Manaaki Whenua
Landcare Research

# SOIL HORIZONS

## What's inside



*A newsletter communicating our work in soil-related research to end-users, customers and colleagues*


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## Visual clues

Landcare Research has developed a visual soil assessment (VSA) tool to help regional council staff and farmers visually score soil in relation to health / condition and crop productivity. The tool provides a framework that allows people with little or no understanding of soil science to assess soil quality as successfully as an 'expert'.

The VSA was developed with, and for, three regional councils — horizons.mw, Hawke's Bay and Wellington — and the Ministry for the Environment (MfE). MAFPolicy funded the colour printing of the four guide-booklets that make up the tool. The VSA provides a common framework using a standardized procedure and suite of indicators to convert visual messages into something meaningful to assess soil quality quickly and cheaply. It is based on a weighted additive model of key soil 'state' indicators of soil quality, and is presented in the form of a scorecard. Soil indicators are

***Visual assessment provides an immediate effective diagnostic tool to assess soil quality, and the results are easy to interpret and understand***

***Figure 1.*** *Poorly managed long-term cropping soil to the left and a well-managed pastoral soil to the right.*

complemented by plant ‘performance’ indicators that link soil quality to plant response and to farm management practices. The soil and plant indicators are linked to economic performance, and are underpinned by sound pedological principles and two decades of laboratory and field-based research.

To demonstrate how easy the VSA is to use, a series of 12 workshops (funded by MfE and MAFPolicy) were run from Northland to Southland. Thirty-six sites, covering a range of soil types of varying age from different parent materials, climate, and topography, and under different land uses and management practices, were investigated. Over 320 people took part, including farmers, regional councils, agribusiness, consultants and researchers. Of the participants, 87–100% indicated they would use VSA, including 92% of farmers. Between 85 and 100% found the VSA method easy to use in the assessment of soil quality, and 82–97% thought the VSA was easy to understand. The workshops demonstrated a high degree of agreement between ‘experts’ and lay people in assessing whether soils had a good, moderate or poor soil quality ranking score under a range of land uses, regardless of where or what the soil was. The indicators used to assess soil quality are therefore demonstrated to be generic and independent of soil type. As such, the VSA provides sound and timely information on soil performance to help establish best management practices, and is also a useful educational tool.

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## The health of New Zealand soils!

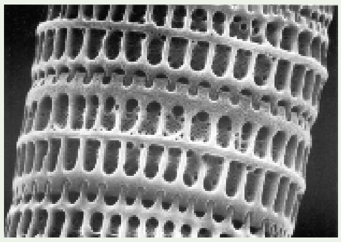
Many popular articles seem to suggest that news about soils is all bad – continuing soil erosion, overloading of nutrients and increasing levels of contaminants. However, Graham Sparling has been analysing data from soils from around New Zealand, and says some of the findings are reassuring.

Graham has been looking at the first two years, data from the 500 Soils Project, a soil monitoring project run by the Regional and Local Councils with support from the Ministry for the Environment Sustainable Management Fund. He has analysed 220 uneroded topsoils for a range of 13 soil quality attributes, including acidity, organic matter content, nitrogen status, available phosphate levels, and macropores.

In most cases, soils under long-term pasture had organic matter contents at least as good as those under indigenous vegetation. Pasture soils were also much less acid than indigenous forest soils. Soils under plantation pines were no more acidic than those under native trees (Figure 2).

The fertility of the arable and pastoral soils was considerably greater than the forested soils, with available phosphate contents being particularly high, sometimes excessively so, in some cropping soils and dairy pastures. Mineralisable N contents were greatest under pastures, reflecting the

## What is it?



Find out on the back page

buildup of soil organic matter and the long-term presence of nitrogen-fixing clovers. Mineralizable N levels were lower under cropping because of the loss of organic matter, and suggest greater dependence on inorganic fertiliser use to maintain fertility.

Soil physical condition, as shown by the proportion of large pores important for aeration and drainage, was generally good, but some dairy and cropping soils had low macroporosity (<8%), suggesting a degree of compaction.

