for two 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 for the cropping round occurred in January 2014. Where possible sites were chosen where the crop was either nearing maturity or recently harvested but not cultivated.

Location details of previously (2007) sampled sites were not sufficiently precise to be certain that the 2014 sampling sites were the same. As such the results are not directly comparable. However, where the soil type was previously sampled a comparison has been made. In addition, general soil quality trends relating to the land use have been described (Section 5.7).

4.4 Sampling and Analysis

Soil sampling and analyses followed the guidelines prepared by the NLMF (2009). The draft NLMF guidelines are based the protocols established by the 500 Soils Project (Hill *et al.*, 2003). A summary of the procedure for sampling and analysis is as follows.

4.4.1 Sampling for Soil Physical Indicators

For bulk density, porosity, macroporosity, field capacity and available water capacity 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.

For aggregate stability analysis one sample per site was collected by digging a square of soil to 100 mm depth and placing it in a plastic container. Care was taken to avoid breaking up the soil clod.

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 approximately every 2 m along the transect. The cores were combined to provide a composite sample for analysis. The sample was used for analysis of organic matter and soil nutrient levels.

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

4.4.3 Sample Handling and Transport

Samples were packed in sealed bags and placed in chilly bins where necessary and transferred to a storage fridge, if not conveyed immediately to a laboratory for analysis. The cores to be analysed for microbial indicators had to be frozen as soon as possible. Intact cores for the physical analysis 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 for chemical analysis were sent to Hill Laboratories in Hamilton.

4.4.4 Sample Analysis

As indicated above, samples were sent to Hill Laboratories and analysed for:

- 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 (for trace elements): 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;

- Available water capacity (AWC); and
- Aggregate stability.

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 i.e. the analysing laboratories typically express results on a gravimetric basis (mass/mass basis), however for some parameters, as they relate to soil quality, it is considered more appropriate to compare them on a volumetric basis (mass/volume). Where historic data has been presented on a volumetric basis the results presented in this report are given on both a gravimetric and a volumetric basis to enable comparison with historical data.

Available N data is received from the laboratory expressed per 150 mm of topsoil depth. Results given in the following sections have been adjusted to reflect the 100 mm depth that was sampled for this soil quality monitoring programme.

5 RESULTS

5.1 Soils and Sites

Fifteen sites were sampled from cropping properties used for a range of, predominantly annual, crops throughout Hawkes Bay. Table 1 lists the soil types at each sample site and the soil order/group to which they belong.

Of the 8 soil orders chosen to represent the region (Pearson & Reid, 2006) 5 soil orders are represented in the cropping soils of the region sampled for this study.

Table 1: Soil Quality Monitoring Sites

Site No	Soil Type	Soil Order*	Recent Crop
1	Kaiapo clay loam	Gley	Squash
2	Twyford silt loam	Recent	Sweet corn (young plants)
3	Mangateretere clay loam	Pallic	Pasture (between Crop and Food trials)
4	Pakowhai silt loam	Recent	Ryegrass (for cutting), previously in onions
5	Hastings silt loam	Gley	Sweet corn (recently hand picked)
6	Te Awa silt loam	Recent	Bare, cultivated (recently in lucerne for 5 years)
7	Farndon silt loam	Recent	Squash (zucchini, butternut and buttercup)
8	Awamate loamy silt	Gley	Sweet corn (recently hand picked)
9	Pongakawa peaty silt loam	Organic	Ryegrass for seed
10	Pukehou silt loam	Gley	Maize
11	Poukawa loamy peat	Organic	Maize
12	Turamoe sandy peat	Organic	Onions under pivot irrigation
13	Takapau silt loam	Brown	Maize
14	Poporangi silt loam	Pallic	Cut and carry ryegrass (rest rotation)
15	Okawa silt loam	Pallic	Recently harvested peas

* New Zealand Soil Classification (Hewitt, 1992)

Soil profile and site descriptions are provided in Appendix A. A number of the sites received some form of irrigation. Irrigation, where present was predominantly by gun type irrigators. This type of irrigator produces a wide range of droplet sizes including large droplets which have the potential to cause damage to bare soil by breakdown of aggregates and ensuing surface crusting. The crusting reduces water infiltration and increases the potential for sheet and rill erosion. One site was irrigated by centre pivot (Site 12, Turamoe series soil) which is not expected to have the same issues for soil aggregate breakdown.

5.2 Analysis Results

Soil chemistry, physical data, trace element levels and agrichemical contaminants are shown in Tables 2 to 4 below. Analysis results as received from the analysing laboratories are given in Appendix C.

Table 2: Soil chemical characteristics of Hawke's Bay cropping sites sampled in 2014

Site	Soil Type	pH	CEC	Total C		Total N		C/N	Olsen P	Base Saturation	Anaerobically Mineralisable N		Available N	K	Ca	Mg	Na
			me/100g	% m/m	mg/cm³	% m/m	mg/cm³	ratio	mg/L	%	µg/g	µg/cm³	mg/kg	me/100g			
1	Kaiapo	5.5	24	3.1	35	0.35	3.9	8.8	44	65	91	101	73	1.12	11.9	2.31	0.1
2	Twyford	6.3	20	3.0	37	0.30	3.7	10.0	43	84	83	102	75	1.77	12.9	2.03	0.07
3	Mangateretere	6.0	22	3.0	40	0.35	4.6	8.6	32	72	104	137	94	1.15	12.4	2.05	0.13
4	Pakowhai	6.1	28	2.7	33	0.30	3.6	9.1	72	82	67	81	59	0.63	20	2.08	0.15
5	Hastings	6.3	17	**1.6**	**22**	0.20	2.8	8.1	47	74	23	32	22	0.48	10.4	1.31	0.09
6	Te Awa	6.2	20	2.6	33	0.27	3.4	9.4	36	79	69	87	67	0.71	13.3	1.39	0.09
7	Farndon	**7.6**	22	**1.6**	**21**	0.18	2.4	8.8	58	100	42	56	47	0.42	20	1.18	0.12
8	Awamate	4.9	16	**2.2**	**27**	0.23	2.8	9.6	36	49	39	48	38	0.29	6.9	0.57	0.16
9	Pongakawa	6.2	44	7.3	67	0.59	5.4	12.5	33	81	124	113	99	0.52	32.5	2.41	0.21
10	Pukehou	7.3	37	4.6	58	0.43	5.4	10.7	40	100	106	134	101	0.39	35.7	0.92	0.21
11	Poukawa	7.4	105	22.0	126	1.93	11.0	11.4	60	100	**237**	**136**	145	0.53	101.2	3.26	0.22
12	Turamoe	6.9	42	8.2	63	0.76	5.9	10.7	61	94	162	125	94	0.37	35.1	3.77	0.64
13	Takapau	5.7	27	5.6	57	0.57	5.8	9.8	56	52	85	86	71	1	11.5	1.5	0.15
14	Poporangi	6.2	15	2.9	35	0.28	3.4	10.3	**9**	64	103	125	103	0.17	8.4	0.95	0.24
15	Okawa	5.8	22	4.9	55	0.44	4.9	11.2	30	66	110	123	96	0.4	12.3	1.47	0.12

