tasman district council

State of the Environment Report

Soil Health Monitoring

2010 Sampling Programme

Soil Health Monitoring Programme

Soil Health Sampling 2010

Document Status: Final Report

The purpose of this report is to provide information about the health status of the soils in the Region

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Cover Photo: Soil profile of a Sherry sandy loam

Tasman District Council Report Ref: XXXX

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Acknowledgements

I wish to acknowledge all the farmers and landowners for their cooperation and for providing access to their land for sampling, also Dr Iain Campbell for carrying out the soil profile assessment and Tom Kennedy from Tasman District Council for assisting with the sampling.

1 Introduction

The aim of this monitoring programme for Council is to collect and interpret information on soil health in the region, as required by the Resource Management Act 1991 for the purposes of State of the Environment reporting. The information will contribute to improved sustainable management by providing quantitative data to evaluate the risk to, and state of, the soil resource under intensive land use.

Monitoring of Soil Health in the Tasman District was initiated in 2000 with the collection of information at 10 sites as part of the Ministry of the Environment's "500 Soils Project". The sites selected were four pastoral (dairying), one market garden, two orchard and three rehabilitation (mining and gravels extraction) sites (Report: Implementation of soil quality indicators for land in the Tasman region – a progress report for Year 1). New sites were sampled in 2005 and 2009 bringing the total number of sites in the programme to 23. In 2010, nine of the ten sites sampled 2000 were re-sampled. Two additional sites were also sampled in the Takaka Valley. These were horticultural sites , a land use that Council has very few monitoring sites on.

This report summarises the soil quality monitoring undertaken at these sites.

2 Method

The 2010 programme includes the original sites sampled in 2000. One site, TDC00.10, was not sampled because it had recently been rehabilitated after gold mining and was not suitable for sampling. Two additional sites were sampled on Kiwifruit orchards in the Takaka Valley. One site, TDC00.4 has had a change of land use. In 2000 it was a pipfruit orchard but now is used primarily as a disposal field for industrial waste water. The area is in pasture and is grazed regularly by sheep. Site TDC00.7 was a site rehabilitated after gravel extraction and at the time of the 2000 sampling was in pasture. For the last three years some market gardening has been carried out on this site.

The sites and their description are listed in Table 1 below.

Table 1: Sites and Description

Site code	Soil type	Land use
TDC00.1	Karamea silt loam	Pasture
TDC00.2	Ikamatua silt loam	Pasture
TDC00.3	Onahau silt loam	Pasture
TDC00.4	Waimea clay loam	Waste water disposal
TDC00.5	Mapua sandy clay loam	Orchard
TDC00.6	Waimea silt loam	Market garden
TDC00.7	Waimea silt loam (anthropic)	Rehabilitated site
TDC00.8	Waimea silt loam (anthropic)	Rehabilitated site
TDC00.9	Ikamatua gritty silt loam (anthropic)	Rehabilitated site
TDC00.24	Karamea	Kiwifruit
TDC00.25	Takaka	Kiwifruit

At each sample site, a site description and soil profile was completed and sampling carried out to assess the following basic soil properties:

1 Total Carbon
2 Total Nitrogen
3 Mineralisable Nitrogen
4 Soil pH
5 Olsen P
6 Bulk density
7 Macroporosity
8 Aggregate stability

These are the soil properties used in the “500 Soils Project” and the sampling protocols for these are found in Appendix 3.

In addition to these properties, the volumetric water content at 5, 10, 100, 1500 kpa, and the heavy metals (total recoverable); arsenic, cadmium, chromium, copper, lead, nickel, zinc were assessed.

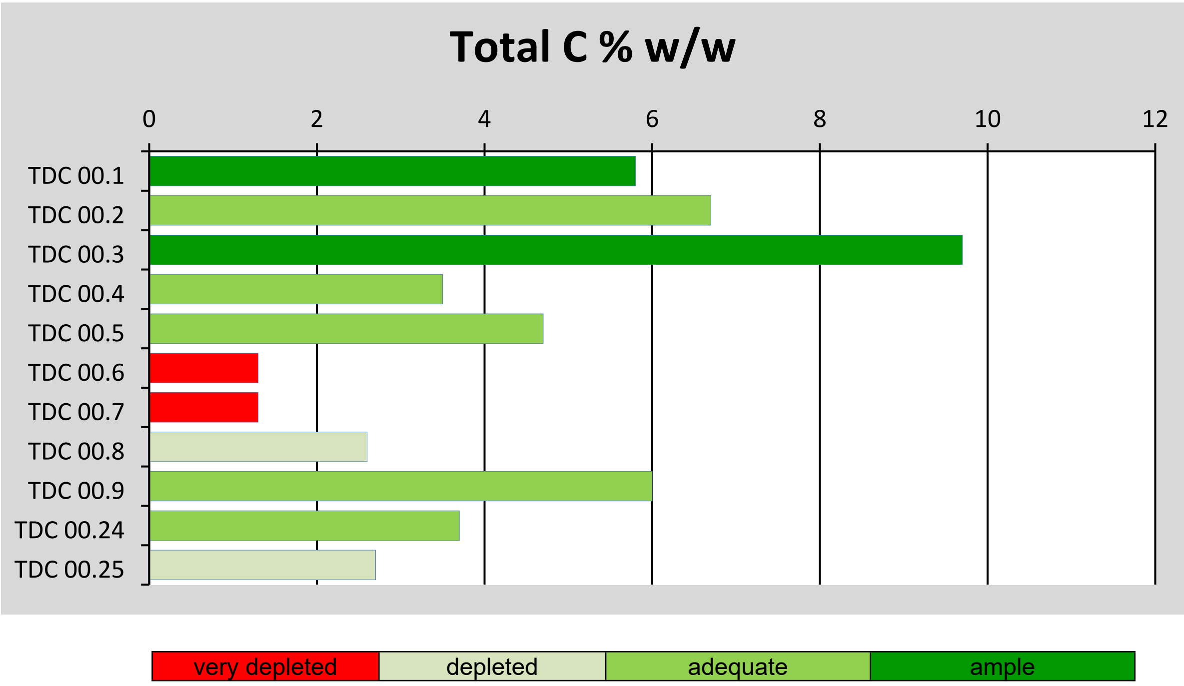
The volumetric water content data is required to assist with irrigation management and will be used specifically by Council for irrigation water allocation purposes. Part V of the Tasman Resource Management Plan details the weekly allocation limit for consents using water for irrigation based on the water-holding capacity of the soils to which it is applied. Heavy metal analysis is a recent addition to the monitoring programme. This has been added due to the potential contamination risk associated with some past and present land use practises such as fertilizer application and disease control. For example, cadmium is a contaminant of super phosphate, facial eczema treatment contains high levels of zinc, and copper is used as a fungicide in orchards. Heavy metals accumulate in the soil hence even small inputs on a yearly basis may in the long term accumulate to detrimental levels.

The soil properties themselves do not measure soil quality; rather soil quality is a value judgement about how suitable a soil is for its particular land use. A group of New Zealand experts in soil science developed soil response curves for each of the soil properties, and established critical values or optimal ranges for the assessment of soil quality for the predominant Soil Orders under a number of different land uses. These critical values and optimal ranges are used to assess soil quality in this report. The critical values and optimal ranges are under constant review as new information is gathered and our understanding of the science grows.

3 Results

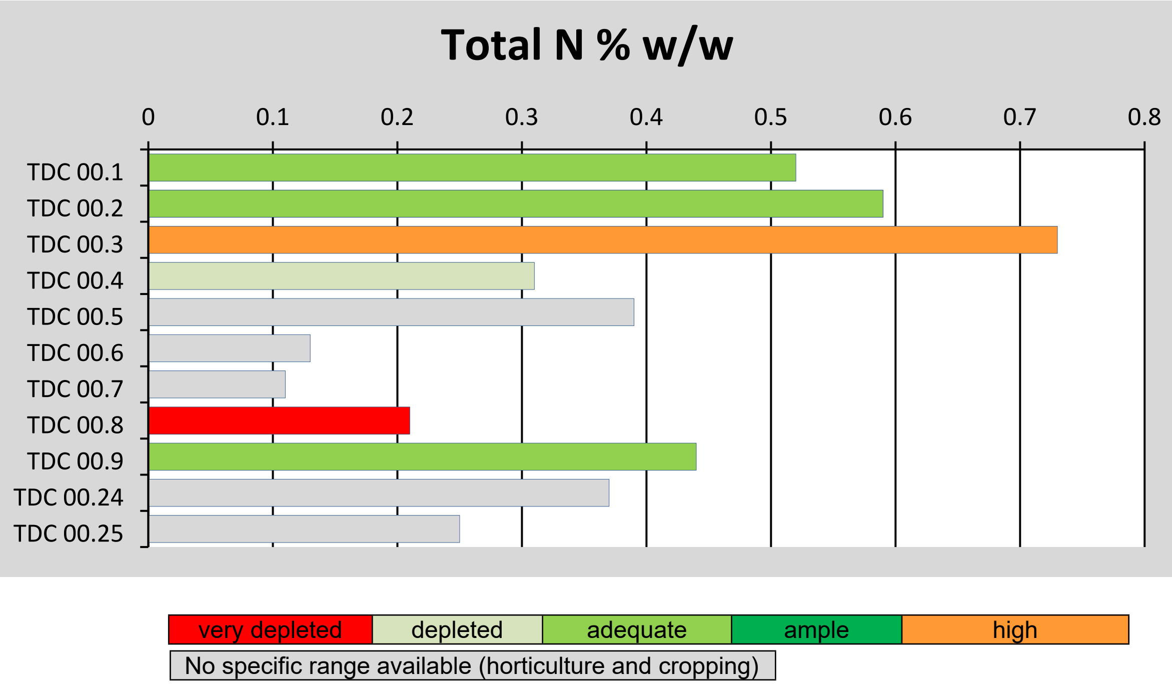
3.1 Organic Resources

Total Carbon levels are an indication of organic matter content, which is important for moisture and nutrient retention and for good soil structure. The issues relating to total carbon are soil organic matter depletion and carbon loss from the soil, generally as a result of intensive land use. The sample results, ranging from 1.3 to 9.7 mg/cm³, are displayed in the following chart.



Nine of the eleven sites were within the target range of “depleted”, “adequate” and “ample”.
Below the critical limit, very depleted levels were measured at sites, TDC 00.6 and TDC 00.7. These are market gardening sites with TDC00.7 also being an historic gravel extraction rehabilitation site.

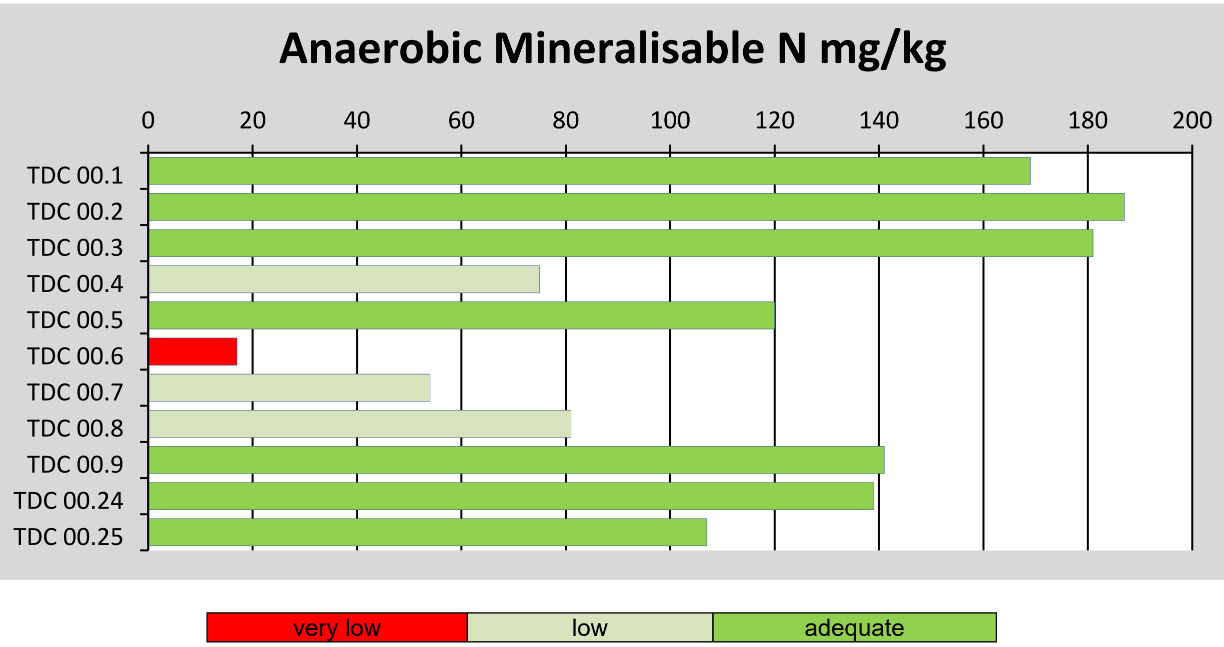
Total Nitrogen gives a measure of the reserves of organic matter in the soil as most nitrogen (N) in soil is within the organic matter fraction. Nitrogen is an essential nutrient for plants and animals. Usually only a small fraction of the total N is immediately available for plant uptake (soluble inorganic nitrogen). While a variable proportion of the total nitrogen is potentially mineralisable to inorganic N. In general, high total nitrogen indicates the soil is in good biological condition. However, very high total nitrogen contents may increase the risk that nitrogen supply may be in excess of plant demand, and ultimately lead to leaching of nitrate to groundwater. The sample results range from 0.11 to 0.73 mg/cm³ of Total Nitrogen and are displayed on the following chart.



One site, old rehabilitation site TDC 00.8 fell below the critical limit. Very low levels of Total N are found on the two market garden sites, TDC 00.6 and TDC 00.7 as well as the horticultural site TDC00.25. There is no target range for total nitrogen for horticulture and cropping as target values will depend on the specific crop grown.

One site, TDC 00.3, on a dairy farm situated on podzol soils was above the critical limit.