By international standards, New Zealand has a large proportion (about 50%) of soils under pastoral use. These pastoral soils have maintained their organic matter contents, and show no evidence of acidification. Possible concerns are that high fertility levels could adversely affect water quality on free draining soils, or that compaction on heavier soils will inhibit root growth and reduce soil aeration, infiltration and drainage. Compaction and high fertility levels are also a potential concern on cropping soils, but effects will be localised because cropping comprises <1% of the land cover.

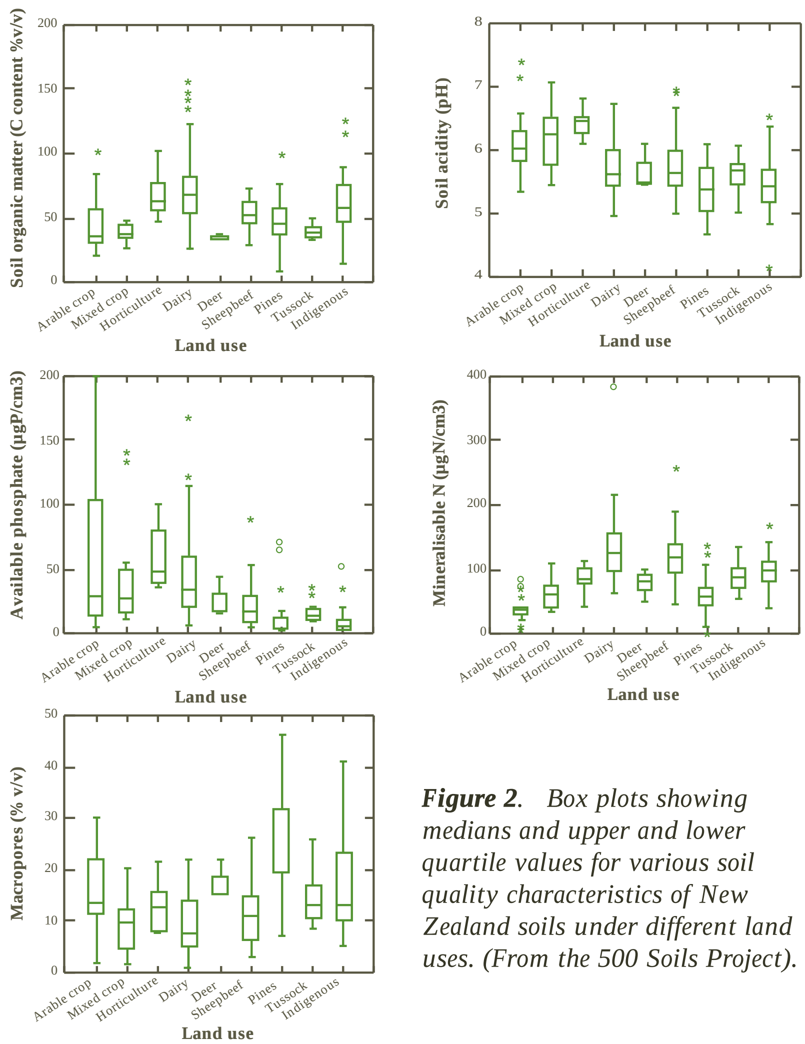



*Figure 2.* *Box plots showing medians and upper and lower quartile values for various soil quality characteristics of New Zealand soils under different land uses. (From the 500 Soils Project).*

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# A tick for no-till

No-tillage systems for crop establishment minimise impacts on energy (fuel), farmers' time, farming equipment, and the soil. Research in the 1980s demonstrated the short-term benefits of no-tillage cropping in New Zealand on soil properties. Sustaining soil conditions in the longer-term has only recently been studied.

A team of Landcare Research scientists at Palmerston North, led by Craig Ross, in collaboration with the NZ Centre for International No-tillage Research and Engineering, examined soil quality after 20 years of no-tillage cropping. The paddocks assessed had a history of double-cropping using Cross Slot® direct drilling. Summer crops were alternating spring barley and peas on a 2-year rotation, and one paddock had 3 years of maize. Winter forage crops were brassicas, oats, annual ryegrass or tic beans, with wheat or oats, initially grazed but mostly harvested for silage. Internationally established soil quality parameters were used to compare soil conditions under no-tillage cropping against those under permanent pasture and 17 years of conventionally cultivated continuous annual maize cropping with a winter fallow.