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

Table 3: Soil physical characteristics of Hawke's Bay sites sampled in 2014

Site	Soil Type	Dry bulk density	Particle density	Porosity	Macro-porosity	Field capacity	AWC	Aggregate Stability
		(g/ cm³)	(g/cm³)	(%)	(%)	(%)	(%)	MWD (mm)
1	Kaiapo	1.11	2.64	58	22	36	8	0.68
2	Twyford	1.23	2.60	53	13	40	13	0.89
3	Mangateretere	1.32	2.59	49	10	39	13	1.70
4	Pakowhai	1.34	2.65	50	11	39	9	1.04
5	Hastings	1.38	2.65	48	16	32	13	0.29
6	Te Awa	1.21	2.61	53	21	33	14	1.38
7	Farndon	1.26	2.67	53	21	31	13	0.29
8	Awamate	1.22	2.54	52	16	36	14	0.79
9	Pongakawa	0.91	2.40	62	15	47	17	2.03
10	Pukehou	1.26	2.51	50	8	42	13	0.45
11	Poukawa	0.57	2.03	72	16	56	23	2.14
12	Turamoe	0.77	2.28	66	8	58	35	1.77
13	Takapau	1.02	2.47	59	17	42	16	1.99
14	Poporangi	1.22	2.56	53	16	37	18	1.56
15	Okawa	1.12	2.50	55	18	37	14	2.07

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

Table 4: Trace element levels of Hawke's Bay sites sampled in 2014

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
1	Kaiapo	1.19	470	10	0.18	23	26	27	< 0.10	16	98
2	Twyford	0.85	390	6	0.21	18	53	26	< 0.10	14	105
3	Mangateretere	1.07	360	5	0.26	17	17	18.9	< 0.10	14	83
4	Pakowhai	1.56	410	7	0.17	24	28	20	< 0.10	17	83
5	Hastings	1.13	390	6	0.16	19	32	16.7	< 0.10	13	69
6	Te Awa	1.03	460	5	0.29	16	11	15.3	< 0.10	11	69
7	Farndon	0.75	370	5	0.1	18	9	13.3	< 0.10	12	60
8	Awamate	0.88	300	3	0.24	12	5	9.1	< 0.10	9	48
9	Pongakawa	1.64	310	5	0.38	15	19	13.6	< 0.10	13	74
10	Pukehou	2.8	270	7	0.37	15	16	11.4	< 0.10	9	51
11	Poukawa	3.6	24	5	0.11	7	20	3.1	< 0.10	7	24
12	Turamoe	1.36	400	5	0.21	6	17	4.7	< 0.10	3	24
13	Takapau	1.08	270	4	0.28	14	17	11.6	< 0.10	8	101
14	Poporangi	0.59	197	2	0.15	10	6	7.5	< 0.10	5	40
15	Okawa	0.89	230	3	0.23	13	10	9.7	< 0.10	6	37

5.3 Priority One Indicators

The results from the soils analysed have been compared to the interpretative frameworks developed by the NLMF expert panel (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.

5.3.1 Soil pH

Soil pH results are shown in Figure 1. The target range for cropping soils is pH 5.0 to 7.6 for all except Organic soils and 4.5 to 7.6 on Organic soils. All except one site were within the target range for soil pH. The Awamate soil (Site 8) with recently hand-picked fresh market sweetcorn was slightly below the target soil pH range. Site 7, the Farndon soil is nearing the top of the target range, however the saline nature of this soil is expected to result in naturally high pH.

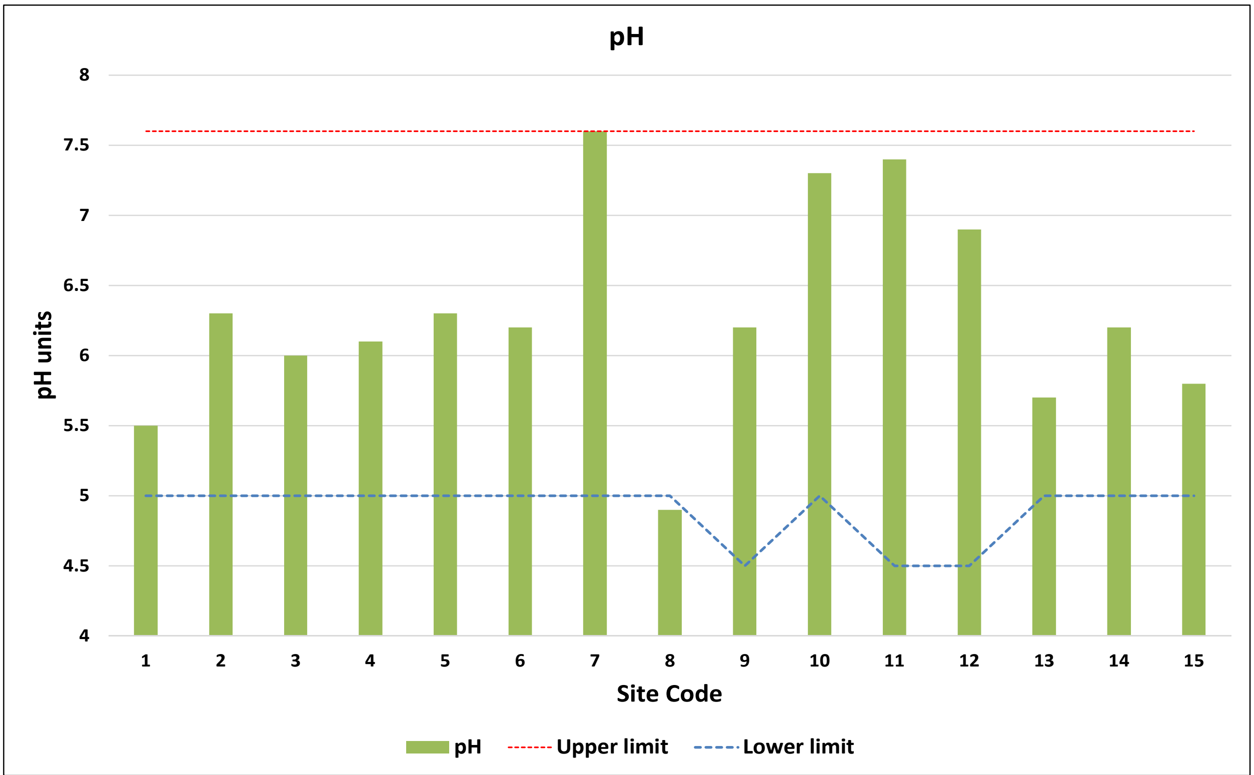

Figure 1: Soil pH for Hawke's Bay cropping sites sampled in 2014

5.3.2 Soil Total Carbon

Soil total carbon results are shown in Figure 2. The target range for soils is dependent on the soil order. Of the soil orders represented by the sites sampled the target range is:

- Recent soils: >2 %;
- Gley, Pallic, Brown soils: >2.5 %; and
- Organic soils have no target range (see below for explanation).

Three sites report total carbon below the target range. Sites 5 and 8 were in recently hand-picked fresh market sweetcorn on gley soils (restricted drainage) and the low carbon may reflect the use of conventional cultivation to "loosen" the soil for sowing. The Farndon soil (Site 7) appears to have been managed as a market garden for some time. It is likely that the site has been continuously cropped and cultivated to maintain an even seed bed. This may have contributed to the low total carbon content.

Organic soils (Sites 9, 11 and 12) have no target range for total carbon since by definition they are high in carbon. It is noted that Sites 9 and 12 have total carbon concentrations below the 15 % that typically classifies a soil as Organic. This may be due to drainage of the soils, cultivation of the soils and, potentially, mixing with underlying mineral soil material. Loss of carbon from these soils may impact on the long term sustainability of their use, and could impact on the surrounding area as regards surface and groundwater levels so should be monitored.

Overall, soil total carbon for the cropping sites is depleted and requires monitoring. The significantly higher total carbon level measured at Site 11 reflects that the soil (Poukawa series) is a peat soil which is dominated by organic material.

