Manaaki Whenua
Landcare Research

# SOIL HORIZONS

## What's inside




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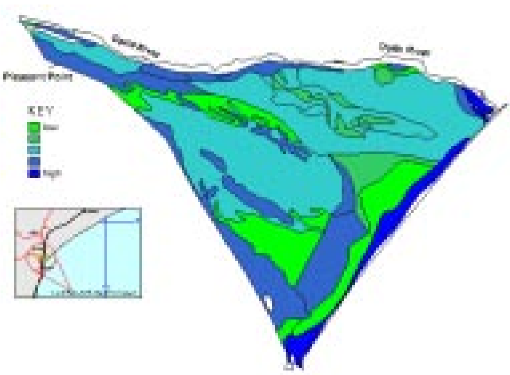
## Reducing the risk of groundwater contamination

There is clear evidence primary production can cause pollution of underlying groundwaters. Land users and regulatory authorities wish to minimise ground-water contamination and to prevent it from exceeding critical values. To achieve these goals they need to understand the factors that increase the risk of contamination and how land-use practices can be modified to reduce contamination.

Over the last three years, Trevor Webb and Linda Lilburne have used computer simulation models to determine the relative importance of land-use, soil, and water-table characteristics on groundwater contamination. This information has then been used to derive maps showing the relative risk of contamination for land within Levels Plain in South Canterbury. The potential for changes in management to reduce contamination is being investigated by running leaching simulations under a range of management options. The economic costs and benefits of alternative management practices are also being calculated. Using this information, Trevor and Linda will collaborate with land-users to develop an array of management practices to reduce the risk of ground-water contamination.



Future research will focus on the development of more quantitative approaches to enhance predictive capacity and to quantify the relationship between management practices and contamination effects.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# Pesticide leaching study site in the Waikato

As part of a nationwide approach to assessing pesticide behaviour in key soils, an experimental pesticide leaching study site has been established on Horotiu soil near the Hamilton airport. This work follows leaching trials which ran from 1993 to 1997 in the Hawke's Bay on sandy / gravelly soils. These trials, using picloram, simazine and atrazine, indicated that the models GLEAMS and LEACHM approximated observed pesticide behaviour in soils, with picloram being less mobile and with less degradation than suggested by the models, and atrazine and simazine being more mobile. Of the three, only picloram reached groundwater (at 4.5 m).

Horotiu soils are formed from silty / sandy alluvium derived from volcanic material, and are extremely versatile soils, deep and well-drained, suitable for a wide variety of uses. Two trials have been set up at the study site, where minimum depth to ground water is 4 m. The main trial is similar in design to the Hawke's Bay trials. Information is provided on soil moisture status at different depths through probes with nine suction cups that are inserted at different depths for soil water sampling. A smaller trial site with minimal instrumentation provides the opportunity to look at movement of a different suite of pesticides. An array of wells across the groundwater flow path away from the site allows sampling of groundwater at different distances from the site.

In November 1997, the pesticides atrazine, terbuthylazine, procymidone and hexazinone were applied to the main site, with 2, 4-D, picloram and triclopyr applied to the smaller site. Br and deuterated water were applied to both sites as tracers. Hexazinone appears to show little adsorption in this soil and arrived at the 0.5 and 0.65 m depths after 3–4 months, continuing at high levels for the next 3 months. The other pesticides are showing much more retardation (due to adsorption) and / or degradation, with some break-down products of atrazine also being detected.

This study is joint with ESR, IGNS and Environment Waikato, and was established with the cooperation of HortResearch and AgResearch.

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# Fate of heavy metals added to soils

Inputs of heavy metals to soils come from the spreading of sewage sludge, chemical spills, poor waste containment procedures (e.g. from timber treatment plants and un-controlled landfills), and from the use of phosphatic fertilisers. What happens to the metals when there is a large addition to soils, perhaps as a result of a spill? Previous work has shown that it takes substantial additions of heavy metals to encompass the full range of effects of heavy metal toxicity on sensitive soil biochemical properties.

To understand heavy metal limits for New Zealand soils better, Harry Percival, Landcare Research, and Tom Speir, ESR, are investigating what happens to the metals when such additions are made to soils. They have focussed on the partitioning of added heavy metals between the soil solid and solution phases and examined in detail the speciation of the heavy metals (i.e. the various forms in which the metal ions exist) in the soil solutions.