Most soil quality indices for no-tillage cropping were at levels of about 80% of those under pasture. These compared with significant declines under cultivated cropping in all parameters except for soil chemical properties, which depend on fertilizer and lime applications (such as pH, available-phosphorus, and exchangeable-Ca / Mg / K).

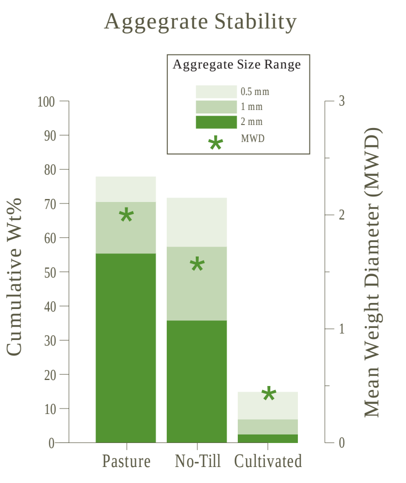


***Figure 3.*** *Aggregate stabilities from wet sieving under long-term pasture, no-tillage and cultivated cropping.*

Total carbon in the tillage zone (0–20 cm) was 84 tonnes / hectare under pasture, 73 t / ha under no-tillage and 68 t / ha under cultivated cropping. Soil structure was very similar between the pasture and no-tillage but exhibited a significant decline to a coarser, cloddy condition and much lower aggregate water stability under cultivated cropping (see Figure 3). Indices of soil microbial activity (such as anaerobically mineralisable-nitrogen) showed a small decline under no-tillage cropping but significant deterioration with repeated cultivations. Earthworm populations gave the most significant differences. No-tillage maintained earthworm populations at 77% of pasture compared with negligible numbers of small earthworms in the soil after 17 years of cultivated cropping.

These results indicate that no-tillage cropping conserves soil quality in the long term, when starting from a good base. In contrast, cultivated continuous cropping, without any restorative pasture stages, degrades soil conditions over time.

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# Carrots and topsoil erosion

Ohakune has an international reputation for growing exceptionally high quality carrots and other vegetable crops. The friable and free-draining volcanic soils provide excellent physical properties for intensive vegetable production. However, these soils are particularly vulnerable to erosion when cultivated and not protected by vegetation; and variable topsoil depths within a paddock often cause uneven crop performance.

The long-term impacts of current cropping practices on the arable soils of the Ohakune district are being evaluated to determine whether current vegetable production systems are sustainable. An initial study of soil erosion rates examined a seven-ha field that previously had 14 years of continuous cropping (10 of these in carrots). Within-field soil erosion and redistribution rates were assessed by measuring topsoil depths and using the radio-nuclide $^{137}$Cs, which 'rained' onto the soil during the nuclear bomb testing in the South Pacific in the early 1950s. Comparing the amount of $^{137}$Cs currently present in arable soil, and its distribution down the soil profile, with that under a nearby permanent pasture provides a measure of topsoil erosion rates over the past 40 years or so.

Topsoil depths showed a strong relationship with topographic position, indicating topsoil relocation through cultivation practices and erosion. Crests, shoulder slopes and backslopes had relatively uniform topsoil depths of 270–280 mm, reflecting erosion and depth of cultivation. Foot slopes, toe slopes and hollows had deeper, more variable topsoil thicknesses. Toe slopes had a mean topsoil depth of 570 mm and a maximum of 1170 mm, clearly indicating soil deposition.

The $^{137}$Cs results indicated erosion rates up to 110 tonnes of soil / hectare / year (15 mm / yr) on the steepest slopes and deposition rates up to 280 t / ha / yr (40 mm / yr) on toe slopes. The mean erosion rate over the field as a whole was 19 t / ha / yr, equivalent to soil losses of 2.8 mm / yr. These results indicate that significant erosion of topsoil has occurred on this paddock since it has been continuously cropped.

***Figure 4.*** *Soil sampling in carrot country.*

**A soil loss of 2.8mm/ year indicates significant topsoil erosion has occurred since continuous cropping began**

Analyses of physical properties showed that soil aggregate stability under the cropping regime deteriorated significantly compared with that under pasture. The toe slope and flat areas of the paddock had less stable aggregates than the eroded shoulder and mid-slope positions. Soil organic matter levels were about half those under pasture, the flat area of the paddock having about 2% more carbon compared with all other slope positions. Soil permeability was very high for both the pasture and arable soils, and generally well above most rainfall intensities. This suggests that erosion along wheel tracks, tillage and wind erosion, and soil losses with crop harvesting are the mechanisms leading to the soil movement.