Anaerobic Mineralisable Nitrogen (AMN) levels measure the readily decomposed organic Nitrogen. This gives a measure of the level of activity of soil organisms. Soil organism activity is important for the overall functioning of the soil as it aids nutrient availability, water and gas movement/exchange and soil structural stability. Generally the higher the AMN content is, the healthier the soil is. The results range from 17 to 187 mg/kg of AMN. Only the market garden site, TDC 00.6, fell significantly below the lower critical limit of 50 mg/kg.



3.1.1 Discussion on the Soil Organic Resources

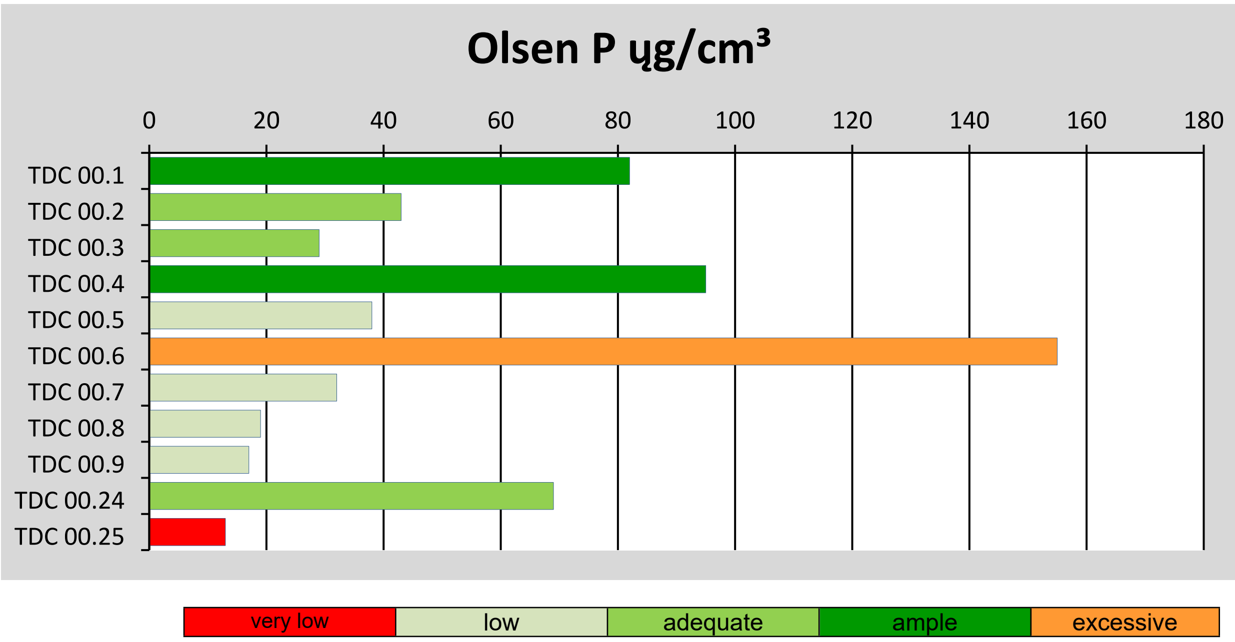
The results indicate that there is significant depletion of the soil's organic resources associated with the market garden sites with low Total Carbon, Total Nitrogen and Anaerobic Mineralisable Nitrogen levels measured at both sites. This is symptomatic of this landuse where intensive cultivation occurs and negligible organic matter inputs are common. Compared with a recent study of market gardening and cropping sites in the Wellington region, the poorest performing Tasman site (TDC00.6) would rank at the same level as the poorest performing Wellington site. Depletion of two of the three historic rehabilitation sites is still evident although the results of site TDC00.7 may be compounded by its current use for market gardening.

All pastoral sites measure an overall adequate organic resource. A high Total Nitrogen level was detected on site TDC00.3 which is a dairy farm site on pakahi. High Total Carbon levels were also measured at this site indicating an ability of these soils to store high levels of nitrogen safely.

The horticultural sites measure a lower level of organic resource than the pastoral sites but overall indicate a healthy state. Site TDC00.24 does have a depleted level of Total C but this may be because the soil is of a young age.

3.2 Chemical Quality

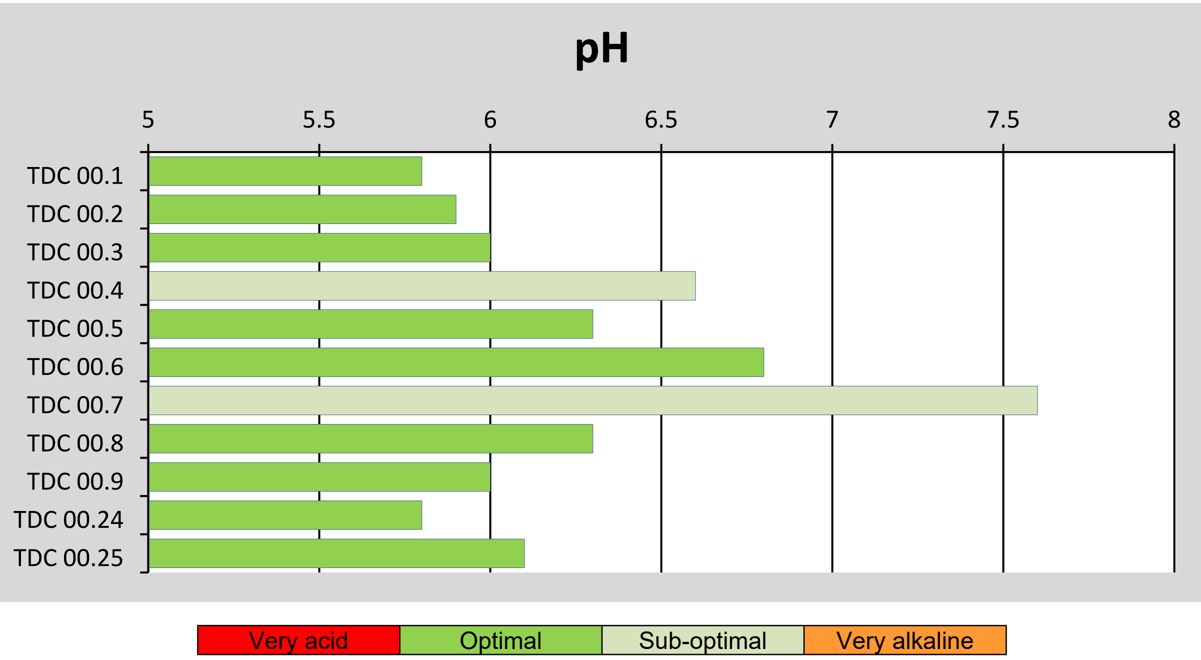
Olsen P levels indicate the level of plant available phosphorus and general fertility of the soil. Phosphorus (P) is an essential nutrient for plants and animals. Plants get their P from phosphates in soil. Many soils in New Zealand have low available phosphorus, and P needs to be added for agricultural use. The issues associated with P levels are the possible depletion or "mining" of the soil nutrient reserve and also excessive fertilizer use and its potential for its loss to waterways which contributes to eutrophication risk.



Two sites fall outside the critical limits; the very low level of 13 is found on the kiwifruit site where as the site with excessive P is one of the market garden site: TDC 00.6.

Note: The critical limits for Olsen P are currently under review by the National Land Monitoring Forum. It is anticipated that the upper limits will be lowered and align with the critical limits for production which is suggested to be around 40 to 50 units, but will vary with soil type and landuse.

pH is a measure of soil acidity. Most plants and soil animals have an optimum pH range for growth. Indigenous species are generally tolerant of acid conditions but introduced pasture and crop species require a more alkaline soil. The issues associated with pH levels are that some sites may fall outside the favourable pH range for some plant species. Also, some heavy metals may become soluble and bioavailable at certain pH ranges. The results range from pH 5.8 to 7.6. All site measured in the target range.

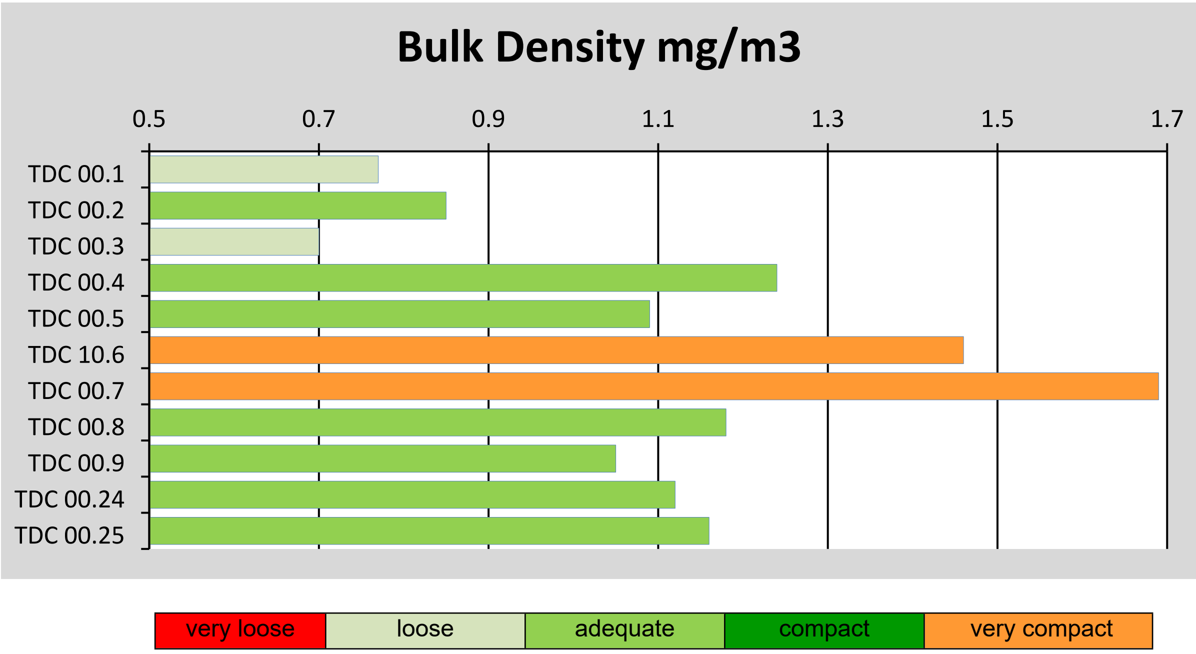


3.2 Discussion on Soil Chemistry

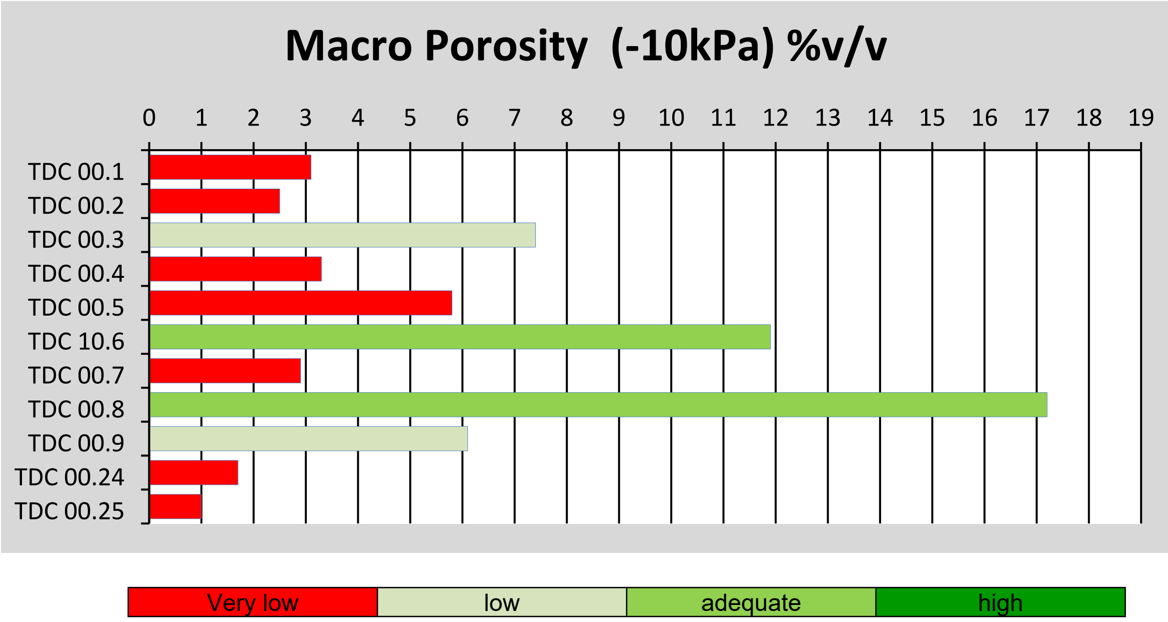
The soil chemistry properties indicate generally healthy soils at all sites. The high phosphate level at the market garden site, TDC 00.6, may be of little environmental significance as potential surface water runoff and hence phosphate loss from the site to adjacent waterways is very restricted. Likewise the sub-optimal pH measure at the market garden site TDC 00.7 is of likely to be of agronomic significance only WHY?????. The very low phosphate level at the kiwifruit site, TDC 00.25 may be of agronomic significance, although the health and vigour of the crop at the time of sampling did not reflect any deficiency.

3.3 Soil Physical Characteristics

Bulk Density levels indicate the level of soil compaction. Compacted soils restrict water or air penetration into the soil profile, which restricts drainage and root growth. This in turn has the potential to increase surface water run-off and nutrient losses. The results range from .77 to 1.24 mg/m³. All but two sites had adequate bulk density levels falling within the target range of "loose", "adequate" or "compact". Outside the target range, very compact levels were found at the 2 sites used for market gardening.