Three soils (Foxton loamy sand, Kaitoke silt loam and Egmont black loam [derived from volcanic ash]) were amended with cadmium, chromium, copper, lead, nickel, lead, and zinc in the form of Cd (II), Cr(III), Cu(II), Pb(II), Ni(II), and Zn(II) nitrate salts respectively, at rates from 10 to 100 mmol metal / kg soil (oven-dry weight basis). From the amended soils, soil solutions were extracted and analysed for pH, and for concentrations of heavy metals and other major constituents.

The outcome of adding the heavy metals was that substantial adsorption of the metals took place on the soil solids, but as the amendments increased heavy metal concentrations in the soil solutions built up and greater and greater proportions of the added heavy metals remained in soil solution (the medium which interacts the most with soil biota). Different metals were adsorbed to different extents by each soil, with chromium, copper and lead generally more adsorbed than cadmium, nickel and zinc. Soil type had a very significant effect, with each metal adsorbed the most strongly by the volcanic ash soil, less strongly by the silt loam soil, and least strongly by the loamy sand soil.

The figure illustrates the overall outcome of adding heavy metals to the three soils at the highest amendment rate (100 mmol / kg), using strongly adsorbed lead (Pb) and weakly adsorbed zinc (Zn) as examples. The rear row of histograms shows the starting levels of the added metals before any adsorption by the soil solids. The next row, "Solution Pb (or Zn)", shows the total metal concentration held in soil solution; the difference between this and the added metal represents adsorption onto the soil solids. The different adsorption characteristics of the metals are clearly demonstrated, as well as the influence of soil type. The third and fourth rows of histograms result from calculations of the distribution of the various forms of the metals within the soil solution (metal speciation). The third

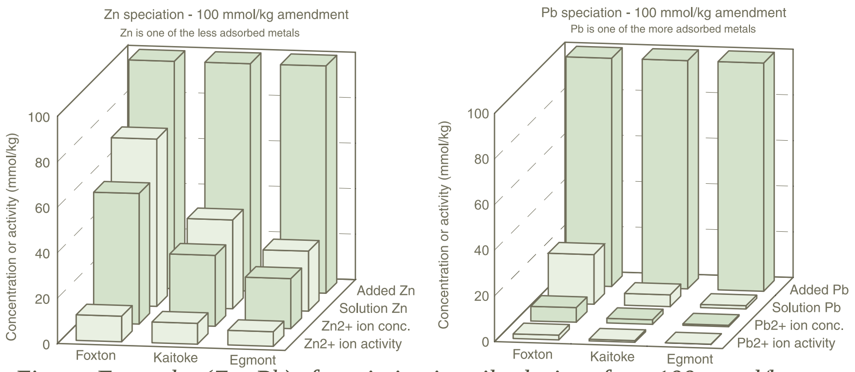


*Figure: Examples (Zn, Pb) of speciation in soil solutions from 100 mmol/kg amendments.s* row, “$Pb^{2+}$ (or $Zn^{2+}$) ion conc.”, shows the concentration of the free metal ions, i.e. that portion of the metal that is not complexed with other soil solution constituents. The fourth row, “$Pb^{2+}$ (or $Zn^{2+}$) ion activity”, shows the effective concentration or “activity” of the free metal ion after the ionic strength of the soil solution (related to the sum of concentrations of all ions in solution) is taken into account.

The free metal ion activity represents the major “bioavailable” component of heavy metals added to soils. The above sequence demonstrates that, depending on soil type, this activity can be small relative to the concentration of added heavy metal after adsorption, metal complexation, and ionic strength effects are taken into account.

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# Modelling soil organic matter

The development of process-based models of carbon and nitrogen turnover, based on well-managed, long-term field experiments, enables us to make sense of soil organic matter dynamics.

Studies at various sites in New Zealand native forests, grasslands, planted forests, pastures and cropped fields have significantly increased our understanding of the processes which control carbon and nitrogen storage in soils. Models help visualise ecological processes, test mechanisms operating under different systems, and organise data.

Landcare Research staff, including Aroon Parshotam, Kevin Tate and Surinder Saggar, are working to develop a soil organic matter model applicable to New Zealand conditions. This involves collecting data from short-, medium- and long-term tracer studies under soils of varying texture, mineralogy, and climatic conditions. These data are used to modify the current Rothamsted soil organic matter model, a model that is widely used throughout the world.