Further research will characterise soil redistribution on a paddock with a more typical rotation of cropping and pasture, and will develop best management practices for cropping in the Ohakune District.

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# Predicting soil physical properties

In recent years, information from soil maps has been used in computer simulation models to address environmental and land-use issues. Until now, a lack of accurate data to estimate soil physical properties has limited widespread application of these models. To address this problem, a group of New Zealand soil scientists recently developed morphological descriptors to predict hydraulic conductivity. These descriptors have been used to group soil horizons into functional horizons, on a basis of their soil physical properties, for eight soil series in Canterbury. The definition of functional horizons is based on a combination of size of soil structure units and "degree of packing" (*in situ* consistence) within soil horizons.

Soil horizons are assigned to four functional groups according to combinations of increasing structure size and degree of packing. The assumption behind this grouping is that small structure units, together with low packing, should correlate with low bulk density, high low-tension water storage capacity, and high hydraulic conductivity.

Thirteen functional horizons were identified for 70 profiles from a total of eight soil series that had been systematically sampled for soil physical characteristics. Three horizons in each soil profile were described in the field and sampled for soil water characteristics, particle size, and saturated and near-saturated hydraulic conductivity. The selected soils formed two soil drainage sequences on the last-glacial and post-glacial surfaces of the Canterbury Plains, and vary from shallow sandy loam, well-drained soils to deep clay loam, poorly drained soils.

Identification of functional horizons has provided a very satisfying correlation between bulk density, field capacity, saturated and near-saturated hydraulic conductivity for the range of soils sampled. The study has increased the confidence we have placed in the simple morphological descriptors recently developed. It is important to note that application of functional horizons to estimate soil physical characteristics is limited to areas where the spatial distribution of functional horizons is known. Regional application will be limited if there is no record of spatial variability of functional horizons. The greatest value of this estimation method of soil physical properties will be found in well-characterised map units or individual fields.

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***Figure 5.*** *Coarse structural units of a poorly drained soil.*

# Harvesting pine trees – does the soil suffer?

Landcare Research and Forest Research have set up a nationwide series of plantation forest plots to assess any changes in site quality over time. In New Zealand, unlike most other countries, we obtain the bulk of our wood from planted forests, enabling the protection of most of our native forests. For plantation forests to supply the needs of society long term, we must ensure that they are managed in a sustainable way. New Zealand has demonstrated its commitment to this issue by signing an international agreement (Montreal Process), which demands a high level of accountability in forest management practices. This agreement, involving countries representing over 90 percent of the world's temperate and boreal forests, has developed seven criteria for sustainable management. These criteria include biological diversity and ecosystem health. Knowledge gained from this study will help with the reporting requirements of the Montreal Process and forest certification schemes.

The goals of the project are to: determine the effect of forest management practices on soil biophysical properties and processes that control productivity, and provide guidelines for improved practices that sustain site (ecosystem) quality.

***Figure 6.*** *Young second rotation pines.*

Sites were chosen to provide contrasts in climate, soil clay content and iron oxide content. Eleven of the 35 sites have so far been clear-cut and planted with *Pinus radiata* and *Cupressus lusitanica*. At each site, seedlings were planted on both undisturbed soils and soils compacted during harvest operations. Half the plots received fertiliser to ensure that nutrients do not limit tree growth.

Measurements include site characteristics, tree height and diameter, volume of previous stand, foliar nutrients, rain, temperature, humidity, radiation, and soil physical and chemical properties. The selected sites have provided a good range of clay content, iron oxide content, soil fertility and soil porosity. Initial results indicate at least 10% less soil macropores occur in compacted plots at most sites, indicating that major pathways through the soil for air and water have been lost during the harvest operations. We are assessing which soils are most resistant and which are most vulnerable to degradation.

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## How do soils contribute to $N_2O$?