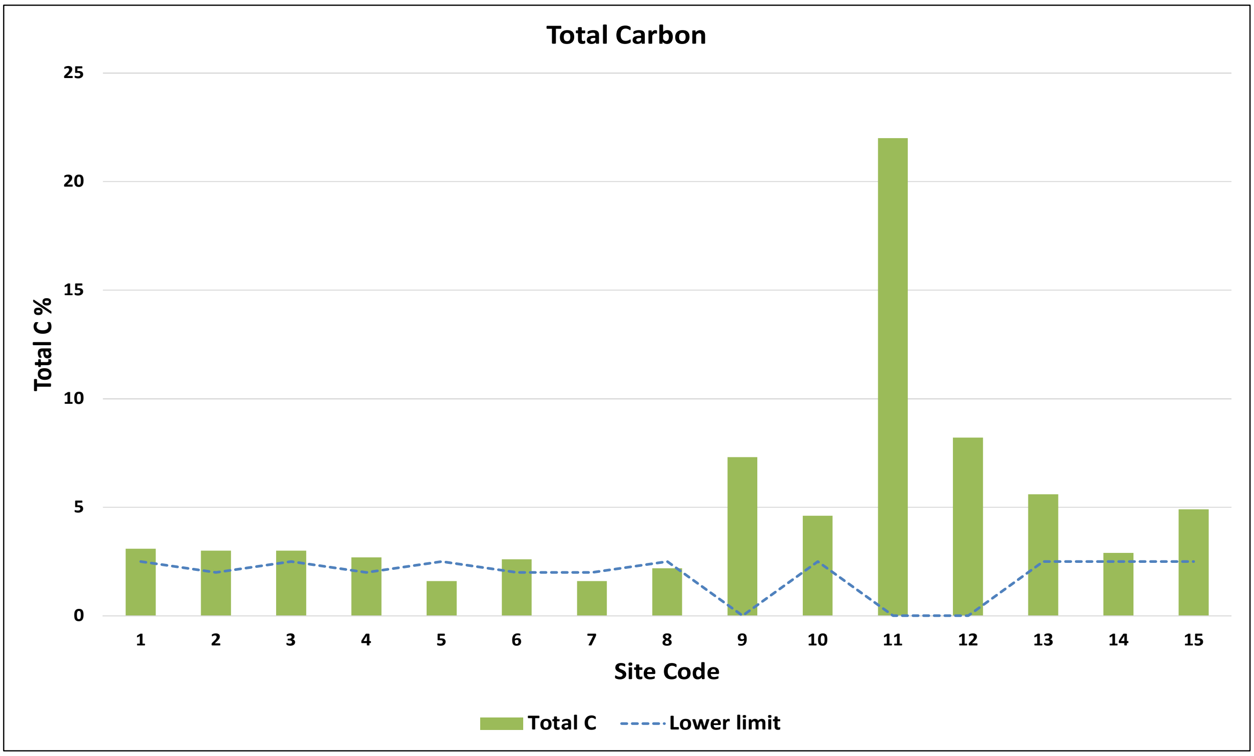

Figure 2: Soil total carbon for Hawke's Bay cropping sites sampled in 2014

5.3.3 Soil Total Nitrogen

Soil total nitrogen results are shown in Figure 3. There is no target range for cropping soils since the optimum level is dependent on the crop grown. The trends in total nitrogen concentrations follow the same pattern as for total carbon.

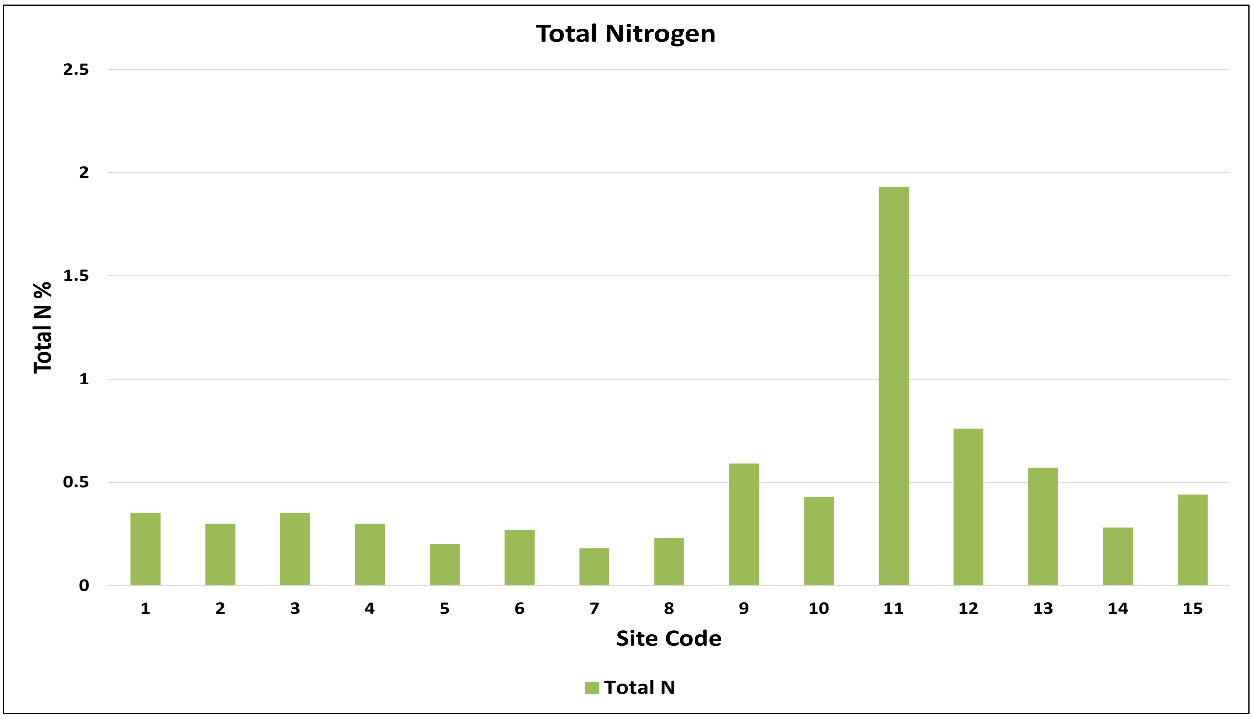

Figure 3: Soil total nitrogen for Hawke's Bay cropping sites sampled in 2014

5.3.4 Anaerobically Mineralisable Nitrogen

Anaerobically mineralisable nitrogen (AmN) results are shown in Figure 4. The target range for cropping soils is considered to be provisional. All sites are within the target range except for Site 11 which is higher than the target range. High AmN may indicate a risk for nitrogen leaching. It is noted that AmN below 100 µg/g is considered to be low, and this is the case for 8 of the sites. Low AmN may indicate a potential short fall for plant growth. However, for the cropping soils it most likely indicates that N is supplied by mineral fertiliser and tends not to be stored in the soil.