Our research has led to a new understanding of the impact of climate and land-use change on organic matter storage and its turnover. It has also demonstrated the uniqueness of New Zealand soils. To assess the effects of land use and global change on soil organic matter, data from satellites, soil and topoclimate databases are coupled to our process-based model. This coupling allows future changes in soil organic matter in New Zealand to be determined (See figure below).

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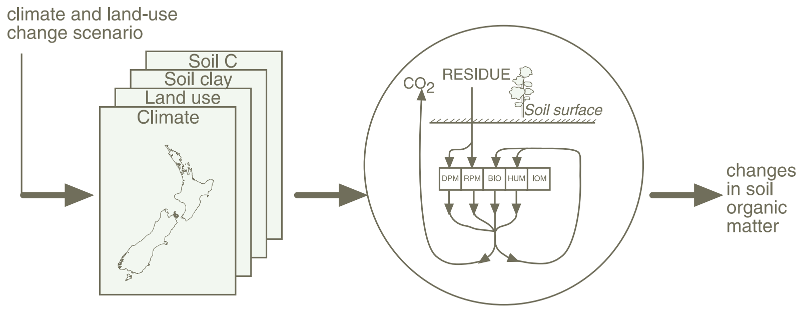


*Figure: Impacts of climate change on soil organic matter. The soil compartments in the model are: DPM, decomposable plant material; RPM, resistant plant material; BIO, microbial biomass; HUM, humic substances; IOM, inert organic matter.*

# Setting soil quality standards for our soils

MfE recently proposed that soil organic matter (total organic carbon % or "OC") be adopted as a "Stage 1" indicator for environmental reporting. For OC to be a useful indicator, there is a need to know the natural ranges in different soils and to define critical limits at which either deleterious effects on the soil ecosystem are likely, or the system loses a significant measure of resistance or resilience.

Allan Hewitt and Graham Sparling, Landcare Research, have investigated a country-wide soils dataset to determine whether the OC data it contains is adequate to derive standards and limits for environmental monitoring. The dataset used included 1482 topsoil samples from the National Soils Database (NSD), and 71 supplementary sites from targetted sampling. The majority of sites (95%) were from pastures. The data were grouped by soil order and are shown as box and whisker plots (Fig.1). The average OC contents of the soil orders differed markedly, being greatest in the Allophanic Soils and least in the Raw Soils.

Allan and Graham suggest two kinds of standards for environmental reporting. The first standard is an *environmental bottom line* below which degradation is very likely. The suggested OC bottom line in Recent and Pallic Soils is 2.0%. Such soils with less than 2.0% OC show deterioration of structure and biological characteristics. Raw soils, typically with very low OC contents, are exceptions to this standard because they are in early stages of development, rather than degraded.

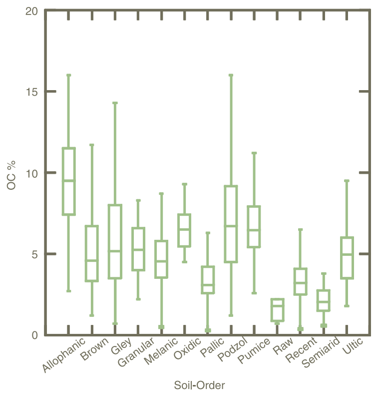


*Figure 1: Box-plots of topsoil organic carbon % (OC) for soil orders showing medians and upper and lower quartiles.*

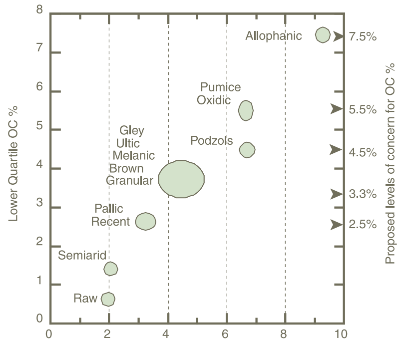


*Figure 2: Medians and lower quartiles of OC (%) for soil orders from the National Soils Database, with proposed levels of concern based on the lower quartiles.*

The second standard is a *level of concern*. This is a level that should signal concern, based on a realistic, but arbitrarily chosen, lower quartile of the indicator range. A plot of median values against the lower quartile values of soil orders gave a linear relationship in which soil orders fell into clusters (Fig. 2). The lower quartile point for each cluster of soil orders is suggested as a level of concern for soils in those soil orders. The OC content of pasture soils is generally greater than equivalent soils under forest and indigenous vegetation, and OC values extracted from the NSD therefore represent an "upper end" level of concern. These standards mean, for example, that there is concern that a Podzol with less than 7.5% OC is approaching a level at which there is increasing risk of it becoming degraded. Although these OC contents are high by world standards, they still represent the loss of at least a quarter of the soil carbon resources, which will take many decades to restore. Accordingly, environmental monitoring should seek to identify areas where there is reason for concern well before environmental bottom line values are reached. Allan and Graham are seeking feedback and discussion on the technical basis of setting limits and how mutually agreed levels can be established.