Nitrous oxide is the result of naturally occurring soil processes associated with nitrogen cycling. These soil biological processes include *nitrification* and *denitrification*. Nitrification converts soil ammonium to soil nitrate, while denitrification reduces nitrogen oxides (e.g., nitrate) to nitrogen gases (e.g., $N_2$). Under certain conditions, these processes do not go to completion and $N_2O$ is formed and released from the soil. Factors that increase soil nitrogen availability, such as the return of dung and urine by grazing animals, generally increase nitrification and denitrification activity. As agricultural nitrogen cycles have intensified to support higher levels of productivity, nitrous oxide emissions have also increased.

# NZ, NzONET and $N_2O$

Ratification of the Kyoto Protocol will mean New Zealand is committed to limiting its greenhouse gas emissions, including nitrous oxide ($N_2O$). Under the UN Framework Convention on Climate Change, New Zealand will also be required to report its greenhouse gas inventory each year. To ensure that we can meet our international commitments on climate change, we need increased understanding of the amounts and sources of $N_2O$ in New Zealand. NzOnet has been formed to ensure an integrated and collaborative New Zealand approach to $N_2O$ research. The group consists of representatives from New Zealand's major research institutions, including Landcare Research.

The short-term goal of NzOnet is to decrease the uncertainties associated with New Zealand's $N_2O$ inventory. Agricultural soils have been identified as the main source of $N_2O$ emissions in New Zealand, with the return of urine and dung to soils by grazing animals being the single largest source of anthropogenic $N_2O$ emissions. The second largest source, indirect emissions, represents $N_2O$ emissions from nitrogen lost from agricultural systems due to nitrate leaching or ammonia volatilisation, which is subsequently emitted as $N_2O$.

***Figure 7.*** *Measuring $N_2O$ emissions using a soil chamber.*

## Why are we interested in $N_2O$?

Nitrous oxide is a gas that affects atmospheric photochemistry and chemistry, and has the dubious distinction of being both a greenhouse gas and an ozone depletor. It adsorbs surface-emitted infrared radiation that impacts on the earth's climate via the 'greenhouse effect'. Nitrous oxide's potential for thermal adsorption is about 310 times that of carbon dioxide. In addition, it is chemically inert in the troposphere, and readily diffuses up to the stratosphere where it initiates chemical reactions that lead to the chemical destruction of ozone.

To date, NzOnet has significantly contributed to a document detailing a national science strategy and research programme for $N_2O$ research for New Zealand. The group has also conducted a field study investigating how much $N_2O$ is released from cow urine applied to different soils in the Waikato, Canterbury and Otago. This work was funded by the Ministry for the Environment (MfE), and the Ministry for Agriculture and Forestry (MAF). Results from the field trial have shown that the proportion of nitrogen in a urine patch emitted as $N_2O$ varies with soil type. This understanding of how $N_2O$ emissions vary with soil type will improve the quality of New Zealand's $N_2O$ inventory.

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SOIL HORIZONS

*Soil Horizons is on the web*
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## Life Under Glaciers

Microbes exist in extreme environments — from deep-sea hydrothermal vents to boiling mud pools, from the highly saline Dead Sea to very acidic mine drainage. Now they have also been discovered living beneath glaciers in the Northern Hemisphere. The activity of these microbes could well affect subglacial weathering processes. Likewise, when ice sheets covered substantial parts of the Northern Hemisphere during past glacial periods, it is likely that subglacial microbes influenced the global carbon budget.

Julia Foght (University of Alberta, Canada, who is spending her sabbatical leave at Landcare Research, Hamilton) and colleagues have been studying

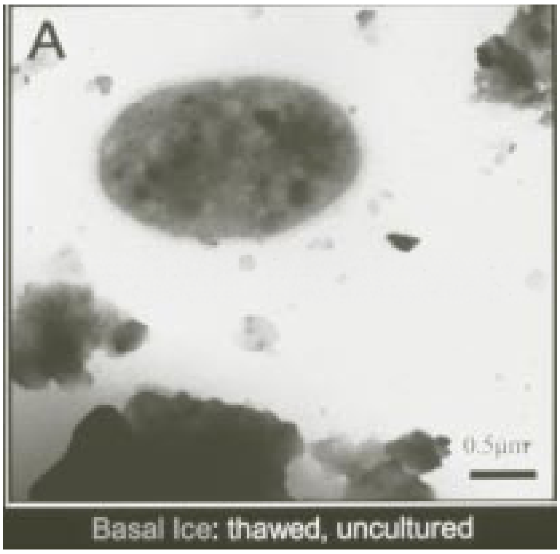


***Figure 8.*** *Transmission electron microscopy image of bacteria in glacial meltwater (scale bar is 0.5 microns)*

sediments and meltwaters from John Evans Glacier on Ellesmere Island in the Canadian high Arctic. This is a “warm-based” glacier, meaning that there is liquid water in the underlying sediments that the glacier has overridden. Those sediments are relatively rich in organic carbon, which most likely represents the remnants of soils and surface vegetation that existed in the area during times of reduced glacier extent earlier in the Holocene.