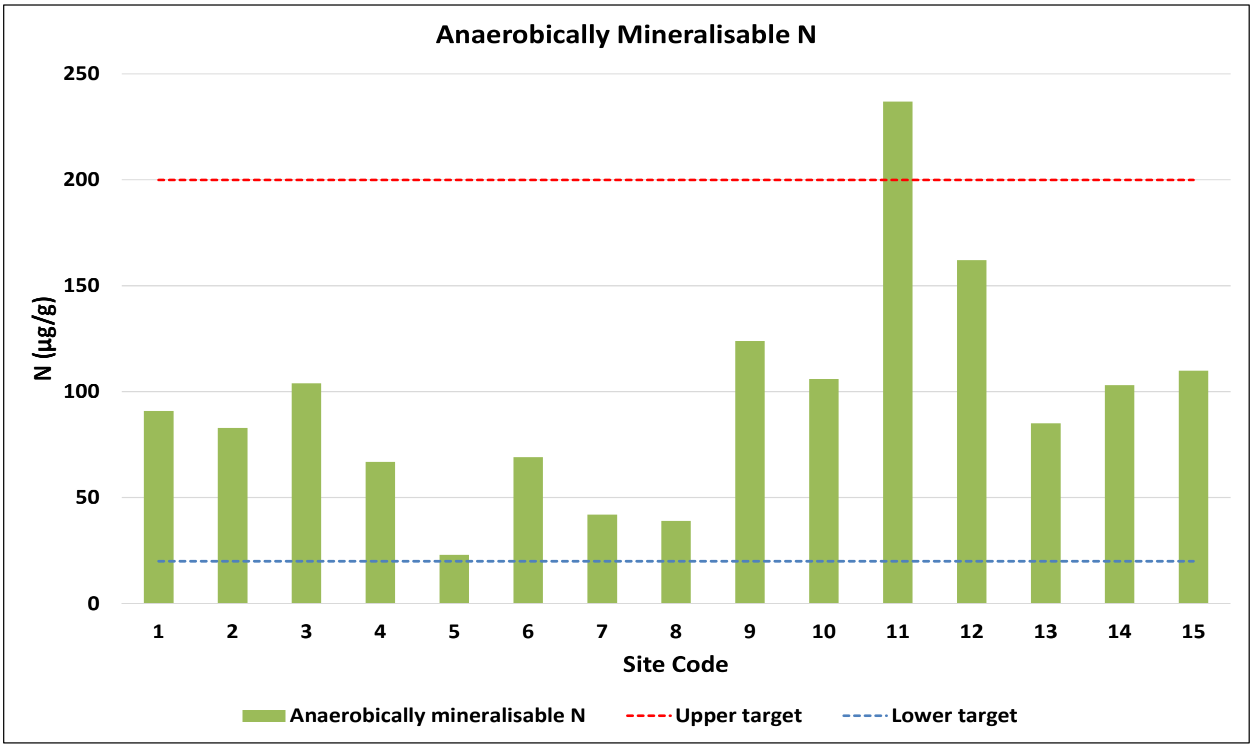

Figure 4: AmN for Hawke's Bay cropping sites sampled in 2014

5.3.5 Available Nitrogen

When the anaerobically mineralisable N results are adjusted for each sites bulk density and expressed on a per ha basis the results can be expressed as Available N. Available N is shown in Figure 5 below for the cropping sites. As with the AmN above, only one site exceeds the target range. When adjusted based on bulk density and depth Site 5 falls below the target range.

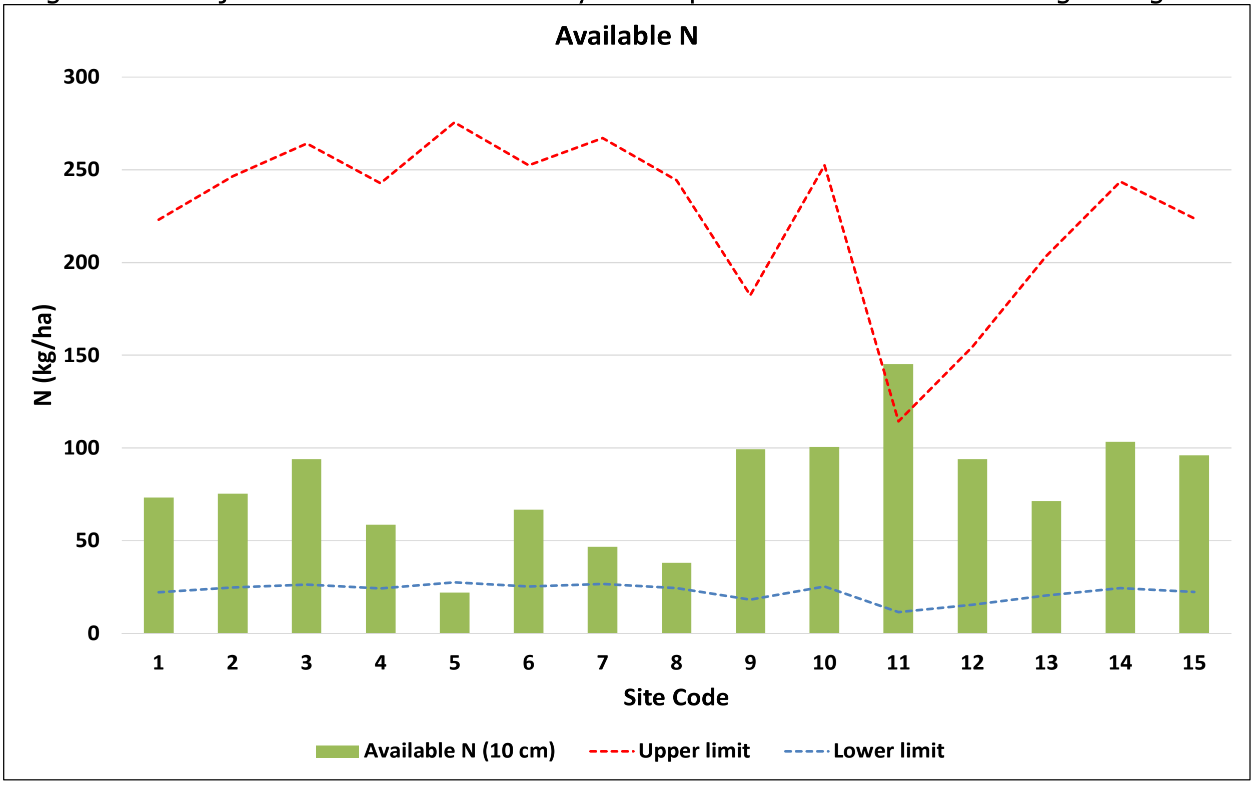

Figure 5: Available nitrogen for Hawke's Bay cropping sites sampled in 2014

5.3.6 Olsen Phosphorus

Figure 6 shows the Olsen P results for the cropping sites. The target range for the cropping soils is 25-100 mg/L for the Organic soils and 20-100 mg/L for the other soils. All except one site fall within the target range. Site 14 was in "rest" phase (pasture which was cut and followed by grazing) at the time of sampling and the low P may indicate a reduced fertiliser regime and low soil reserves of P.