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# The effect of cultivation on soil organic matter dynamics

A Landcare Research investigation aims to compare the impacts of cultivation on soil organic matter (SOM) dynamics. Sites were chosen in the Manawatu region where cultivation of pasture for arable cropping is a common practice. Two soil types (Marton silt loam and Kairanga silt clay loam) under permanent pasture and cultivation (5 to 34 years) were studied. Based on the changes in the rate of SOM decomposition and soil biological parameters, the influence of cultivation on SOM sustainability was assessed.

Cultivation of pastures for up to 34 years resulted in a 30 to 60% decline in soil organic carbon and nitrogen, and had a significant influence on soil biological parameters. The amount of microbial biomass (mostly bacteria and fungi with some microfauna and algae) was determined under pasture and cultivated soils. It was found that not only did the cultivated soils contain less carbon and nitrogen, but less of this carbon and nitrogen was in the microbial biomass form. This observation means cultivated soils are in poorer condition and contain less microorganisms.

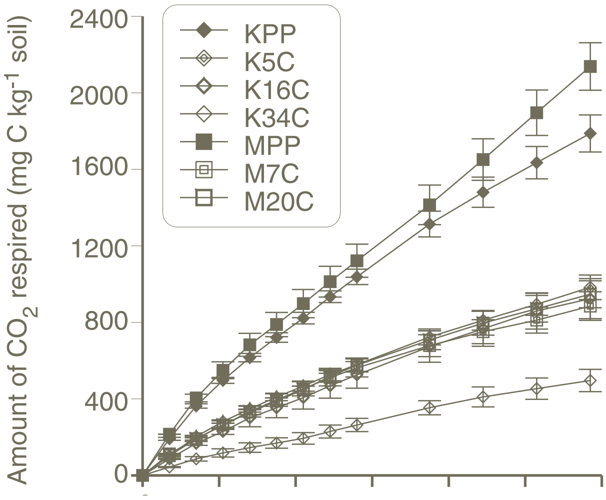


*Fig 1:Effect of cultivation on carbon decomposition in two soils.*

Soil carbon decomposition and microbial activity were measured by trapping the carbon dioxide produced by cultivated and pasture soils over a 16-week period. The results (Figure 1) showed soil carbon decomposition rates were half as much in the 5-year to 20-year cultivated soils as in the pasture soils, and were further reduced by half again in the 34-year cultivated soil. The metabolic quotient was higher under cultivated soils, suggesting that the microorganisms were working harder than their counterparts in permanent pastures. Both the amount and proportion of mineralisable N was also reduced with cultivation. The % C loss also differed with soil type: Marton silt loam (26% clay) soil losing one and half times as much % carbon as Kairanga silty clay loam (42% clay)soil.

This work suggests that cultivation of pastures for arable cropping reduces surface soil organic C and N and microbial C and N levels, and increases metabolic quotient. High metabolic quotient in cultivated soils indicates the presence of stressed microbial communities, and low mineralised N values are suggestive of smaller pools of metabolisable N. These shifts in biological parameters, and reduced C and N mineralisation, suggest that long-term cultivation leads to deterioration in soil quality and a reduction in the potential productivity in these soils.

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# Indices for soil quality monitoring

Graham Sparling and Louis Schipper have trialed a standard sampling method and set of soil quality indicators on 11 soil types and 6 land uses in the Auckland, Waikato and Canterbury Regions. Land uses included: dairy pasture, dry stock pasture, radiata pine plantation, native forest vegetation, arable cropping and market gardening. This study was part-funded by FRST, the MfE Sustainable Land Management Fund, and by Auckland, Waikato and Canterbury Regional Councils.