The organic carbon appears to sustain a diverse population of non-photosynthetic microbes, predominantly bacteria, active at temperatures as low as +0.3ºC, and possibly lower. A variety of metabolic types is found among the community, including aerobes (dependent on oxygen), microaerophiles (dependent on oxygen at a concentration less than atmospheric), and facultative and strict anaerobes (require no oxygen) such as methanogens.

While in New Zealand, Julia will be sampling glacial sediments and meltwaters in the Southern Alps for microbial life, for comparison with the high Arctic communities. These studies will help determine the global distribution and importance of subglacial microbes. In parallel studies, colleagues in the United States have begun study of an Alaskan glacier, examining its water chemistry in light of the microbial community that has been discovered there.

**The existence of diverse and active microbial populations beneath some glaciers has implications for carbon budget calculations during glacial cycles**

The existence of diverse and active populations beneath warm-based glaciers has implications for carbon budget calculations during glacial cycles. Slow microbial metabolism of forest soils and peats beneath the ice sheets may produce carbon dioxide and methane *in situ*. Subsequent release of those greenhouse gases during glacial retreat may account for at least 8.1 Gt (billion tonnes) of carbon over a glacial cycle.

*For more information contact Julia Foght, ph 07 858 3700 until June 2001 e-mail julia.foght@ualberta.ca*

# Bioavailability of Heavy Metals in Sewage Sludge Amended Soils

Amendment of agricultural soils with sewage sludge provides organic matter and major nutrients to the soil. However, sewage sludge can also contain potentially harmful substances such as heavy metals. Worldwide guidelines are set to prevent harmful build-up of heavy metals in soils and plants.

As part of a programme on sludge application to land being researched jointly by

ESR, Landcare Research, and Lincoln University, Harry Percival (Landcare Research) and Tom Speir (ESR) are studying the bioavailability of the three heavy metals of greatest concern – copper (Cu), nickel (Ni) and zinc (Zn). The study, now in its third year, investigates heavy metal concentrations in soil solutions from soils under pasture near Lincoln treated with both spiked (Cu, Ni, and Zn) and unspiked sewage sludge from Christchurch City Council. Highest rates of heavy metal-spiked sewage sludge were chosen to exceed the New Zealand Department of Health guidelines, which state that maximum total metal concentrations of Cu, Ni, and Zn in soil are to be no more than 140 mg / kg for Cu, 35 for Ni, and 300 for Zn. These totals include heavy metals already in the soils that have been derived from natural geochemical processes. The most bioavailable fraction of heavy metal in soil, i.e. the fraction available and potentially toxic to plants, is held in soil solution between the soil particles.

In the trial plots of pasture soil, total soil metal concentrations increased with increasing levels of metal in the spiked sludge. This pattern was reflected in the soil solution concentrations of the metals. They were always higher, with higher metal-spiking levels in the three annual samplings (1998–2000) after the 1997 sludge amendment. Over time, Cu did not show much change in solution concentration, but Ni and Zn tended to decrease, especially Zn at the highest spiking level (see Figure 9).

In the soil solutions, the free metal ions, $Cu^{2+}$, $Ni^{2+}$, and $Zn^{2+}$, were the dominant forms of the soluble metals. The remaining forms were mainly complexes of the metals with sulphate derived from the sludge itself and from the metal spiking salts. The free metal ions are the most toxic soluble forms of the metals but their concentrations were generally too low to be a problem. Sensitive biochemical properties of the sludge-amended soils showed no adverse effects in the short term that could be attributed to Cu or Ni, even at the highest total soil levels or soil solution concentrations. Only with Zn at the highest concentrations were there indications of heavy metal stress.