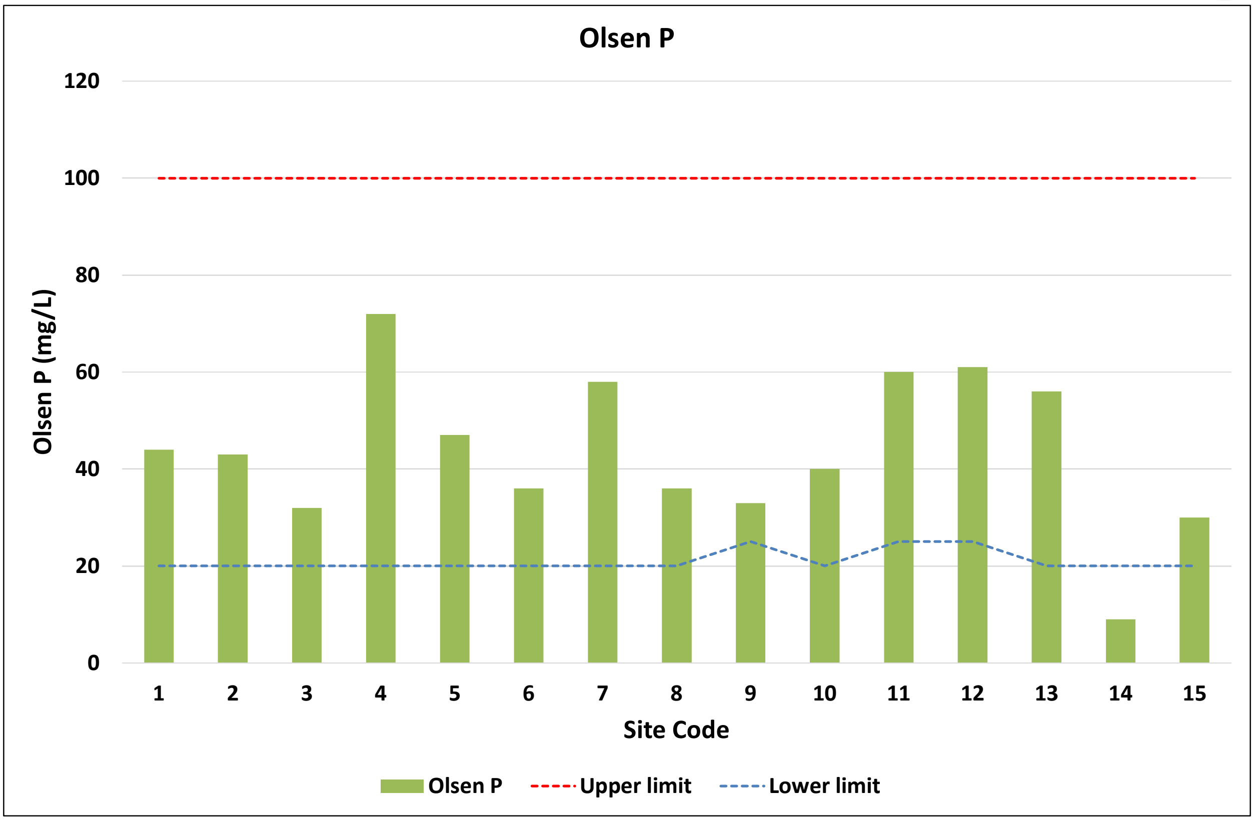

Figure 6: Olsen phosphorus for Hawke's Bay cropping sites sampled in 2014

5.3.7 Carbon : Nitrogen Ratio

Figure 7 shows the C:N results for the cropping sites. All the sites had C:N in a range considered to be relatively stable and favouring mineralisation of nitrogen for plant uptake.

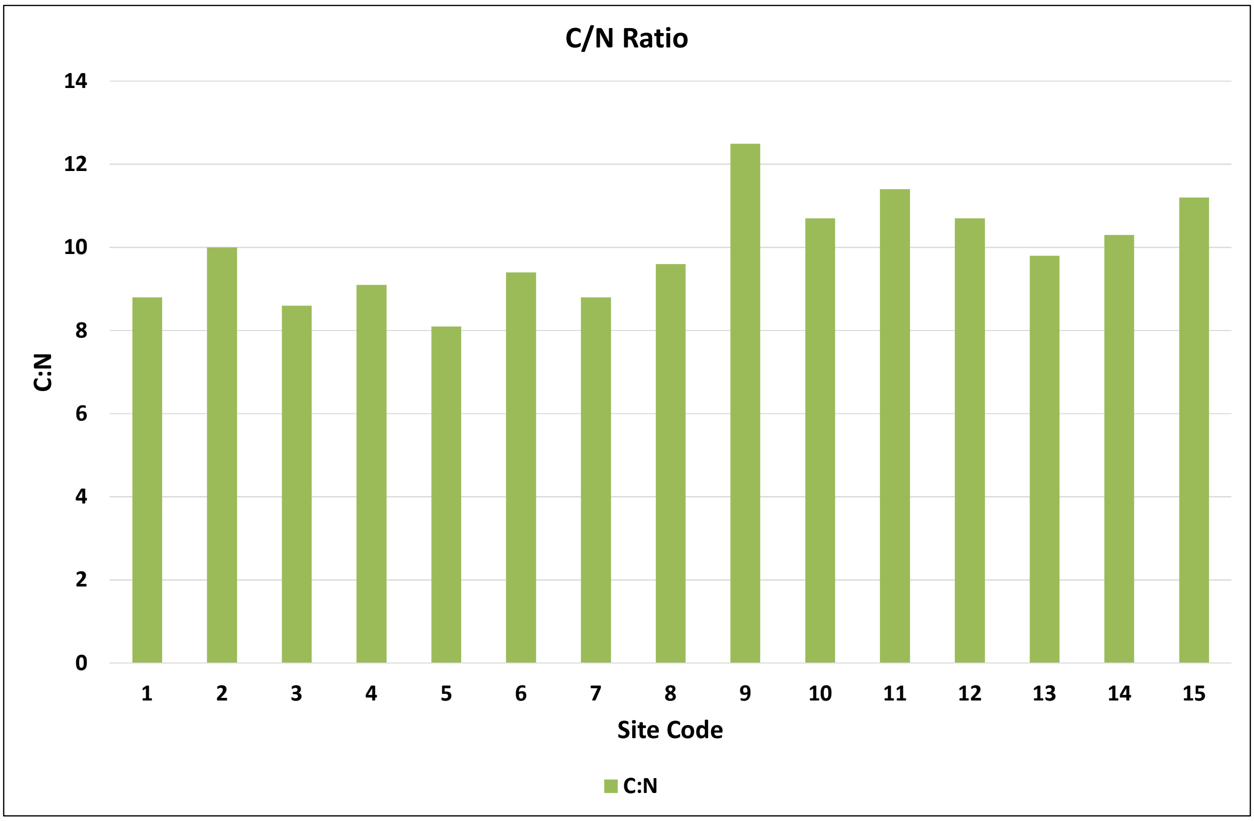

Figure 7: C:N for Hawke's Bay cropping sites sampled in 2014

5.3.8 Bulk Density

Figure 8 shows the bulk density results for the cropping sites. All sites were within the target range.

No soil sampled is expected to be subject to impeded root growth from reduced aeration and drainage. However Site 5 near to the upper bound of the target range and may require modified management to avoid future compaction (at the time of the site visit the farmer indicated a recent change in land manager was expected to result in improved soil physical management).