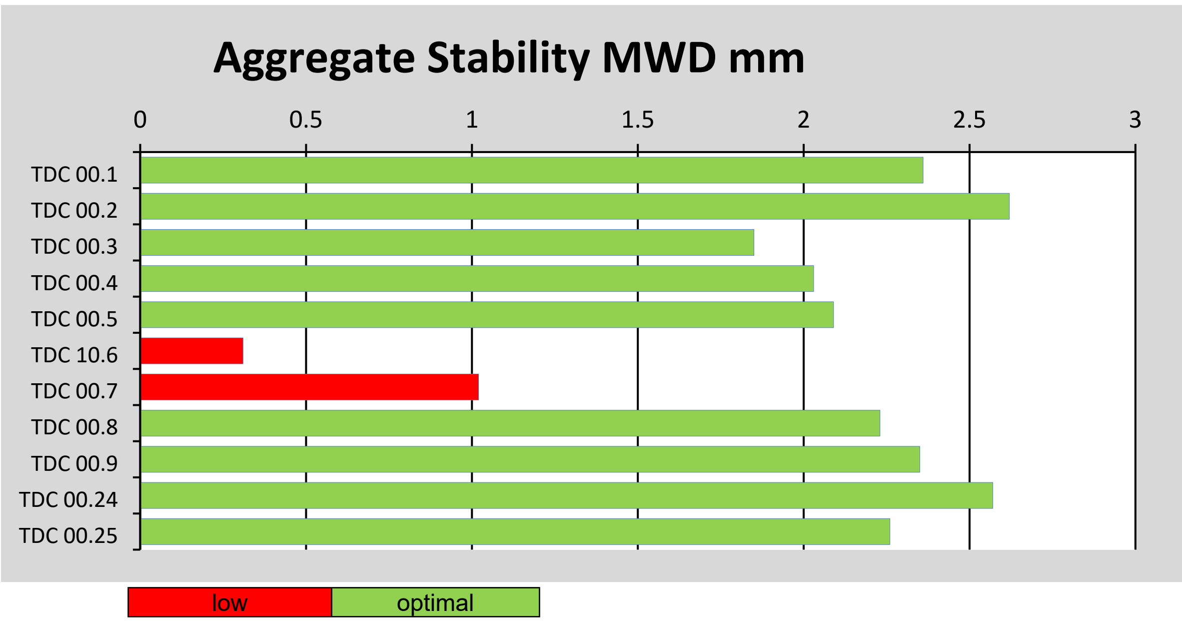


Macroporosity levels also indicate the level of soil compaction and aeration. Macropores are important for air penetration into soil, and are the first pores to collapse when soil is compacted. This can adversely affect plant growth due to poor root environment, restricted air access and N-fixation by clover roots. The results range from 4.6 to 13.8 %v/v as indicated in the chart below.



Seven of the samples fell below the critical limit of 6%v/v, and four within the target range of 6 - 30%v/v.

Aggregate Stability is a measure of how resistant soil crumbs are to breakage. A stable “crumbly” texture lets water quickly soak into soil, doesn’t dry out too rapidly, and allows roots to spread easily. Measured levels ranged from 0.31 to 2.62. There is currently no soil quality ranking for aggregate stability under a grazing regime. However, scientific opinion indicates that an aggregate stability of greater than 1.5 mm mean weight diameter is considered necessary for optimal soil quality for environmental parameters. The two market garden sites: TDC00.6 and TDC00.7 fell below this critical limit.



3.4 Discussion on Soil Physical Results

The market garden sites show significant levels of soil degradation. For the majority of soil physical indicators, the critical limits were not met. This degradation is due to the intensive cultivation regimes associated with market garden operations. Cultivation breaks up soil aggregates and so affects the soil structure. Soils with low aggregate stability are susceptible to erosion and are more prone to dispersion by wind and water. Soil particles dispersed by water tend to fill surrounding pores, impeding the infiltration of water and air into the soil profile. Intensive traffic movement associated with cultivation can also break up soil aggregate and also cause soil compaction.

Two out of the four pastoral sites had macroporosity levels below the critical limit and the other two pastoral sites were categorised as “low”. There are several comprehensive reviews on soil compaction related to pastoral grazing systems. It is commonly accepted that through a reduction in the macroporosity, intensively managed grazing systems can result in reductions in pasture yield, biodiversity, increased soil erosion and surface water run-off and reduced soil weight-bearing capacity.

The effect of soil compaction is to reduce porosity, restrict air and water movement, and increase density and resistance. The volume of large connected drainage and aeration pores (macropores) is particularly prone to reduction from soil compaction by animals. Typically, soil compaction occurs at soil moisture contents less than for pugging, although both processes may occur over a range of soil moisture values.

Bulk density is another soil physical property used to assess soil compaction. Measurements indicate that bulk density at all but the market garden sites were adequate. The macroporosity results would indicate otherwise and as it is the more sensitive of the indicators used it should not be ignored.

All three orchard sites also registered macroporosity levels below the critical limit. The sampling was carried out in the centre of the grassed strip between the crop rows. It should not have been affected my machinery, or significant stock grazing. The reason for the low macroporosity levels at these sites is uncertain.

3.5 Trace Element Analysis

A deficiency or an excess of trace elements in soil can have a major bearing on soil health despite their low concentrations. Some trace elements are essential micronutrients for plants and animals. Others are not. However, both essential and non-essential elements can become toxic at higher concentrations.

A suite of the most common environment-impacting elements arsenic, chromium, cadmium, copper, lead, nickel and zinc were measured at each site. These trace elements can accumulate in soils as a result of common agricultural and horticultural land use activities and are most likely to have a negative effect on soil quality.

The Ministry for the Environment's "Environmental Guideline Value (EGV) database" has been used to provide guidance as to which soil guideline values to use for interpretation of the data gathered. The guideline is used to assess if values for specific trace elements are at concentrations in soils that are likely to have a negative effect on soil quality. These effects specifically include factors such as soil microbial function, soil invertebrate populations, phytoxicity, animal health, the protection of groundwater and the protection of human health. The results of the trace element tests are presented in Table 2 below.

Table 2: Trace Element levels (total recoverable) of Sites Sampled in the Tasman District: 2010

Site Code	Land Use	Soil Type	Arsenic mg/kg dry wt	Cadmium mg/kg dry wt	Chromium mg/kg dry wt	Copper mg/kg dry wt	Lead mg/kg dry wt	Nickel mg/kg dry wt	Zinc mg/kg dry wt
TDC00.1	Pasture	Karamea silt loam	**7**	**0.46**	**41**	**26**	**14.7**	**30**	**96**
TDC00.2	Pasture	Ikamatua silt loam	**18**	**0.39**	**95**	**36**	**15.7**	**32**	**61**
TDC00.3	Pasture	Onahau silt loam	**<2**	**0.50**	**4**	**8**	**2.8**	**<2**	**5**
TDC00.4	Orchard	Waimea clay loam	**30**	**0.42**	**161**	**260**	**100**	**210**	**105**
TDC00.5	Orchard	Mapua sandy clay loam	**21**	**0.23**	**11**	**58**	**119**	**6**	**75**
TDC00.6	Market garden	Waimea silt loam	**4**	**0.18**	**187**	**31**	**9.4**	**280**	**73**
TDC00.7	Rehabilitated site	Waimea silt loam (anthropic)	**5**	**<0.10**	**86**	**42**	**10.7**	**113**	**72**
TDC00.8	Rehabilitated site	Waimea silt loam (anthropic)	**3**	**0.10**	**90**	**23**	**9.3**	**121**	**60**
TDC00.9	Rehabilitated site	Ikamatua gritty silt loam (anthropic)	**4**	**<0.10**	**24**	**12**	**11.9**	**18**	**45**
TDC00.24	Kiwifruit	Karamea	**8**	**0.54**	**59**	**23**	**19**	**28**	**121**
TDC00.25	Kiwifruit	Takaka	**7**	**0.18**	**70**	**29**	**10.1**	**33**	**70**
Guideline values adapted from NZWWA (2003)			***20***	***1***	***600***	***100***	***300***	***60***	***300***

3.6 Discussion on Trace Element Analysis

Arsenic levels are above guideline levels at two of the orchard sites; TDC 00.4 and TDC 00.5. This is due to historic pesticide use particularly the use of the insecticide lead arsenate. Arsenic based pesticides and herbicides have been withdrawn from use in New Zealand for several decades. Consequently arsenic levels should decrease slowly over time.

Cadmium levels range from <0.10 to 0.54 mg/kg, with an average of 0.29 mg/kg. New Zealand has a national average baseline (ie, the 'natural' background level in soils) value for cadmium of 0.16 mg/kg, which is consistent across all regions and soil types. The current national average concentration of cadmium from soils used for agricultural production is 0.35, with a range of 0-2.52 mg/kg.

The Canadian Environmental Quality Guidelines (CCME 2002) provide the only assessment levels for agricultural soils, where 1.4 mg/kg is set as an upper limit for the soil cadmium content. The NZWWA (2003) limit is 1 mg/kg. Although the measured levels are below the guideline limits, they are above what is considered typical background levels. The source of rising cadmium levels is primarily due to repeated applications of phosphate fertilizer such as super phosphate containing cadmium as a trace impurity. Cadmium accumulation in agricultural soils is recognized as an emerging issue by government and industry. The "Cadmium Working Group" has recently been set up by the Ministry of Agriculture & Forestry to produce a national strategy to manage the cadmium issue.

Copper levels are above guideline levels at TDC 00.4 which was historically an orchard site but now being used as a waste water disposal site for a processing plant. The levels are likely to be attributable to the previous orchard operations. Products containing copper were historically and are still widely used in New Zealand as fungicides. This site's current use should not add to any additional copper accumulation in the soil. The current level of contamination will have toxic effects on soil macro-invertebrate life and may have phytotoxic effects on some crops.

Nickel levels exceeded the guideline levels at the 4 sites situated on the Waimea soils. These soils are historically high in nickel as a consequence of their genesis. Outwash from the ultramafic hill country in the eastern ranges leads to high levels of some soil trace elements such as nickel and magnesium.

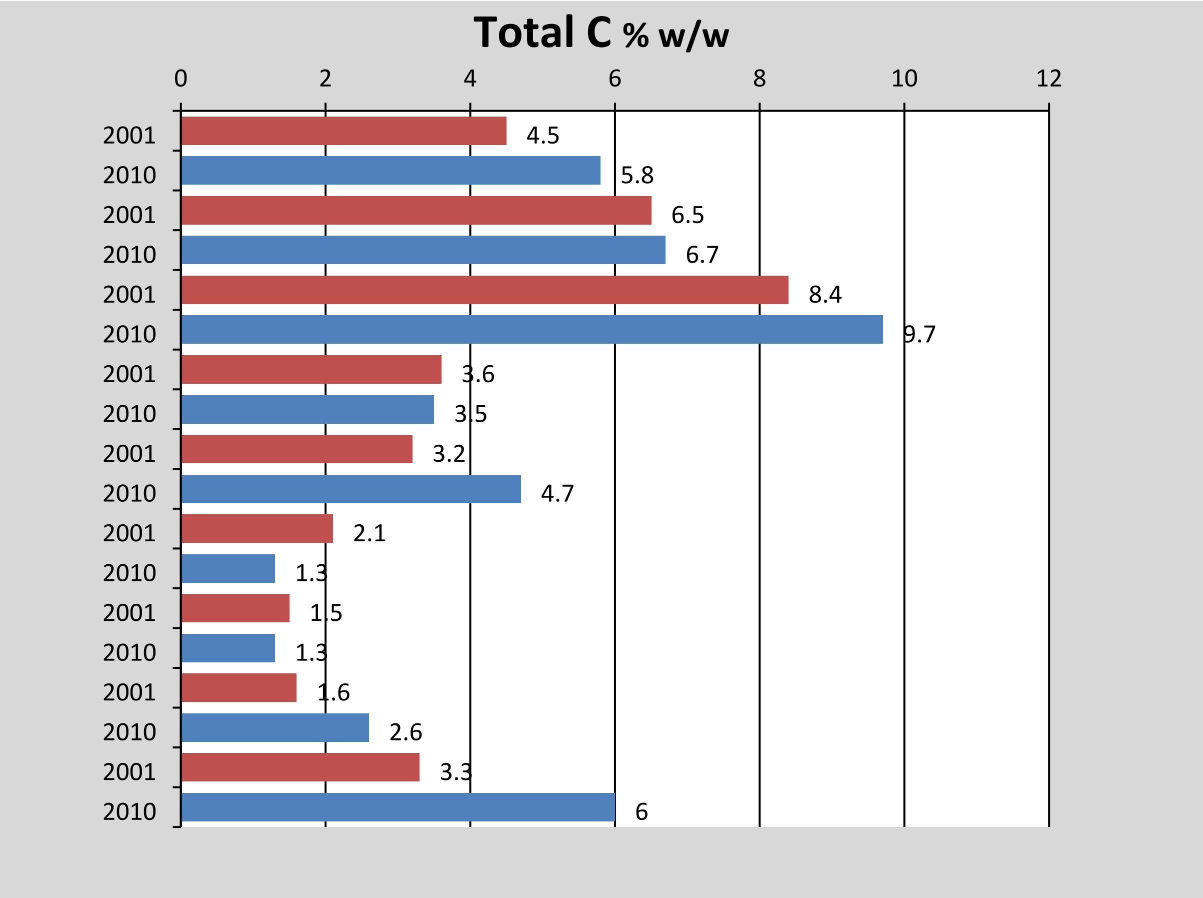
4 2001 – 2010 data comparison

The following charts represent the data collected at sites TDC00.1 to TDC00.9 in 2001 and 2010. Samples were collected from the same transects at the sites using the same sampling and testing protocol. Site TDC00.10 could not be compared as it was not possible to sample the site in 2010.