To develop better and more rational guidelines for safe heavy metal levels in soils, the sludge application programme will continue to investigate potential toxic effects.

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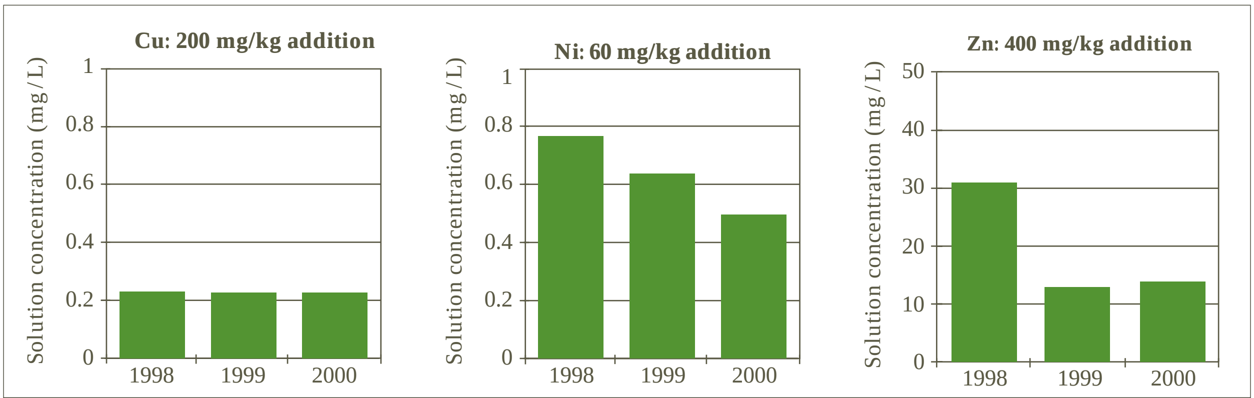



***Figure 9.*** *Soil solution Cu, Ni, and Zn concentrations in 1998, 1999, and 2000, after amendment at the highest metal addition levels. Note the change in scale for Zn.*

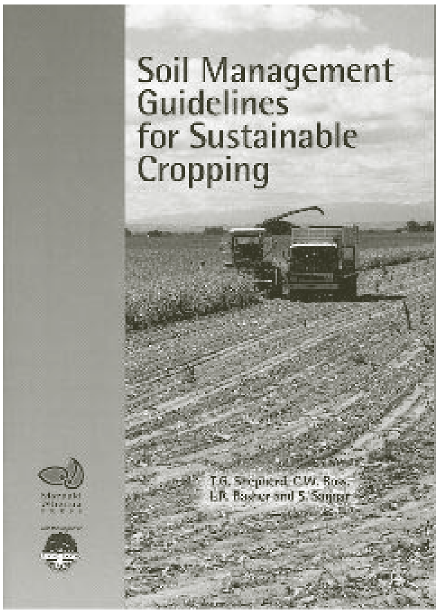
# Simple Guidelines Demystify Soil Management Practices

Manaaki Whenua PRESS

## Soil Management Guidelines for Sustainable Cropping

By Shepherd, Ross, Basher, Saggar

Do you need to know how to assess the condition of your soil? Do you suspect degraded soil quality is causing you rising production costs and poor yields? Are you concerned about the impacts of medium-term cropping on your soil? This new 26-page booklet contains basic guidelines to help you manage your soil sustainably and profitably.




Arable farmers and vegetable growers will be able to identify weaknesses in their soil and learn how simple practices can improve soil structure, increase soil organic matter and prevent or minimize soil erosion by wind or water. Discover how to use simple, visual soil assessment methods, then match your management practices to the limitations and potential of your soil types.

The conclusions of this full colour booklet, devised by Landcare Research soil experts, deliver a positive message for the arable farmer: improved soil quality can lead to increased yields, greater profits, and environmentally friendly farming. Clear photographs, charts and step-by-step instructions help to make this an indispensable self-help guide.

*An indispensable self-help guide for farmers and vegetable growers*

LIVING EARTH

2000, 26 pp, 295x210 mm, soft cover, colour photos, $19.95, ISBN 0-478-09338-1

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Answer to 'What is it' on Page 2: Microscopic diatom *Paralia sulcata*, a chain-forming plant from Huon River sediments. Magnified 5000 times. *Courtesy, CSIRO*