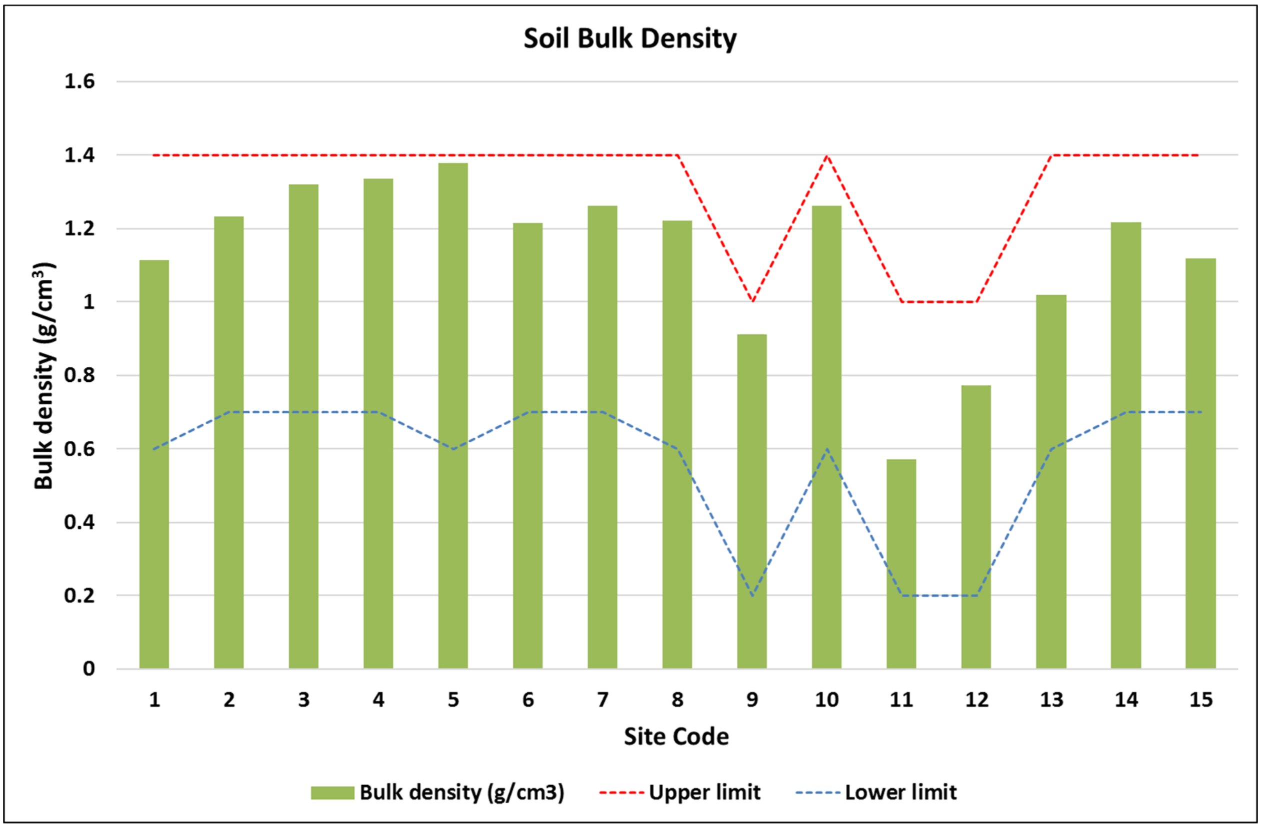

Figure 8: Bulk density for Hawke's Bay cropping sites sampled in 2014

5.3.9 Macroporosity

Figure 9 shows the macroporosity results for the cropping sites. All sites were within the target range. Site 10 and Site 12 were toward the lower bound. The low result for Site 12 (Turamoe soil) may reflect the amount of cultivation required for the onion seed bed, followed by settling which is increased by the irrigation of water from the pivot system. The low macroporosity did not correspond to a high bulk density which is likely to reflect that there is pumiceous material in the soil. The low result for Site 10 is reflected in a high bulk density (although still within the target range) which corresponds to the Pukehou soil being fine grained, subject to drainage limitations and therefore is susceptible to compaction.

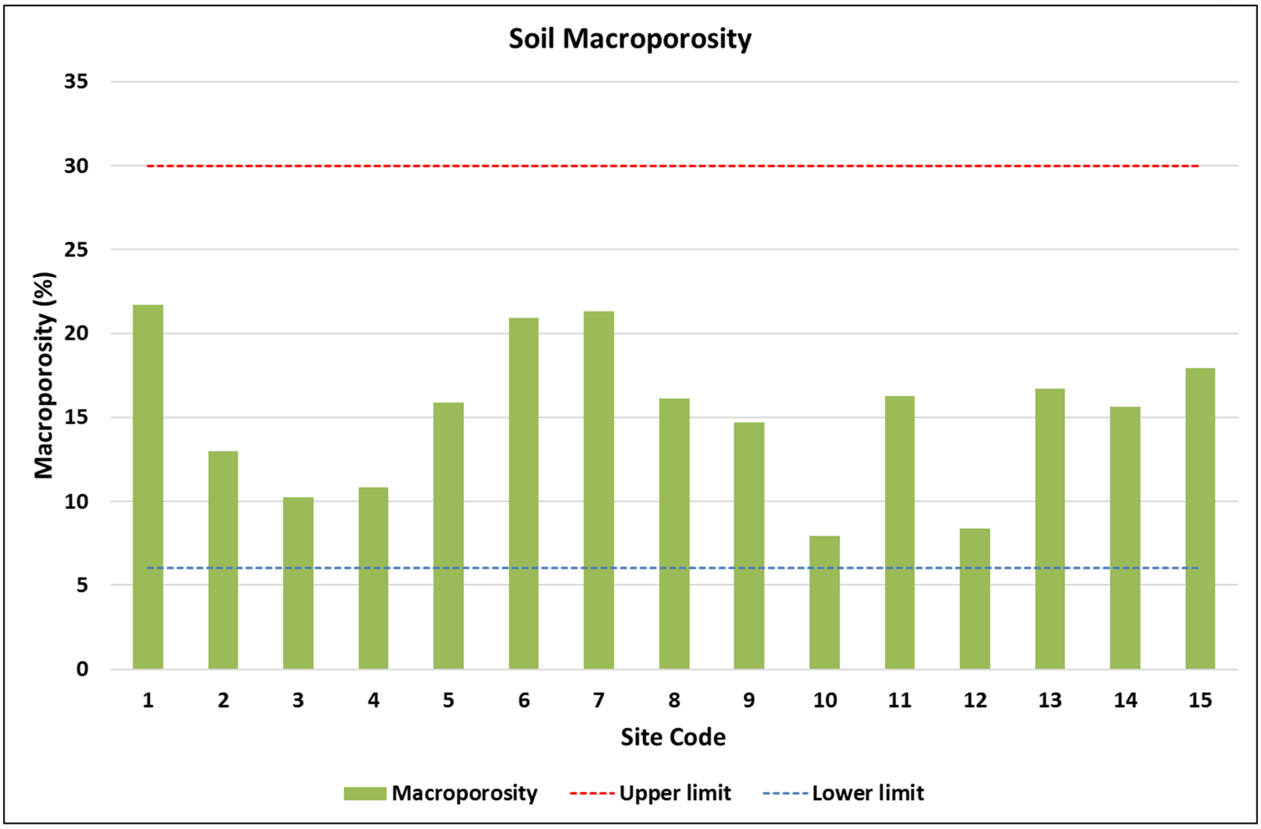

Figure 9: Macroporosity for Hawke's Bay cropping sites sampled in 2014

5.3.10 Aggregate Stability

Figure 10 shows the aggregate stability results for the cropping sites. Aggregate stability has not been monitored for other land uses. However, due to the frequent disturbance of many cropping sites aggregate stability is a concern for these soils. Low aggregate stability represents a loss of or lack of soil structure and indicates a vulnerability to compaction and soil crusting, and to loss from wind and sheet erosion. Aggregate stability has previously been identified as poor for Hawke's Bay cropping soils (Sparling and Stevenson, 2008).

There is no target range for aggregate stability, however it is considered that a value < 2 mm (mean weight diameter) would influence both production and environmental factors (Sparling and Stevenson, 2008). All but three of the analysed soils were below this level.