4.1 Organic Resources

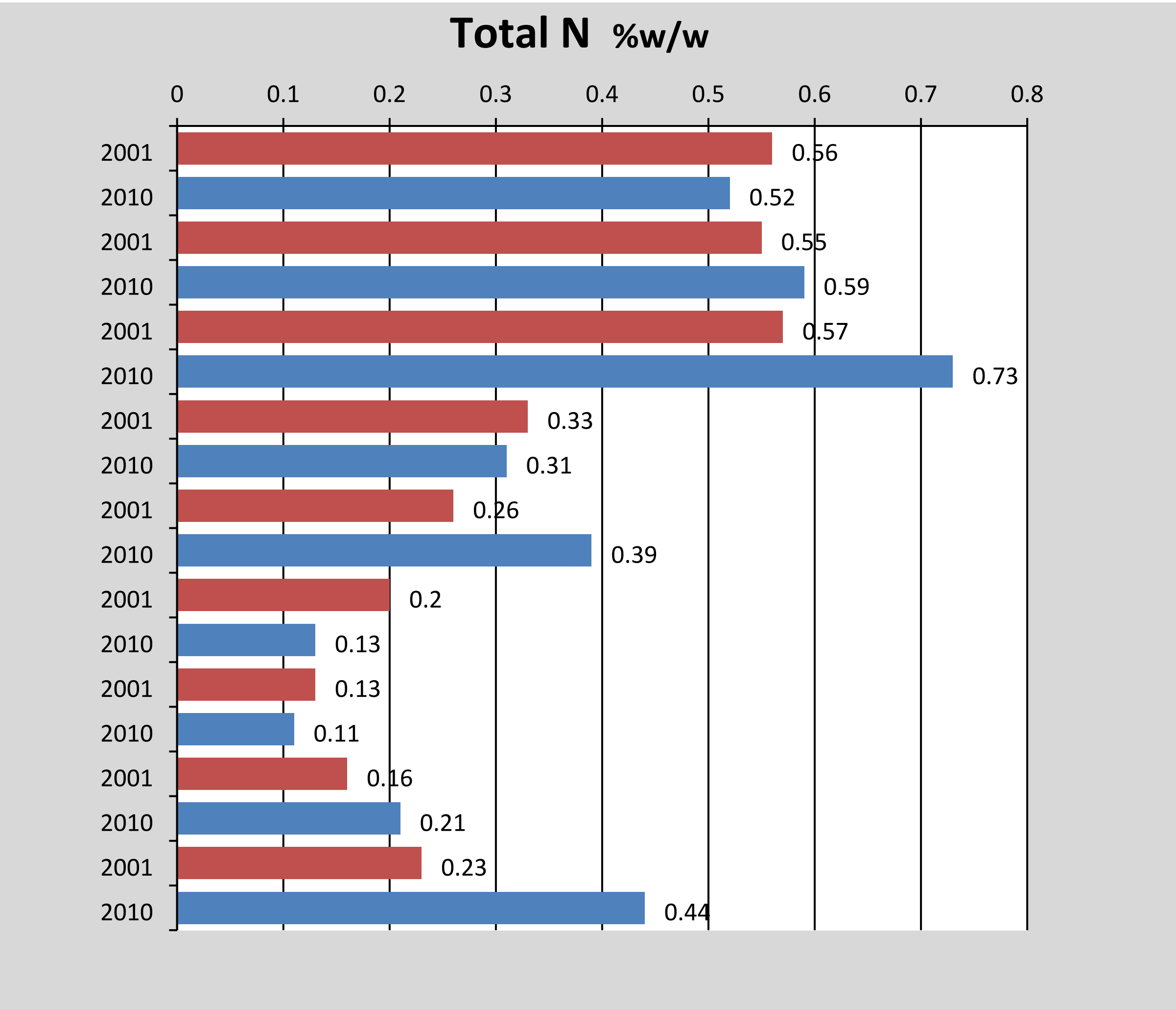
Total Carbon levels are an indication of organic matter content, which is important for moisture and nutrient retention and for good soil structure. The issues relating to total carbon are soil organic matter depletion and carbon loss from the soil, generally as a result of intensive land use.

Total Carbon has increased at the majority of sites. All site that have a permanent perennial plant cover such as pasture or orchard have maintained or increased their total carbon content. The market garden site, TDC00.6 has decreasing quantities This site is already considered "very depleted". Site TDC00.7 is a rehabilitated site that has been recently used for market gardening. This site shows signs of decreasing quantities of total carbon as well, by comparison the two rehabilitated sites, TDC00.8 and TDC00.9 which are in permanent pasture, have increasing quantities of total carbon.



Total Nitrogen gives a measure of the reserves of organic matter in the soil as most nitrogen (N) in soil is within the organic matter fraction. Nitrogen is an essential nutrient for plants and animals. Usually only a small fraction of the total N is immediately available for plant uptake (soluble inorganic nitrogen). While a variable proportion of the total nitrogen is potentially mineralisable to inorganic N. In general, high total nitrogen indicates the soil is in good biological condition. However, very high total nitrogen contents may increase the risk that nitrogen supply may be in excess of plant demand, and ultimately lead to leaching of nitrate to groundwater.

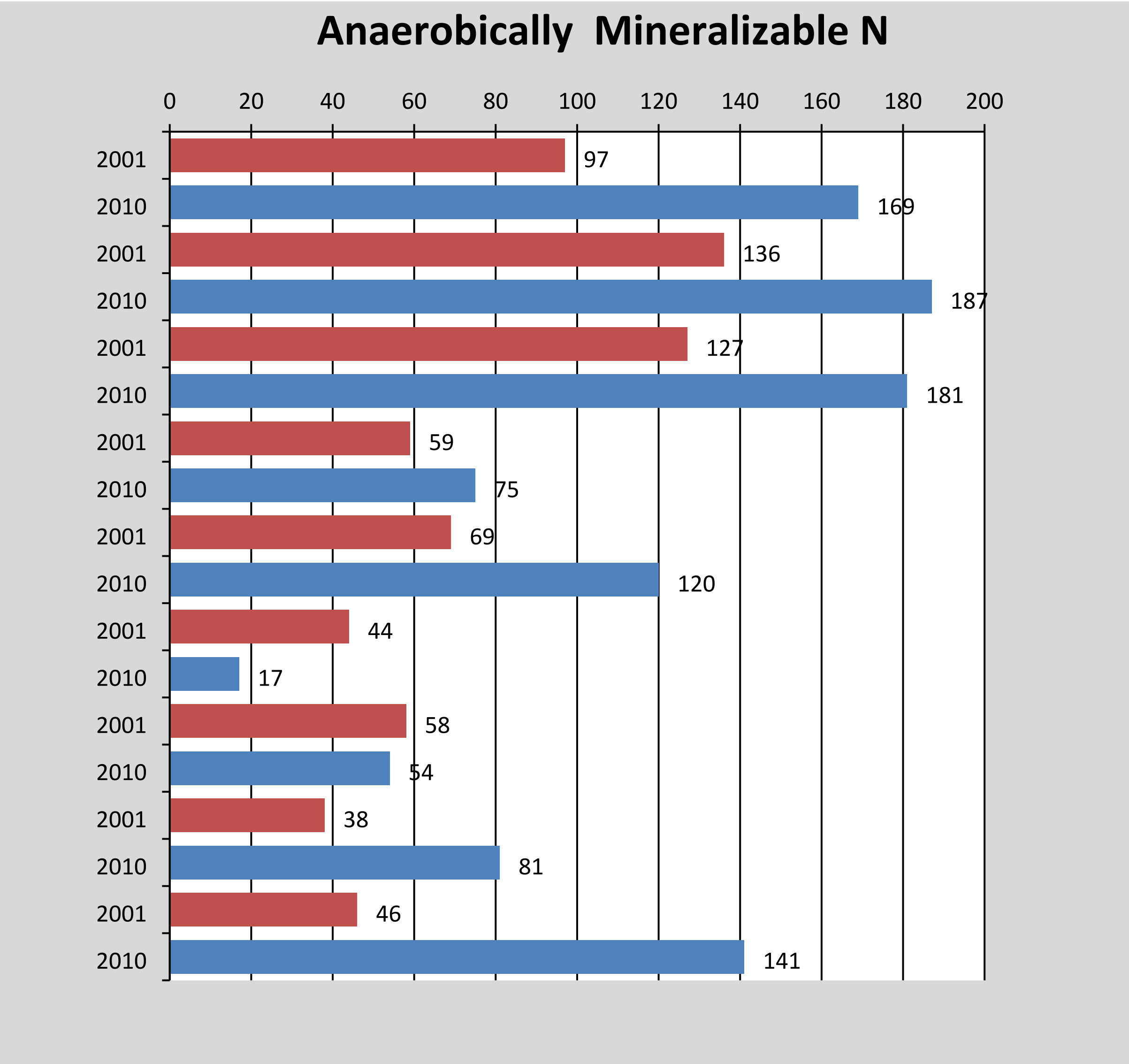
Total Nitrogen changes have been variable over time and between sites although the changes are not great except for 2 sites. TDC00.3 which is a pastoral site on "pakahi" has moved from "ample" to "high" and the rehabilitated site - TDC00.9 has moved from "very depleted" to an "adequate" status. The status of the other sites has remained the same.



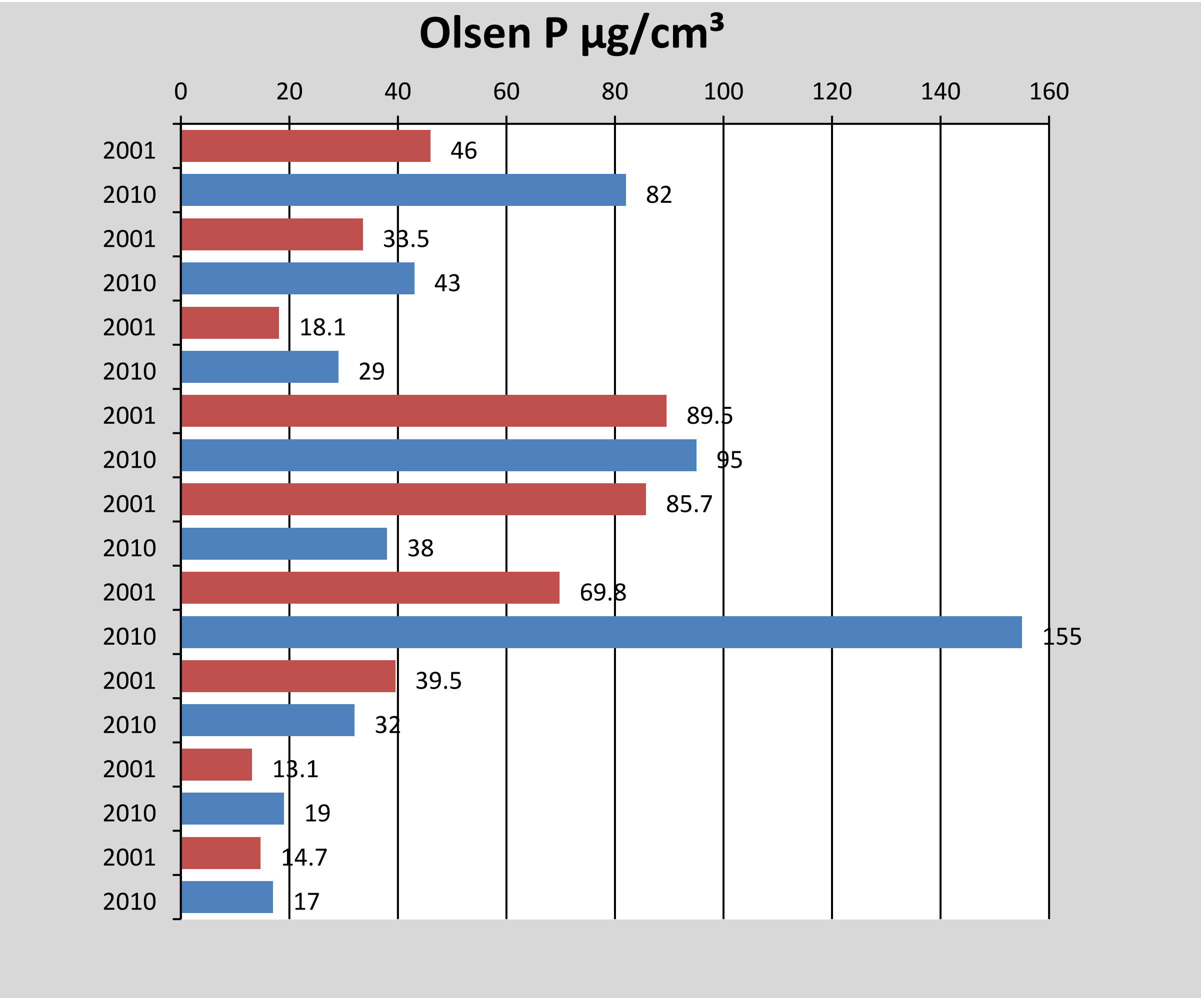
Anaerobic Mineralisable Nitrogen (AMN) levels measure the readily decomposed organic Nitrogen. This gives a measure of the level of activity of soil organisms. Soil organism activity is important for the overall functioning of the soil as it aids nutrient availability, water and gas movement/exchange and soil structural stability. Generally the higher the AMN content is, the healthier the soil.

The status of several sites has changed. TDC00.1, (dairy pasture) has moved from “low” to “adequate”. TDC00.5 (waste water disposal site) has also moved from “low” to “adequate”. This is likely due to it change from orchard to a permanent pasture regime. TDC00.6 (market garden) has declined from “low” to “very low”. TDC00.8 (rehabilitated-pasture) has moved from “very low” to “low” and TDC00.9 (rehabilitated-pasture) from “very low” to “adequate”.

In general there has been an improvement in AMN level across all sites except the market garden sites.