Indices used to assess biological condition were microbial biomass, soil respiration, and mineralisable-N; for chemical condition, total C, total N, CEC, base saturation, pH, and Olsen P; and for physical condition, bulk density, non-saturated hydraulic conductivity, moisture release characteristics and particle size and density. The effect of different land uses on soil quality was compared by selecting matched sites on each soil type.

Results show that in general, the biological indices were more responsive to land use, whereas physical characteristics differed more between soil types. Comparisons with matched sites allowed trends in soil quality indices to be followed. Despite the wide range of soil characteristics, there were consistent trends under different land uses. Using soils under native vegetation as a base line, the pine forest soils had similar physical and biological condition, but slightly greater N status. Under pastures, the pH was greater than under forests, and Olsen P, total N and mineralisable N were much increased. Biological activity and microbial biomass were greater under pastures than any other land use. Soils under long-term cropping and market gardening had extremely high chemical fertility, and high pH, but there had been a marked loss in total C, total N, mineralisable N and biological activity and biomass.

To simplify the display of soil quality characteristics from the 23 items measured, the multivariate statistical technique of Principal Components Analyses was used to reduce the soil quality data set to an easily viewed two-dimensional graph (Fig. 1). This approach grouped similar land uses and identified outlier sites despite wide differences in soil types and geographic location (Fig. 1A). The multi-variate approach does not identify soils of high or low soil quality, but does allow unbiased identification of a site that differs from others under similar use. This approach also identifies those soil properties that separate land uses (Fig. 1B).

This study has demonstrated that a standardised sampling method and set of indices were effective in showing differences in soil condition resulting from land use. Pasture soils have improved soil quality compared with those under native forest as there has been an increase in natural capital resource (organic matter) and nutrient status (total and mineralisable N, Olsen P and pH), with no decline in physical condition. Long-term cropping has

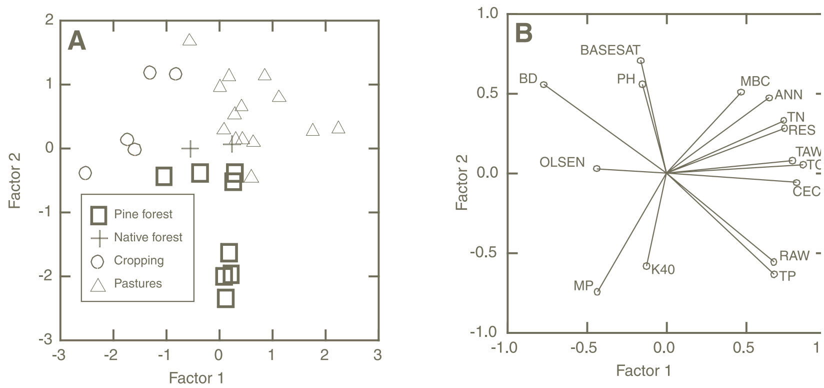


*Figure 1: Principal Component Analyses of soil quality indices showing grouping the various land uses (2A) and the loading factors responsible for the separation (2B).*

generally decreased soil organic matter content with loss of physical and biological condition. The increased chemical fertility of cropping soils and higher N status of pasture soils carry risks of nutrient leaching and adverse effects on water quality.

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## Nematodes increase carbon leakage and cycling

Historically, nematode infections were regarded as being damaging to crops and crop yields. However, as nematodes excrete considerable amounts of carbon and other plant nutrients into the rhizosphere, researchers have long suspected that nematode interactions with plant roots and other soil organisms could have positive influences on soil organic matter. Now Landcare Research scientists, Gregor Yeates and Surinder Saggar, in collaboration with AgResearch scientist, Chris Mercer, think they know how root-feeding nematodes could play a positive role in soil organic matter cycling. Using expertise in $^{14}C$ pulse-labelling they showed that infection of white clover roots with clover cyst nematode (*Heterodera trifolii*) significantly increased 'leakage' of root materials into the rhizosphere. This led to increased soil microbial activity and consequently enhanced levels of organic carbon and rates of nutrient cycling.

All roots leak carbon. To take a detailed look at how different types of nematodes differ in causing "leakage" of root material these scientists conducted a further pot trial experiment. They included five different types of nematodes because there are a range of potential pathways along which carbon and other plant nutrients can be lost from the roots in the presence of  sedentary and migratory nematodes. The addition of the nematode species indeed resulted in an increased leakage of root materials to the soil microbial biomass, indicating the generality of leakage of photosynthetically fixed carbon from roots. The increase in leakage, however, was found not to be proportional to the size of the nematodes involved. This meant that some nematodes had a greater effect than the others in causing the leakage. The root:nematode relationship was an overriding factor. The root lesion nematode (*Pratylenchus*) showed a particularly large proportion of leaked carbon in the microbial population. Gregor, Surinder and Chris believe that the more rapid carbon cycling indicated by the levels of leaked carbon is important in controlling nutrient dynamics in soils.