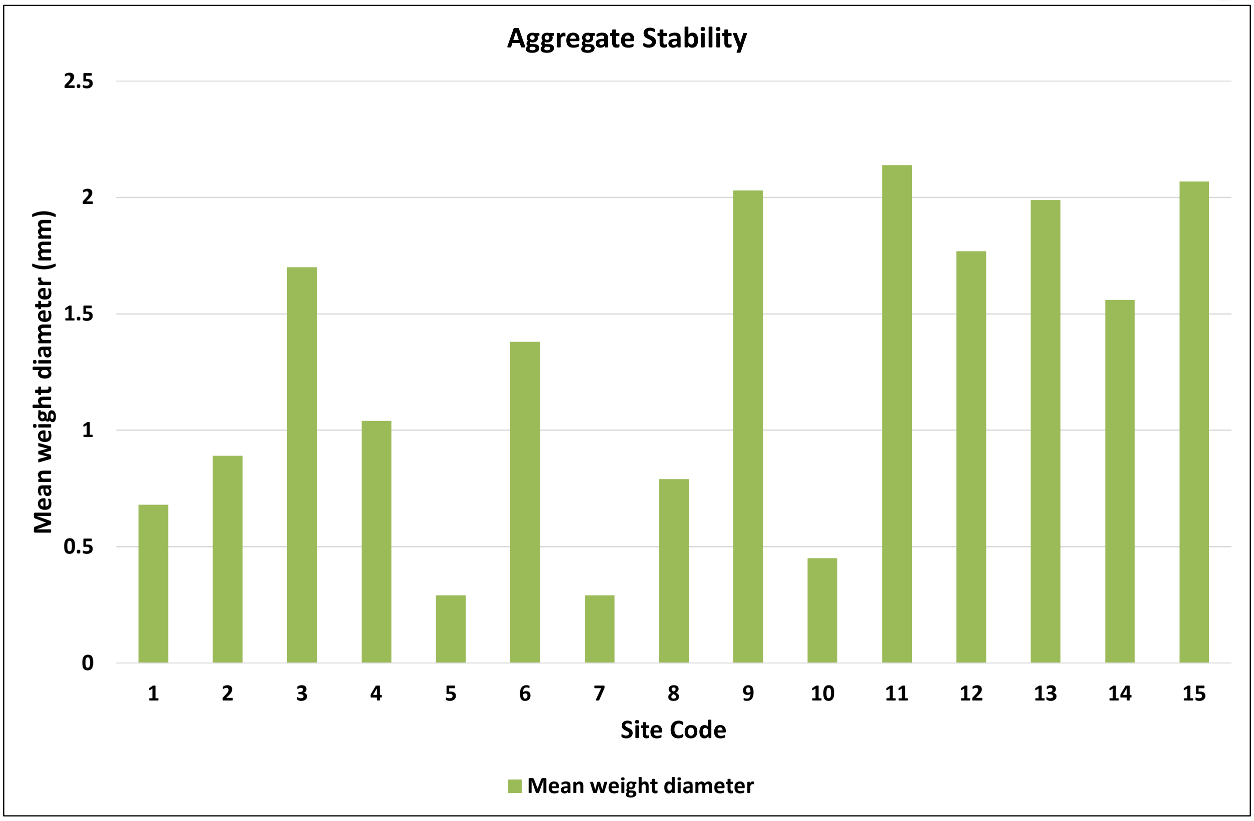

Figure 10: Aggregate stability for Hawke's Bay cropping sites sampled in 2014

5.4 Priority Two Indicators

Priority Two indicators were not determined for this sampling round.

5.5 Priority Three Indicators

The results from the soils analysed are described as follows.

5.5.1 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) or dieldrin were detected. DDT/DDD/DDE was detected in soils at 4 sites, being:

- Site 2, Tywford series, sweetcorn (0.102 mg/kg);
- Site 5, Hastings series, sweetcorn (0.088 mg/kg);
- Site 12, Turamoe series, onions (0.316 mg/kg); and
- Site 13, Takapau series, maize (0.323 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.

Dieldrin was detected at two sites, being:

- Site 1, Kaiapo series, squash (0.016 mg/kg); and
- Site 5, Hastings series, sweetcorn (0.028 mg/kg).

When compared to soil limits given in the biosolids guidelines (NZWWA, 2003) of 0.02 mg/kg dieldrin, Site 5 marginally exceeds the guideline.

Both DDT and dieldrin were used in market gardens as pesticides. For sites with a relatively short history of cropping the 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, and dieldrin may be residue from historic sheep dipping practices.

5.5.2 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 for all sites (NZWWA & MfE, 2003).

Section 3.4 above indicates the potential for elevated Cd levels where superphosphate is applied. No recorded values for Cd were above the guideline limit and this is reflected in the P status, F and U values measured which all indicate there is not significant accumulation in the cropping soils.

5.5.3 Fluoride (F)

None of the cropping sites sampled had fluoride results above the expected range for NZ soils (200-500 mg/kg, FLRC, 2009). Four sites recorded fluoride above 400 mg/kg (close to the upper end of the range), being:

- Site 1, Kaiapo soil (470 mg/kg);
- Site 4, Pakowhai soil (410 mg/kg);
- Site 6, Te Awa soil (460 mg/kg); and
- Site 12, Turamoe soil (400 mg/kg).

As with P, Cd and U results, high values may reflect phosphate fertiliser addition, however there appears to be no clear correlation between the results for these four elements.

Another potential source of F is from volcanic ash which has showered the Hawke's Bay in the past.

5.5.4 Uranium (U)

Measured U varied from 0.59 to 3.60 mg/kg. In general, levels are low and below the proposed Canadian soil limit of 23 mg/kg (CCME, 1999). Further information is required to determine a New Zealand limit (Taylor *et al.*, 2007).

5.6 Overall Soil Quality

The results from the soils analysed have been compared to the interpretative Framework which provides terms to categorise the results and target ranges or critical limits.

Nine sites met all soil quality targets, 5 met all but one target and 1 site had two targets unmet. Figure 11 shows the proportion of targets for which there is a range or limit, that were met by each site.

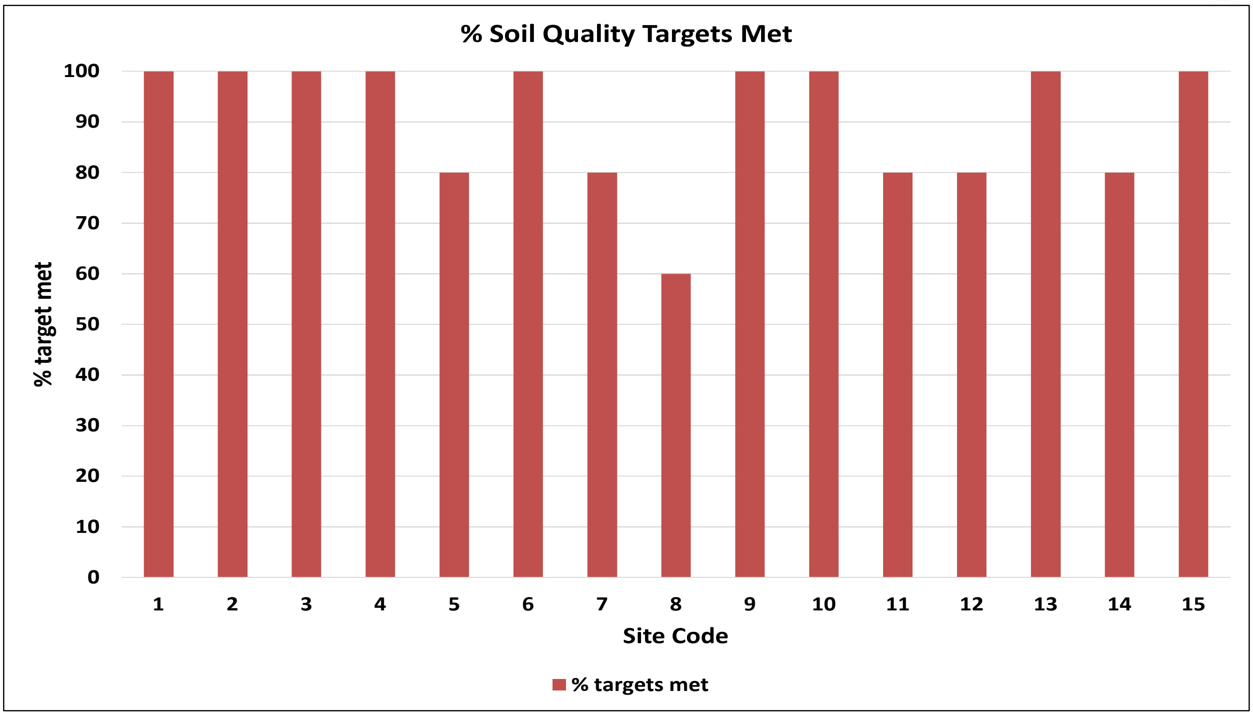

Figure 11: % Soil quality targets met for Hawke's Bay cropping sites sampled in 2014

Soil quality indicators for which a target was not met were:

- pH (Site 8);
- Total carbon (Site 5, Site 7, Site 8);
- Anaerobically mineralisable nitrogen (Site 11);
- Olsen P (Site 14); and
- Macroporosity (Site 12).