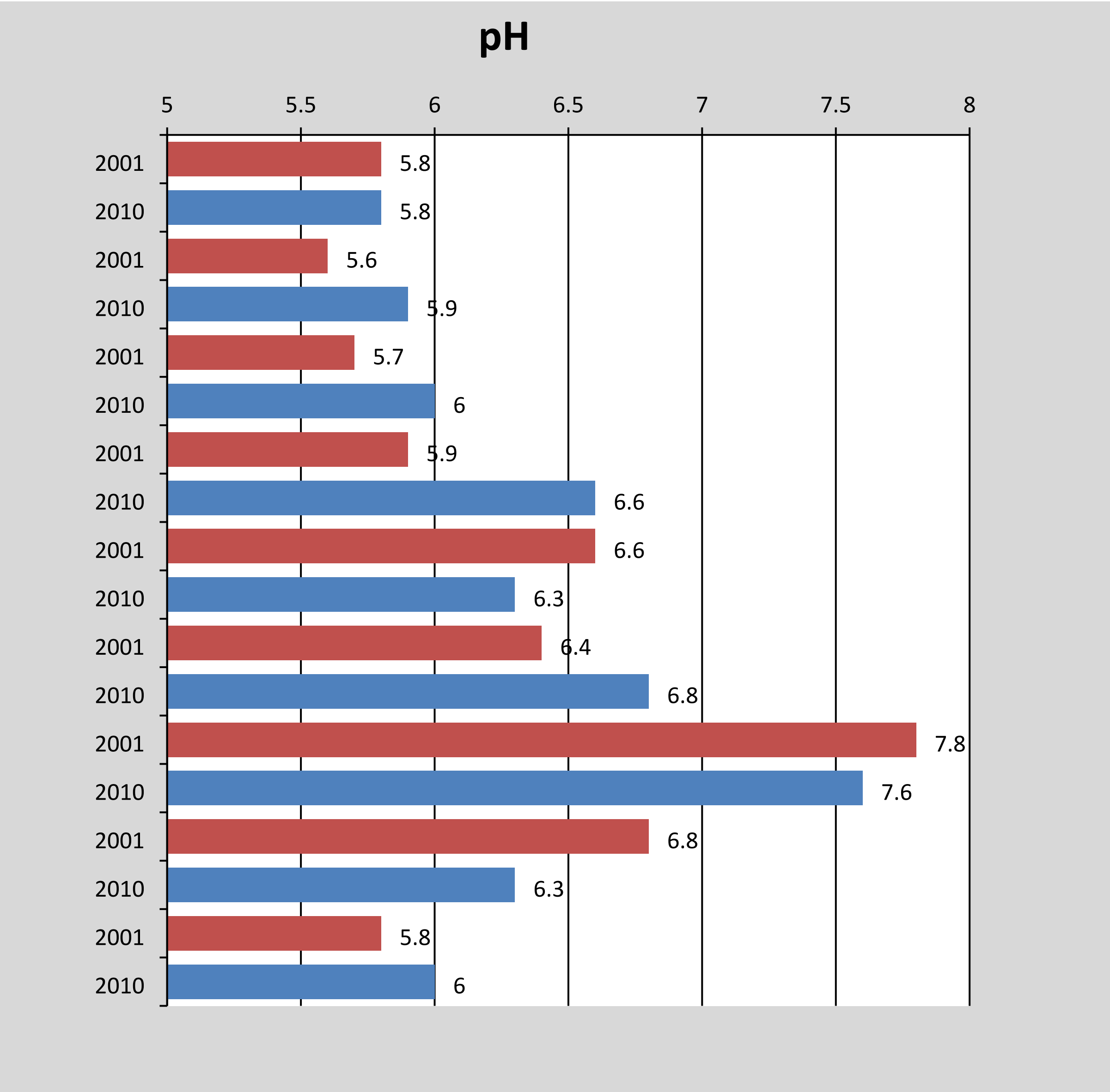
Olsen P levels indicate the level of plant available phosphorus and general fertility of the soil. The concentration of P in surface runoff is closely related to the level of available P in the soil – and hence the Olsen P test. Thus, any increase in Olsen P levels in soils could increase P runoff into rivers, streams and lakes.



The 3 dairy farm sites – TDC00.1,TDC00.2 and TDC00.3 have measures significant increases in Olsen P. Although all currently still within the target range future trends should be scrutinised. As noted earlier in the report, the target range for Olsen P is currently under review by the National Land Monitoring Forum. Soil type and crop considerations will influence the new target range or critical limits. As an example TDC00.2 situated on brown soils, with a olsen P level of 43 may currently fall within the target range where as TDC00.3 situated on Podzol soils with very low phosphate retention ability and a current Olsen P level of 29 may be above the target range.

A large increase in Olsen P was measure at TDC00.6 the market garden site. Fluctuations in soil P levels are inevitable on market gardens where highly soluble, high input and variable fertilizer inputs are generally used to match crop requirements.

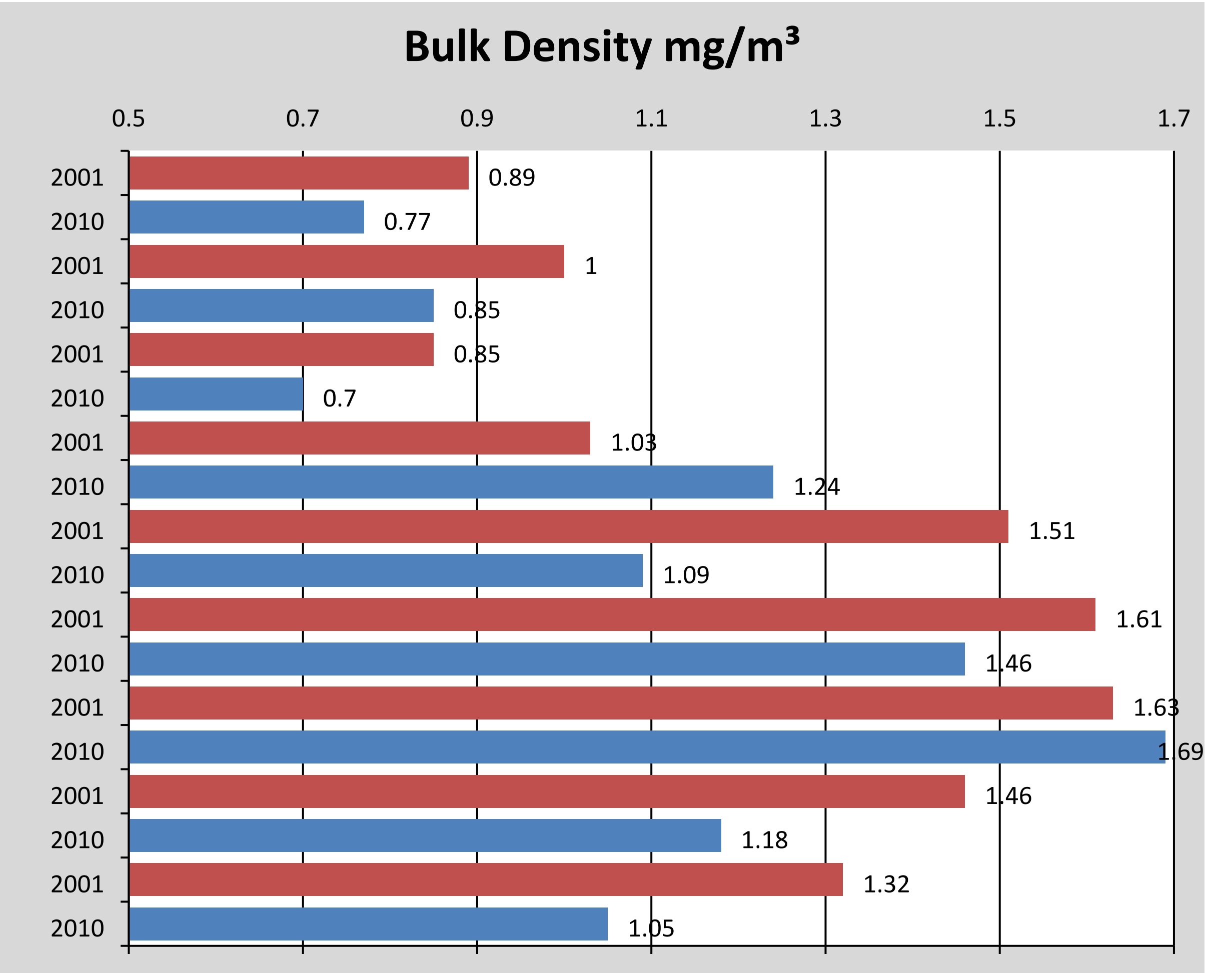
pH is a measure of soil acidity. Most plants and soil animals have an optimum pH range for growth. In General there has been little change in the pH level at the sites.



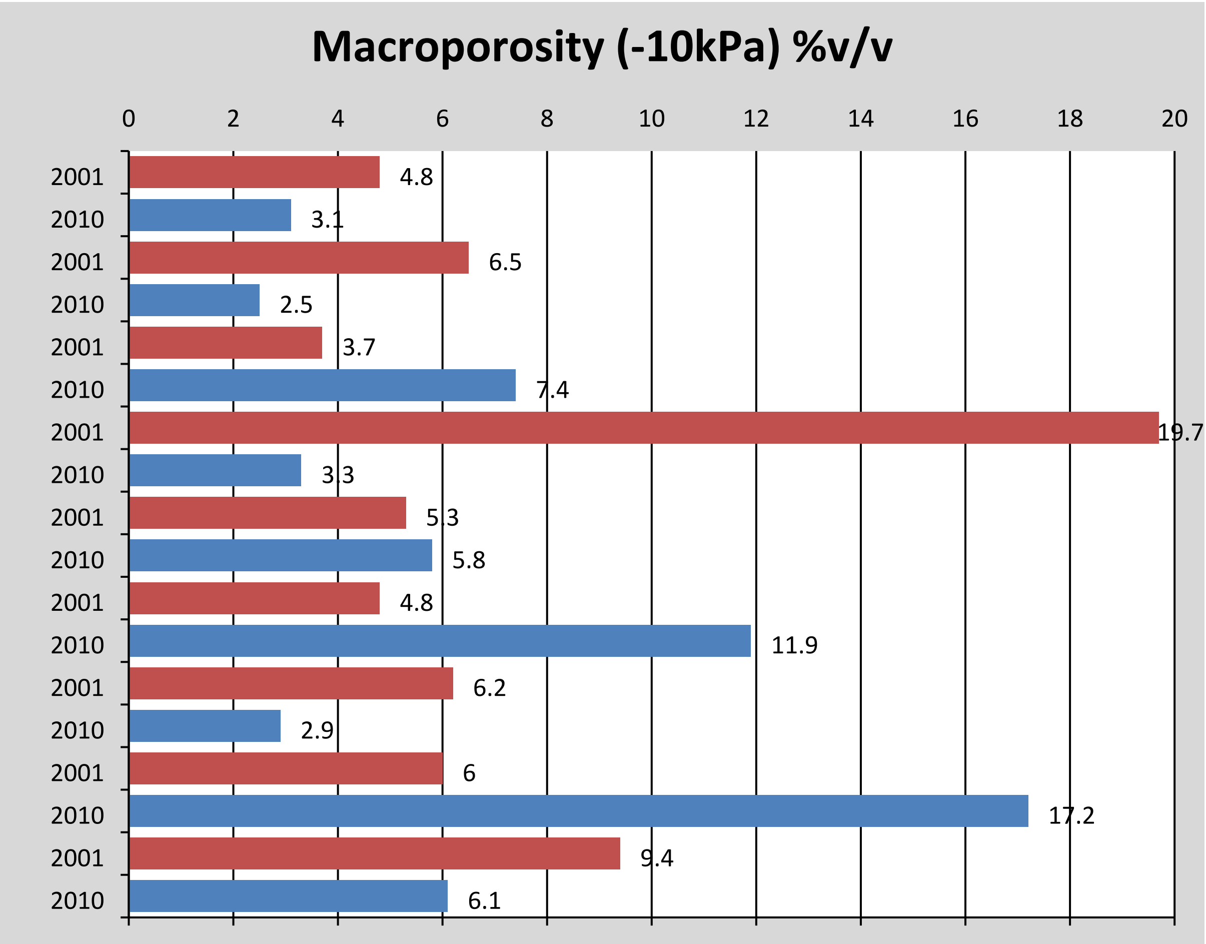
Bulk Density levels indicate the level of soil compaction. Compacted soils restrict water or air penetration into the soil profile, which restricts drainage and root growth. This in turn has the potential to increase surface water run-off and nutrient losses

No significant changes have been measured that have shifted any of the sites from one category to another.

A change in sampling time from spring to autumn could account for a general trend on the majority of pastoral sites where bulk density has lowered. It is anticipated that bulk density would be at its lowest, due to compaction from treading, at the end of winter but there would be some recovery over the summer months.



Macroporosity levels also indicate the level of soil compaction and aeration. Macropores are important for air penetration into soil, and are the first pores to collapse when soil is compacted. This can adversely affect plant growth due to poor root environment, restricted air access and N-fixation by clover roots.



There have been marked changes in macroporosity measurements at a number of sites and it is difficult to provide reason for these changes.