While not reflected in the proportion of soil quality targets met, it is of concern that organic carbon and aggregate stability were low for a high proportion of the sites. This is not unexpected for cropping soils but may indicate limitations for the sustainability of the land management practices.

5.7 Changes in Soil Quality Over Time

There are no sites in this sampling round that can be directly compared to previous sampling rounds. However, it is considered appropriate to evaluate differences observed for the same soil types. Table 5 gives a summary of previously reported results compared to the current (2014) round.

Table 5: Comparative soil sites from 2007 and 2014

2014 Soil Sites			2007 Soil Sites		
Site No	**Soil Type**	**Crop**	**Client Code**	**Soil Type**	**Crop**
4	Pakowhai	Ryegrass	BWO-07-10 cm	Pakowhai	Silver beet
			NMA-07-10 cm	Pakowhai	Strawberries
5	Hastings	Sweet corn	500S-03-10 cm	Hastings	Sweet corn
			HY-Ri-07-10 cm	Hastings	Cabbage
			RJO-07-10 cm	Hastings	Leeks
7	Farndon	Squash	PYO-07-10 cm	Farndon	Squash

In addition, data from one site from the 2000 '500 soils' programme is available. A comparison of reported results is given in Table 6.

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 cropping land can be made. It should be noted that general observations have been made here and no statistical evaluation of significant difference has been made. Due to the heterogeneous nature of soils, both spatially and seasonally, a change of greater than ±15 % is considered to indicate a change in soil quality. It is unlikely that the measured results indicate a change. However, general discussion is given since it will assist with identifying trends in the future.

Table 6: Comparative soil sites from 2000, 2007 and 2014

Soil Type	Year	bulk density (g/cm^3)	Macroporosity (%)	Aggregate stability (mm MWD)	pH	Total C (mg/cm^3)	Total N (mg/cm^3)	Olsen P (mg/L)
Hastings silt loam	2000	1.33	10.1	0.32	6.4	26.2	2.13	98
Pakowhai silt loam	2007	1.24	23.7	0.29	7.5	21.0	2.59	98
Karamu silt loam	2007	1.19	22.2	0.44	6.1	17.8	1.90	85
Hastings clay loam	2007	1.09	23.9	0.58	6.3	23.9	2.60	46
Pakowahi silt loam	2007	1.17	22	0.37	6.6	17.5	1.75	18
Hastings clay loam	2007	1.14	26.2	0.38	6.0	21.6	2.50	75
Farndon silt loam	2007	1.13	25.5	0.9	7.7	18.0	2.03	16
Hastings silt loam	2007	1.14	27	0.35	5.7	19.4	1.83	53
Pakowhai silt loam	2014	1.21	18.2	1.04	6.1	32.8	3.64	72
Hastings silt loam	2014	1.38	13.7	0.29	6.3	22.0	2.76	47
Farndon silt loam	2014	1.34	9.7	0.29	7.6	21.4	2.40	58

In general the soil quality parameters measured in this sampling round (2014) reflect the values measured in 2000 and 2007. The 2014 results indicate there has been no improvement in soil condition between 2000 and 2014 and there soil physical condition may have worsened since 2007.

6 DISCUSSION

As outlined in Section 3.5, in previous soil quality monitoring for cropping soils the primary concern identified was low carbon reserves. All soils were also identified as having poor aggregate stability. From the current (2014) sampling round, while the measured levels for these indicators were predominantly within target ranges, it is considered that these indicators remain a concern for cropping soils in the Hawkes Bay.

In general for the sites evaluated the measured soil quality parameters suggest that the quality of soils in cropping is acceptable. There were some specific issues identified, and these are discussed below.

Overall the carbon content of the 12 mineral soils was considered normal for only three sites while the remaining 9 were depleted or outside the target range. This is a strong indication that these soils are at risk of negative impacts to:

- Soil structure;
- Moisture retention capacity;
- Nutrient retention; and
- Ability to maintain a healthy biological community.

Loss of carbon from two of the three Organic soils has the potential for a detrimental effect to the land surface level. Because the soil is predominantly composed of organic matter, as it is oxidised (due to drainage or cultivation) or blown away the land surface drops, impacting groundwater levels.

The other key indicator of concern for cropping soils is the aggregate stability. The analytical results are generally low and less than was measured in 2007. This is likely to be exacerbated by low carbon which tends to form stable colloids in the soil. Poor aggregate stability is a risk on cropping soils both because of the high cultivation incidence, and also because cropping soils are often located on young, poorly developed soils of fertile river plains. Poor aggregate stability may lead to issues such as crust formation and reduced water infiltration. This in turn requires an increased cultivation regime leading to potential for wind erosion of the fine grained material due to both the action of cultivation and also lack of plant cover during fallow and crop establishment. Soils with poor aggregate stability are susceptible to sheet and rill erosion, including due to droplet impact.

Soils with better developed structure such as the Mangateretere clay loam, Poporangi silt loam and Okawa silt loam, tended to have better aggregate stability.

Poor aggregate stability and low carbon reserves are likely to be interrelated. Both indicators are slow to recover, but further damage can be minimised by conservation tillage practices and careful selection of fertilisers, favouring types which encourage biological activity in the soil. It is noted that many of the farmers spoken to are well educated in the management of the soil physical health and incorporate reduced or conservation tillage practices on their sites. It is likely that improvements in carbon and aggregate stability will be slow, however the fact that many of the soil quality indicators at most sites were within target ranges suggests that the overall health of Hawke's Bay cropping soils is acceptable.

Contaminant levels on the cropping soils were predominantly low to undetectable, with the exception of one site having elevated dieldrin results. The dieldrin result may warrant further investigation.

7 CONCLUSIONS

- In general soil quality in the Hawke's Bay cropping sites is good.
- Soil fertility is expected to be adequate for cropping sites due to fertilisation, and to vary rapidly due to the cultivation cycle. While every attempt to sample immediately prior to harvest was made, some variance may be expected which can be accounted for by the crops growth phase.
- Soil physical condition is a concern for cropping sites, in particular those sites with fine textured soils or Organic soils.
- Aggregate stability and carbon reserves are considered to be the key issues for soil quality and sustainability of cropping land use for the Hawke's Bay.
- Reduced nutrient retention resulting from low carbon may increase potential leaching from these sites.
- Ground level change may be an indicator of sustainability limitations of cropping on Organic soils where, a reducing ground level elevation may indicate that the land use is unsustainable on that soil or at that location.

8 RECOMMENDATIONS

- 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.
- Wider monitoring of the receiving environment around cropping sites may be needed to quantify the sustainability of existing practices. This may include groundwater level monitoring near sites with low carbon, ground level monitoring of organic soils and potentially, evaluation of soil loss by wind and sheet erosion in areas where conventional tillage is practiced.
- 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.

9 REFERENCES

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10APPENDICES

APPENDIX A

Soil Descriptions

APPENDIX B

Photos

APPENDIX C

Analysis Reports