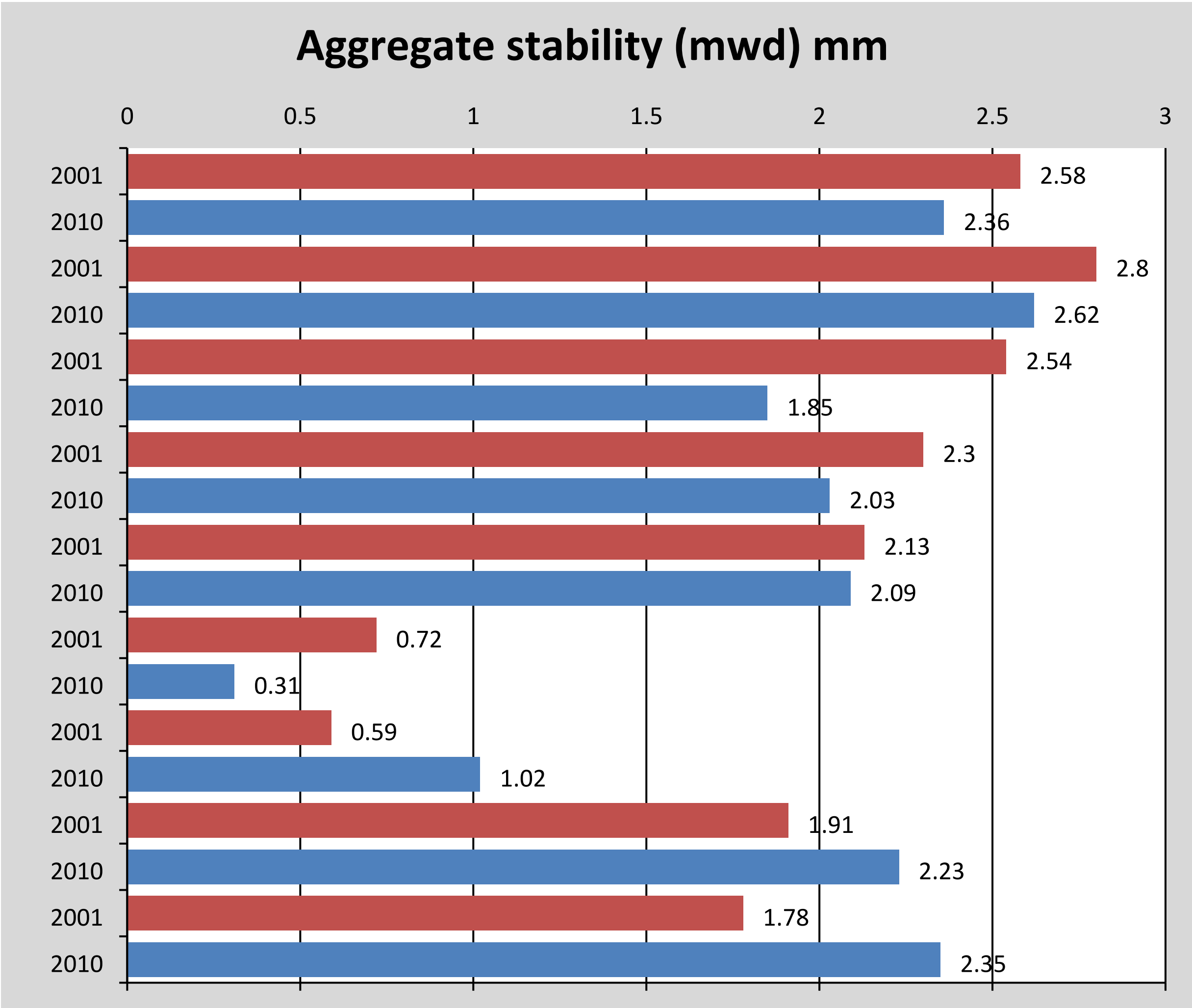
The most significant change is at site TDC00.4 where macroporosity has dropped from an “adequate” level to a very low level. This site has changed in landuse from apple orchard to waste water disposal site, for a glasshouse complex. It is in grass and grazed by sheep. There would have been major changes to the physical characteristics of the soil when the trees were ripped out and the area regrassed. This is likely to account for the changed in macroporosity at this site.

TDC00.6 is a market garden site was in an onion crop in early stages of growth. The surface was a fine, easily worked, cultivated tilth. This could account for its high macroporosity measure although the bulk density was also high indicating there were compaction issues. The indication from the macroporosity and bulk density for the 2010 results for this site are contradictory.

TDC00.7 is also a market garden site that had been rehabilitated after gravel extraction and was and had been in pasture for the seven years prior to the 2001 sampling. Prior to the 2010 sampling it had been used for marked gardening for three seasons and was recently back in grass at the time of the 2010 sampling. The recent phase of market gardening in this site could account for the reduction in macroporosity between sampling.

The same number of sites fall outside the target range for macroporosity at both sample dates although some sites that were in are now out and vice versa. The change is not readily explained.

Aggregate Stability is a measure of how resistant soil crumbs are to breakage. A stable "crumbly" texture lets water quickly soak into soil, doesn't dry out too rapidly, and allows roots to spread easily.



Little change was measured at the sites over time. The two rehabilitation sites TDC00.8 and TDC00.9, which are currently in permanent pasture have improved aggregate stability measures which may indicate their general improvement in soil quality with time since being rehabilitated after alluvial goldmining of these sites.

TDC00.3 is the only pastoral site showing a significant reduction in aggregate stability over time. This site had been heavily grazed by dairy cattle immediately prior to sampling. Pugging was significant on the site. This could account for the decrease. This site was to be cultivated and new pasture established prior to winter.

5 Summary

The 2010 sampling included the re-sampling of the majority of the 2001 sites with the addition of two new sites located in Kiwifruit blocks.

The results indicate that soil quality is poor on market gardening sites where soil biological and physical characteristics are affected.

In general the pastoral sites were in good condition. Macroporosity was the only indicator that fell outside the optimal range at 2 of the three dairy pasture sites. Other indicators of soil physical quality did not indicate the prospect that there are significant issues with soil compaction. On a national scale low macroporosity levels are emerging as a significant issue, particularly on dairy farms.

The orchard sites were in good condition. Macroporosity was the only indicator that fell outside the optimal range. This is believed to be an inherent soil characteristic rather than an effect caused by landuse. Concentrations of trace elements indicated elevated levels at two of the orchard sites. These elevated levels are most likely to be a consequence of historic orchard practises rather than current ones.

A comparison of the data collected at 2001 and 2010 indicates that at the majority of site there has been an improvement in the organic resources of the soils. The sites used for market gardening were the only one that did not follow this trend. Monitoring of soil chemistry showed an increases in Olsen P at the dairying and market garden sites, with some sites having excessive levels. Monitoring of the physical health of the soils indicated that overall there was little change between sample dates although macroporosity at some sites showed some unexplained changes.

5 References

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Appendix 1: 2010 Soil Quality Site Descriptions (new sites)

Site number:	**TDC 00.24**
Soil Name:	Karamea
Location:	3km south of Takaka and 500m East of Kotinga
GPS Co-ordinates:	2493457 6036088
Land use:	Orchard (Kiwifruit)
Topography:	Terrace
Elevation:	18.5 m
Slope:	2º
Soil material:	unweathered silty/sandy quartzitic alluvium
Soil drainage:	Well drained
Date sampled:	1/11/2010

Horizon	Depth	Description
A	0-14cm	dark yellowish brown (10YR 4/4) silt loam;
		weakly developed fine polyhedral structure;
		weak soil strength; friable; very few fine stones;
		many fine and few medium and coarse roots
AB	14-18cm	dark yellowish brown to light olive brown
		(10YR 4/4-2.5Y 5/6) silt loam; weakly developed fine
		polyhedral structure; weak soil strength; friable;
		very few fine stones; many fine and few medium
		and coarse roots
(B)	18-48cm	dark yellowish brown to light olive brown
		(10YR 4/6-2.5Y 5/6) fine sandy loam; weakly
		developed medium blocky structure; weak soil
		strength; friable; fewfine and few medium and
		coarse roots
C1	48-80cm	light olive brown (2.5Y 5/6) loamy fine sand;
		apedal; earthy; very weak soil strength;
		very few fine roots and few medium roots
C2	80-90cm	olive (5Y 5/3) coarse sand; apedal; loose;
		5% fine stones

Sample name: **TDC 00.25**
Soil Name: Takaka
Location: 3km south of Takaka and 500m East of Kotinga
GPS Co-ordinates: 2493621 6036023
Land use: Orchard (Kiwifruit)
Topography: Terrace
Elevation: 17.5 m
Slope: 2º
Soil material: unweathered silty/sandy quartzitic alluvium over gravel
Soil drainage: Well drained
Date sampled: 1/11/2010

Horizon	Depth	Description
A	0-8cm	brown to dark brown (10YR 4/3) silt loam; weakly developed fine polyhedral structure; weak soil strength; friable; many fine and many coarse roots
C1	8-32cm	light olive brown (2.5Y 5/4) sandy loam; apedal; earthy; very weak soil strength; very friable; 5% fine to medium stones; few fine and few medium roots
C2	32-60cm+	olive (5Y 4/3) coarse sand; apedal; single grain; 35% fine to very coarse stones; many fine and few medium roots

Appendix 2: 2010 Soil Physical and Chemical Characteristics Data

Table 3: Soil Physical Characteristics of Sites Sampled in the Tasman District: 2010

Site Code	**Land Use**	**Soil Type**	**Bulk Density** mg/m^3	**Particle Density** mg/m^3	**Total Porosity** % v/v	**Macro Porosity (-10kPa)** % v/v	**Readily Available Water** % v/v	**Total Available Water** % v/v	**Aggregate Stability** MWD mm
TDC 00.1	Pasture	Karamea silt loam	0.77	2.49	69.3	3.1	10.5	38.6	2.36
TDC 00.2	Pasture	Ikamatua silt loam	0.85	2.48	65.7	2.5	8.5	33.6	2.62
TDC 00.3	Pasture	Onahau silt loam	0.70	2.34	70.3	7.4	21.1	36.3	1.85
TDC 00.4	Waste water	Waimea clay loam	1.24	2.65	53.0	3.3	4.2	20.9	2.03
TDC 00.5	Orchard	Mapua sandy clay loam	1.09	2.50	56.5	5.8	5.8	26.3	2.09
TDC 00.6	Market garden	Waimea silt loam	1.46	2.74	46.6	11.9	5.0	13.1	0.31
TDC 00.7	Rehabilitated site	Waimea silt loam (anthropic)	1.69	2.74	38.3	2.9	6.9	18.9	1.02
TDC 00.8	Rehabilitated site	Waimea silt loam (anthropic)	1.18	2.68	55.9	17.2	8.7	22.1	2.23
TDC 00.9	Rehabilitated site	Ikamatua gritty silt loam (anthropic)	1.05	2.55	58.8	6.1	10.9	29.7	2.35
TDC 00.24	Kiwifruit	Karamea	1.12	2.63	57.4	1.7	10.5	38.0	2.57
TDC 00.25	Kiwifruit	Takaka	1.16	2.67	56.4	>1	11	43.4	2.26

Table 4: Soil Chemical Characteristics of Sites Sampled in the Tasman District: 2010								
Site Code	**Land Use**	**Soil Type**	**Total C mg/cm^3**	**Total N mg/cm^3**	**C:N Ratio**	**AMN[1]**	**Olsen P Φg/cm^3**	**pH**
TDC 00.1	Pasture	Karamea silt loam	5.8	0.52	11.2	169	82	5.8
TDC 00.2	Pasture	Ikamatua silt loam	6.7	0.59	11.3	187	43	5.9
TDC 00.3	Pasture	Onahau silt loam	9.7	0.73	13.3	181	29	6.0
TDC 00.4	Waste water	Waimea clay loam	3.5	0.31	11.3	75	95	6.6
TDC 00.5	Orchard	Mapua sandy clay loam	4.7	0.39	12.1	120	38	6.3
TDC 00.6	Market garden	Waimea silt loam	1.3	0.13	10.0	17	155	6.8
TDC 00.7	Rehabilitated site	Waimea silt loam (anthropic)	1.3	0.11	11.8	54	32	7.6
TDC 00.8	Rehabilitated site	Waimea silt loam (anthropic)	2.6	0.21	12.4	81	19	6.3
TDC 00.9	Rehabilitated site	Ikamatua gritty silt loam (anthropic)	6.0	0.44	13.6	141	17	6.0
TDC 00.24	Kiwifruit	Karamea	3.7	0.37	10.0	139	69	5.8
TDC 00.25	Kiwifruit	Takaka	2.7	0.25	10.8	107	13	6.1

Appendix 3: Sampling and Analytical Methods

At each site a 50 m transect is laid out. For chemical analysis 25 individual soil cores 2.5 cm in diameter to a depth of 10 cm are taken every 2 m along the transect. The cores are bulked and mixed in preparation for chemical analyses. Analysis is carried out at the Landcare Research soil chemistry and soil physics laboratories in Palmerston North.

For the physical analyses three undisturbed soil samples are also obtained from each site at 15, 30 and 45 m intervals along the transect by pressing steel liners 10 cm in width and 7.5 cm in depth into the top 10 cm of soil. Analysis is carried out at the Landcare Research soil chemistry and soil physics laboratories in Palmerston North.

For the aggregate stability measure take triplicate samples from the same transect positions as the soil cores (15-, 30- and 45 m). The sample consists of a vertical block of soil 10 cm deep, 10 cm wide and 1-3 cm thick from a fresh soil face. Analysis is carried out at the Plant & Food Research laboratories at Lincoln.

The trace element sampling procedure is a replicate of that carried out for the soil chemical analysis, with 25 individual cores bulked. Analysis is carried out at R J Hills Laboratory in Hamilton.

Recommended procedures for soil physical and chemical analyses are:

- **Total C and N** – Analyses using high temperature combustion methods.

- **Soil pH** – measured by glass electrode in a slurry of 1 part by weight of soil to 2.5 parts water.

- **Olsen P** – Extraction by shaking for 2 h at 1:20 ratio of air-dry soil to 0.5 M NaHCO3 at pH 8.5, filtered, and the phosphate concentration measured by the molybdenum blue reaction using Murphy-Riley reagent.

- **Potentially mineralisable N** – estimated by the anaerobic incubation method. Moist soil is incubated under waterlogged condition (5 g equivalent dry weight with 10 ml water) for 7 days at 40°C. The increase in ammonium-N extracted in 2 M KCl over the 7 days gives a measure of potentially mineralisable N.

- **Water release** (used to calculate porosity) - Calculated from drainage on pressure plates at specific tensions (Gradwell and Birrell, 1979).

- **Dry bulk density –** Measured on a sub-sample core of known volume dried at 105°C (Gradwell and Birrell, 1979). The weight of the oven-dry soil expressed per unit volume, gives the bulk density. The bulk density is also needed to calculate porosity.

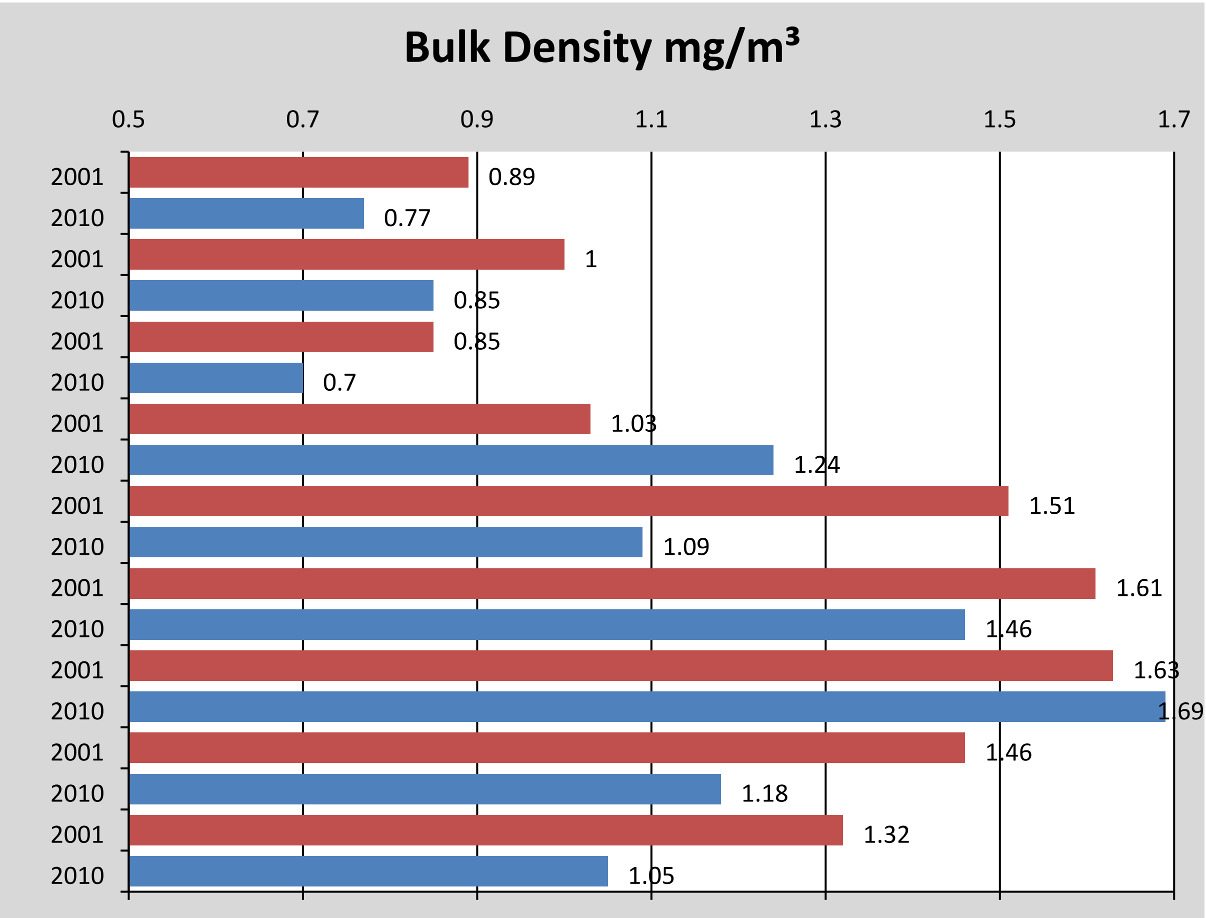
- **Particle density -** Measured by the pipette method as described by Claydon (1989). The particle density information is needed to calculate total porosity (see below).

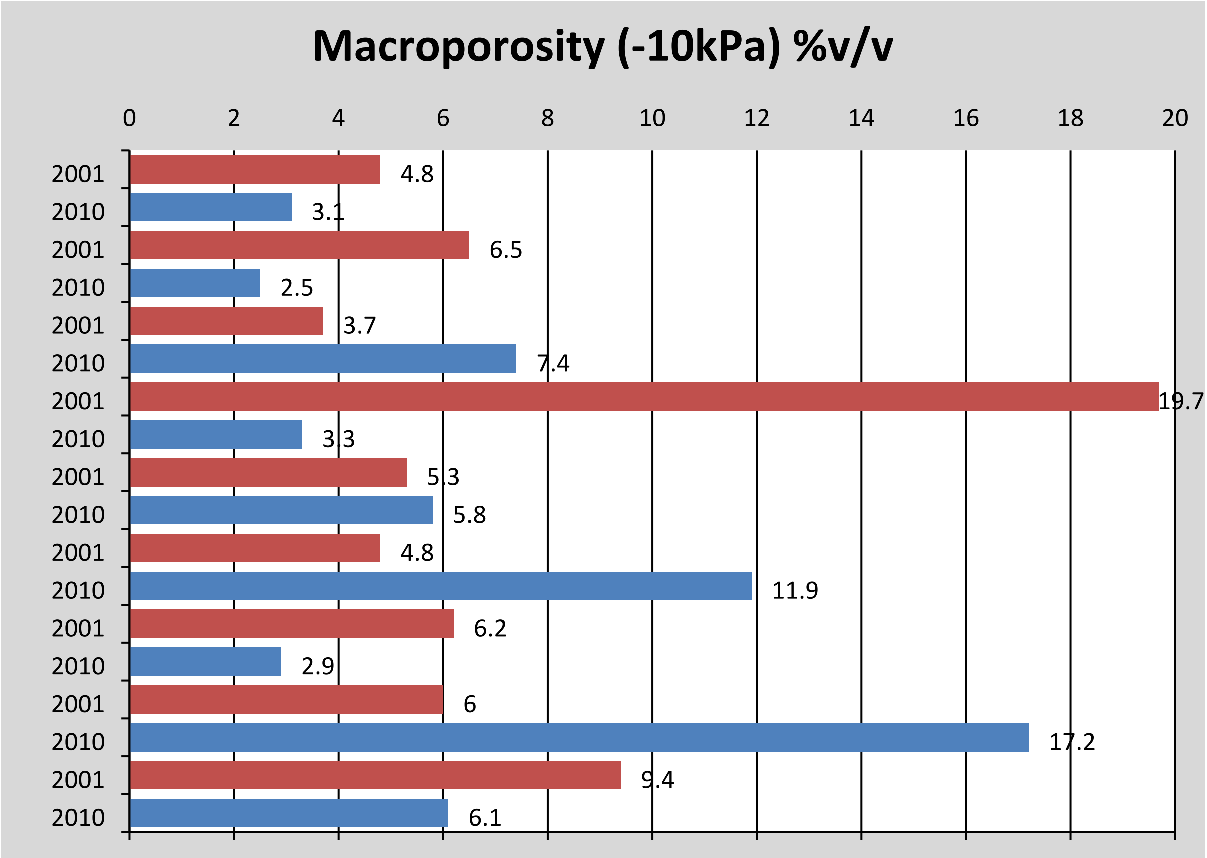
- **The total porosity -** Calculated from the formula: $S_t = 100[1- (p_b/p_p)]$ (Klute, 1986), where S_t is total porosity, p_p is the particle density and p_b is the dry bulk density.

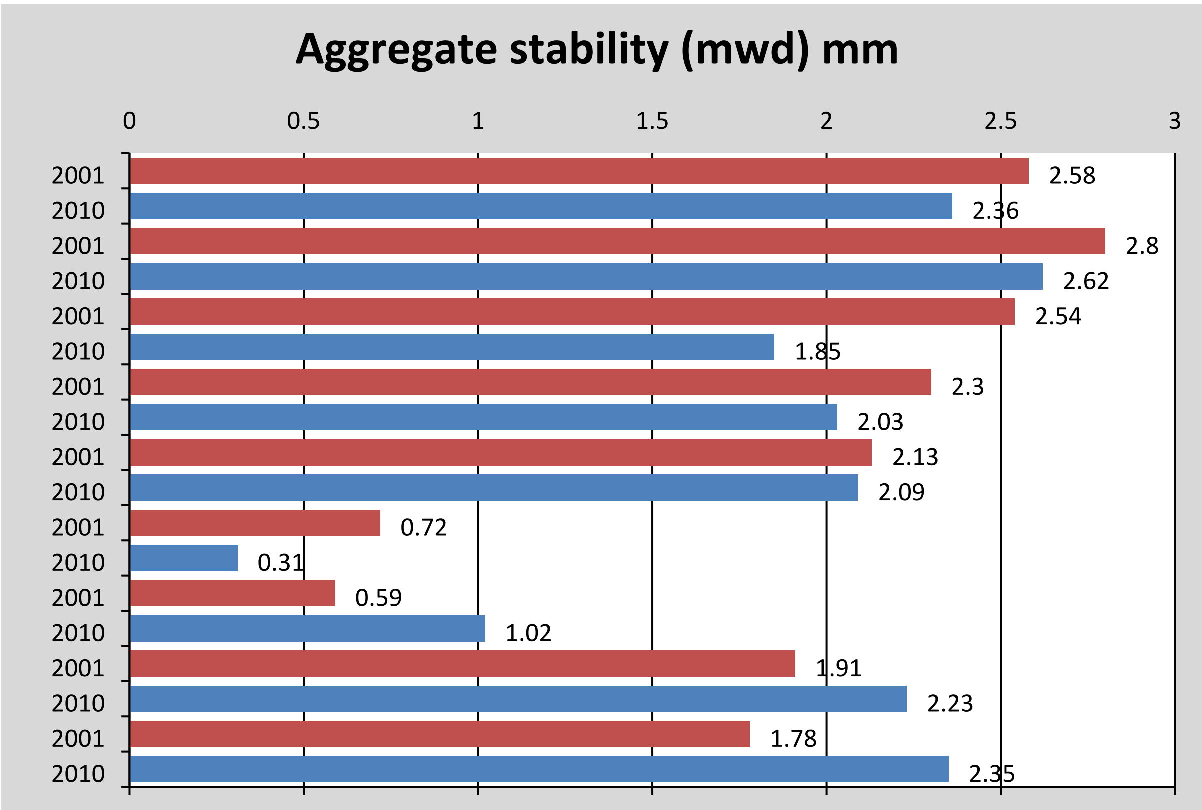
- **Macroporosity -** is calculated from the total porosity and moisture retention data: $S_m = S_t$ - where S_m is macroporosity, and S_t is the volumetric water content at -10 kPa tension (Klute, 1986).

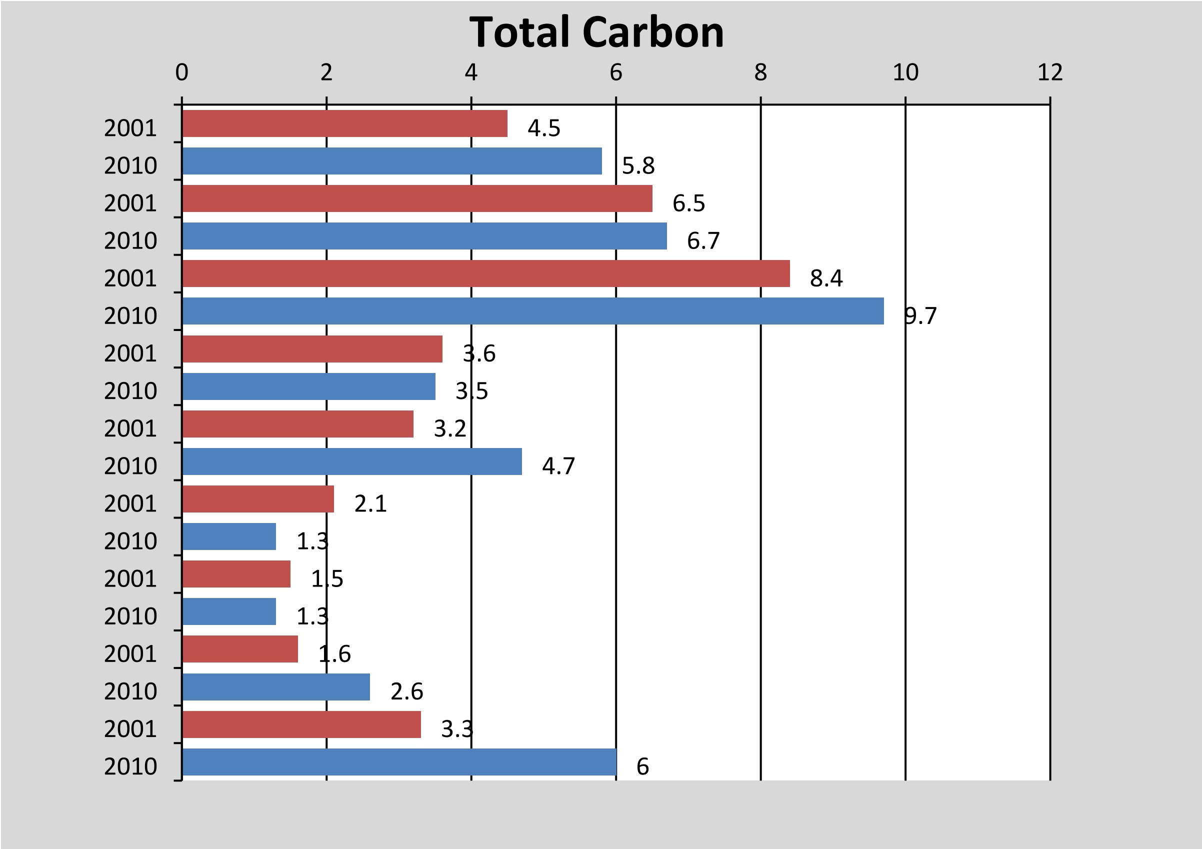
- **Aggregate stability** is calculated from the mean weight diameters of aggregates remaining on 2 mm, 1 mm and 0.5 mm sieve after wet sieving.

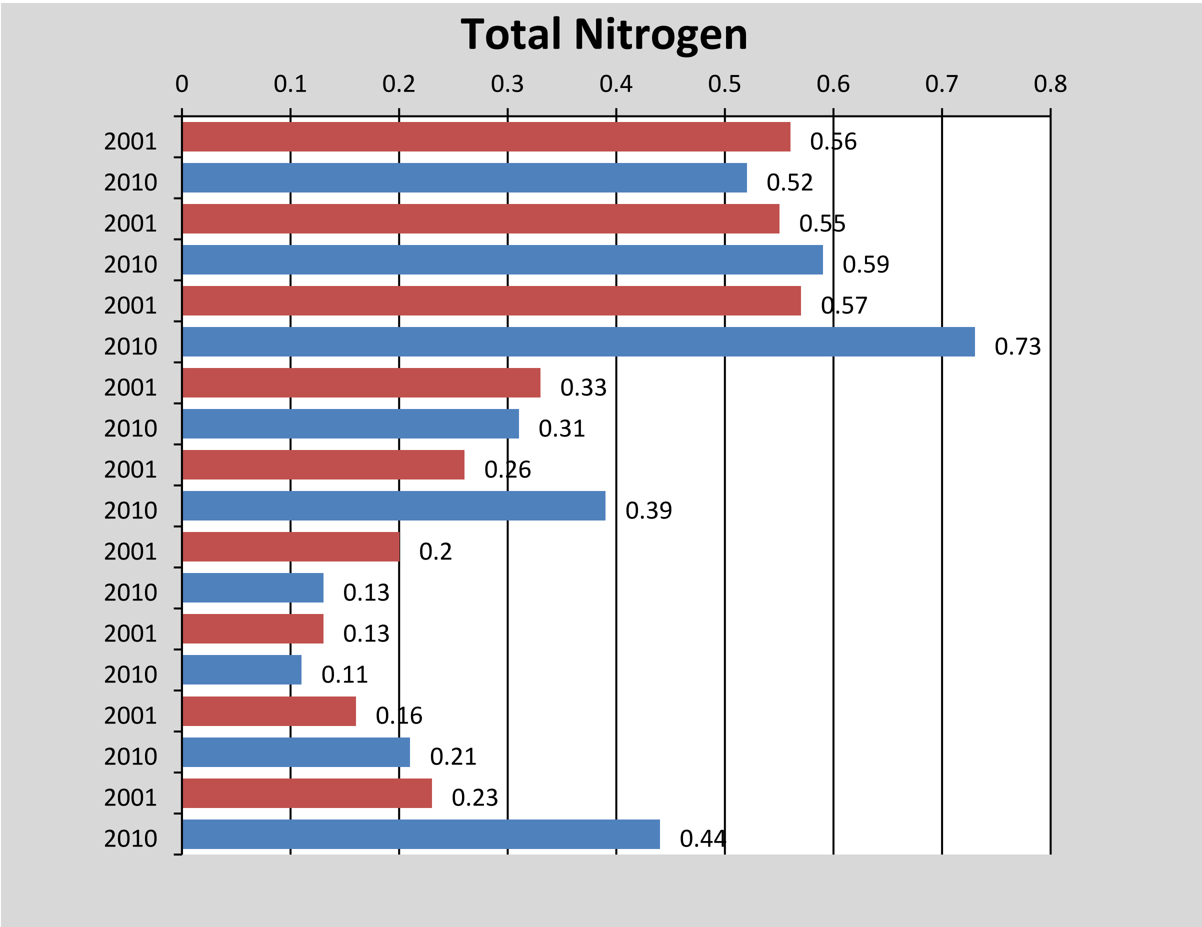
- **Trace elements** - use the total recoverable trace element extraction method - US EPA 200.2.

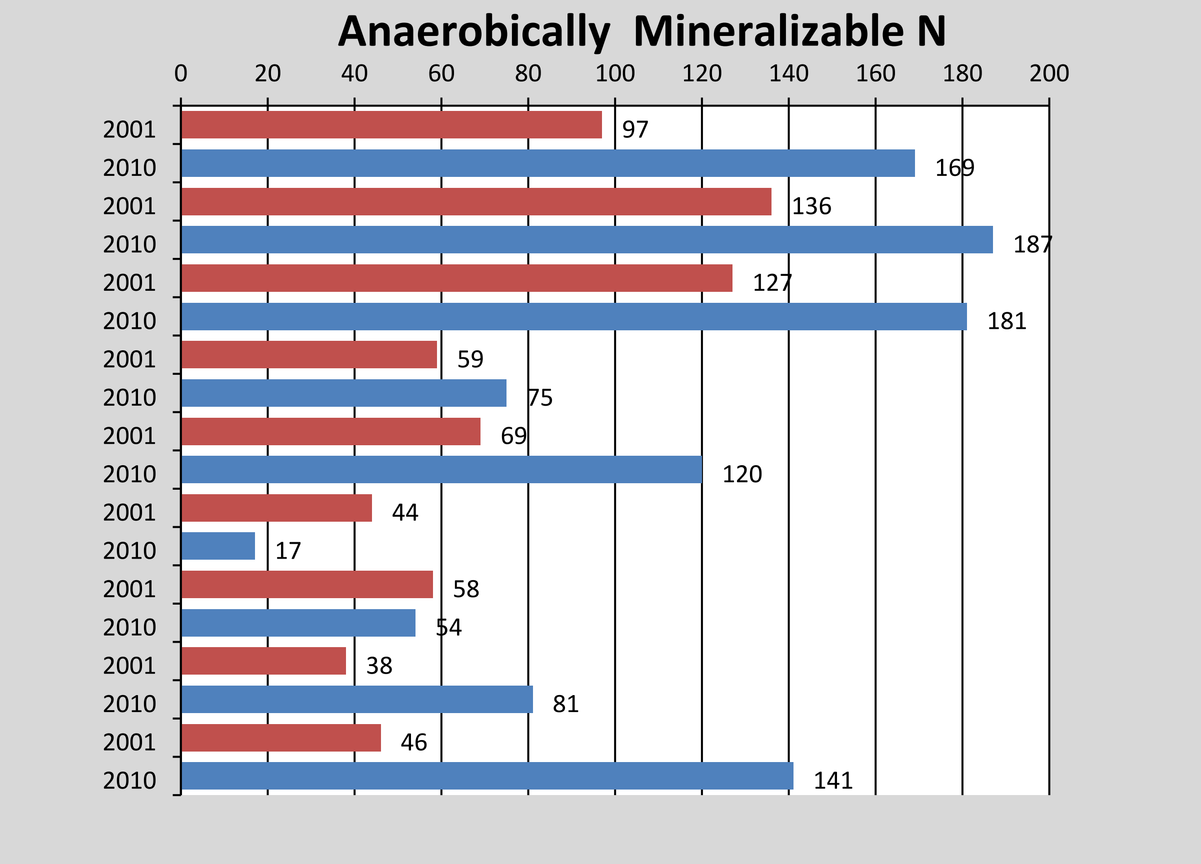


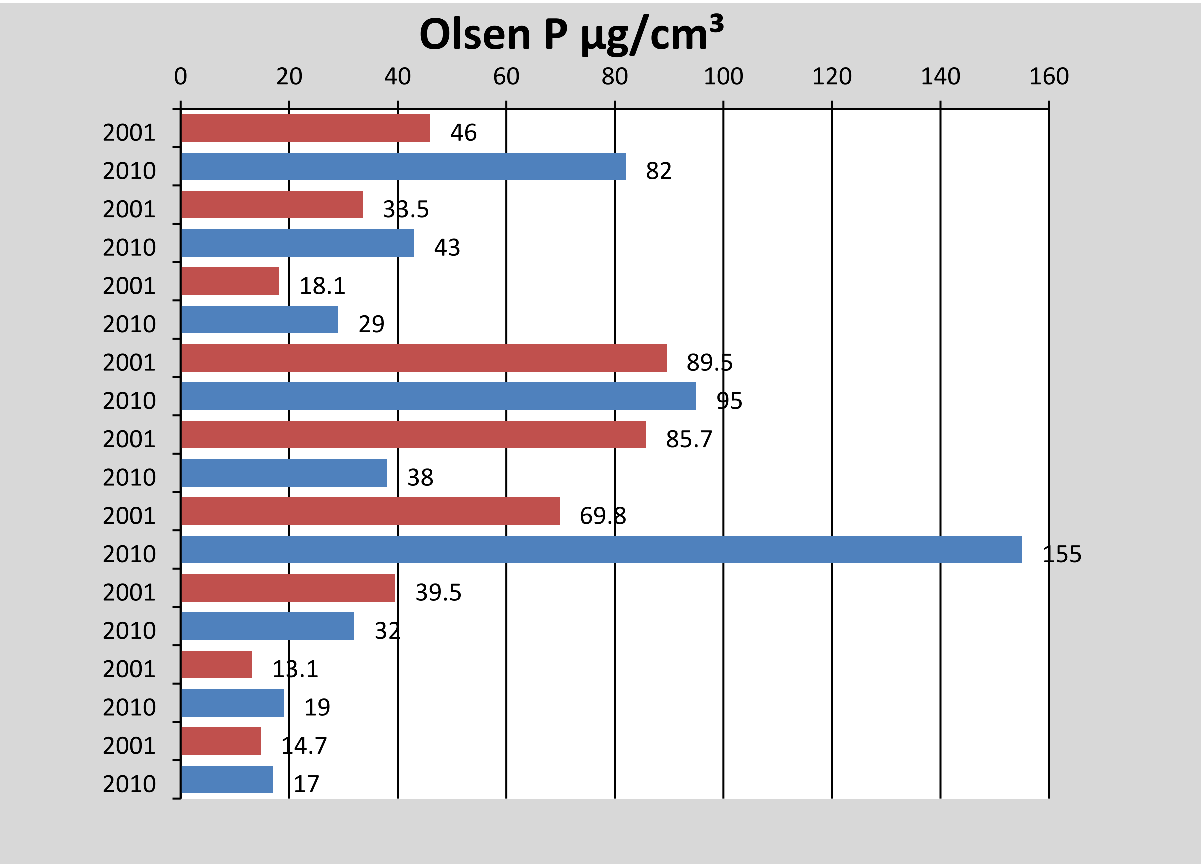

Macroporosity (-10kPa) %v/v
0
2
4
6
8
10
12
14
16
18
20
2001
2010
4.8
3.1
6.5
2.5
3.7
7.4
19.7
3.3
5.3
5.8
4.8
11.9
6.2
2.9
6
17.2
9.4
6.1


Aggregate stability (mwd) mm
0
0.5
1
1.5
2
2.5
3
2001
2010
2.58
2.36
2.8
2.62
2.54
1.85
2.3
2.03
2.13
2.09
0.72
0.31
0.59
1.02
1.91
2.23
1.78
2.35


Total Carbon
0
2
4
6
8
10
12
2001
2010
2001
2010
2001
2010
2001
2010
2001
2010
2001
2010
2001
2010
2001
2010
2001
2010
4.5
5.8
6.5
6.7
8.4
9.7
3.6
3.5
3.2
4.7
2.1
1.3
1.5
1.3
1.6
2.6
3.3
6


Total Nitrogen
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
2001
2010
2001
2010
2001
2010
2001
2010
2001
2010
2001
2010
2001
2010
2001
2010
2001
2010
0.56
0.52
0.55
0.59
0.57
0.73
0.33
0.31
0.26
0.39
0.2
0.13
0.13
0.11
0.16
0.21
0.23
0.44


Anaerobically Mineralizable N
0
20
40
60
80
100
120
140
160
180
200
2001
2010
2001
2010
2001
2010
2001
2010
2001
2010
2001
2010
2001
2010
2001
2010
2001
2010
97
169
136
187
127
181
59
75
69
120
44
17
58
54
38
81
46
141


Olsen P µg/cm³
0
20
40
60
80
100
120
140
160
2001
2010
2001
2010
2001
2010
2001
2010
2001
2010
2001
2010
2001
2010
2001
2010
2001
2010
46
82
33.5
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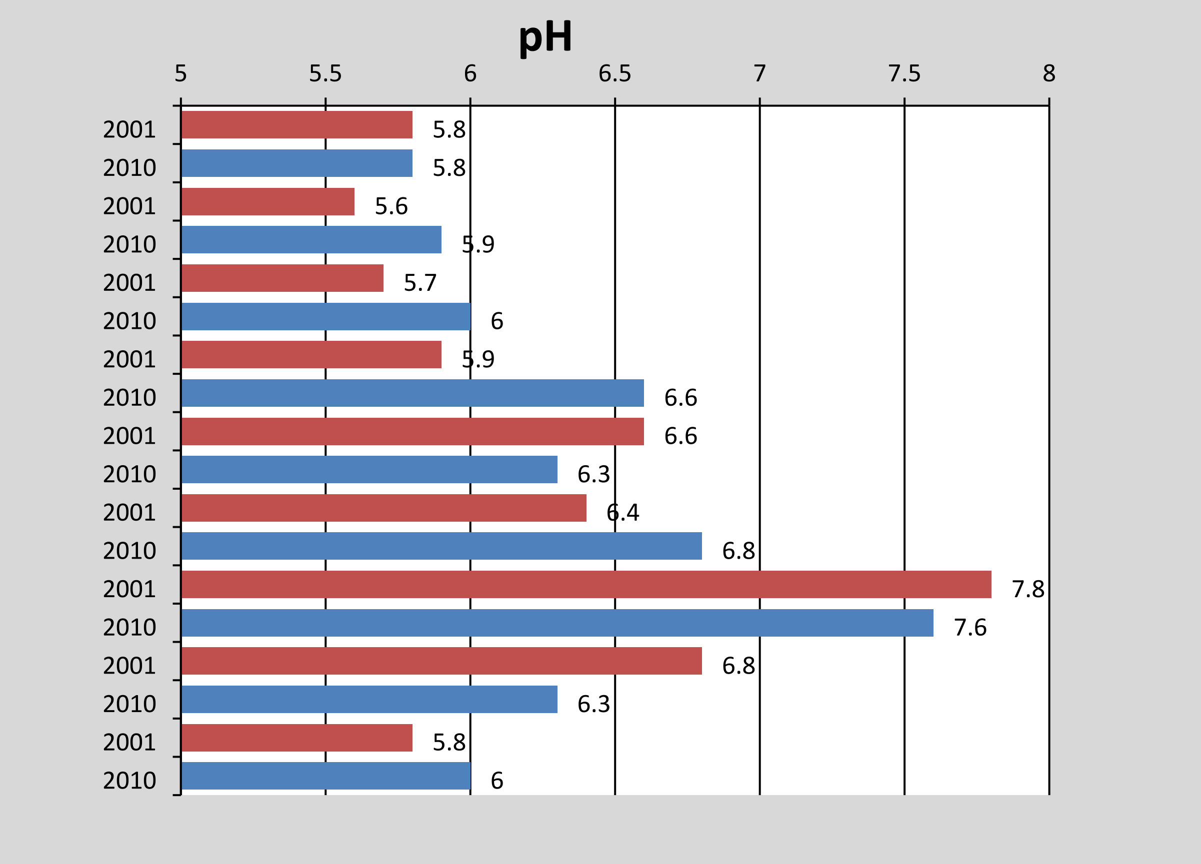
13.1
19
14.7
17



Gley podzols (pakihi soils) that have not been hump and hollowed or flipped have a range of Olsen P 12-15 for near maximum pasture production.