Gregor's previous field work demonstrated a positive correlation between pasture herbage production and total nematode abundance. Overseas studies have shown increased nutrient fluxes as a result of nematode grazing on soil microbes. This may enhance plant growth. Now this team of scientists has established that nematodes feeding on the roots also make a positive contribution to organic carbon and nutrient cycling. Future work needs to address how these leaked materials behave under different soil, land-use and climate regimes.

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## Why are volcanic-ash soils unique?

The combination of volcanic ash, climate and vegetation has produced soils that are peculiar to New Zealand. Soils derived from volcanic ash generally have allophane as the dominant mineral in the clay fraction. These soils were known as Yellow-

Brown Loams but are now called Allophanic Soils because it is the presence of allophane that gives these soils their special properties such as resistance to puddling, friability and water permeability. Allophanic Soils occur mainly in Waikato, Taranaki, Wanganui, and Bay of Plenty. Because of their favourable physical properties Allophanic Soils are well suited to dairy farming and have potential for cropping. There is, however, some risk of water erosion on rolling slopes, and of wind erosion when topsoil is exposed.

There are costs as well as benefits associated with Allophanic Soils. The reactivity of allophane towards phosphate means that Allophanic Soils need larger amounts of phosphate fertiliser than their non-allophanic counterparts. Since allophane particles are made up of small spheres about a millionth of a millimetre in diameter, a teaspoonful of this mineral would expose an area of 800 square metres – roughly the same size as a household section! This huge specific surface area, and the poorly ordered particle structure, lie behind the ability of allophane to adsorb plant nutrients such as phosphate, and to store soil humus.

The ability of allophane to bind phosphate, as well as fluoride and arsenate, has been used to advantage in New Zealand where technologies for filtering out such compounds from water have been developed. Our recent work further suggests that allophane is equally reactive towards humic acid, and hence can retard the decomposition of humus. Calcium, an element commonly present in New Zealand soils, promotes this reaction. The strong association of allophane with humus accounts for the long-term stability and persistence of organic matter in Allophanic Soils, and also for their good soil quality.

Roger Parfitt, Benny Theng and Guodong Yuan (Landcare Research) are currently studying the effect of aluminium in Allophanic Soils on these soils ability to retain more carbon than other soils, and so produce less carbon dioxide, a major greenhouse gas.

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## Soil biodiversity changes under *Pinus radiata*

Conversion of improved pastures and high-country tussock grasslands to *Pinus radiata* plantations may improve land stability, sequester atmospheric carbon dioxide and yield financial benefits. What, however, does this significant landuse change do to biodiversity – the variety and variability among living organisms and the soil ecosystems in which they occur?

Several indices of biodiversity are used to assess ecosystems, all basically with the premise that more is better. Previous research by Gregor Yeates, Landcare Research, Palmerston North, on soil nematodes has established that under grazed pastures nematode diversity varies strongly with soil type but their abundance correlates with pasture production. The soil microfauna is dominated by forms grazing on soil microbes and such grazing may keep the soil microbes (microbial biomass) in a more active state. As soil microbes play a vital role in making nutrients available to plants, the activity and turnover of microbial biomass is ecologically important. Gregor and his colleagues have also demonstrated that nematode infection increases leakage of carbon from roots, and results in increased microbial biomass activity (see *Nematodes increase leakage of carbon and cycling* in this issue).

Comparing soil biological characteristics under grassland and *P. radiata*, Gregor and Surinder Saggar found microfaunal populations differ significantly, although the direction of change varied (Figure 1). However, in both lowland Manawatu and the less fertile tussock grasslands of Otago, nematode diversity was consistently significantly lower under *P. radiata* than under grassland. The consistent differences in nematode diversity have been attributed to differences in nutrient pathways, with the inference that soil fungi made a greater contribution under *P. radiata*.

Measurements of soil pH (soil acidity) and the distribution of pools of carbon and nitrogen showed consistent decline with afforestation. The more acid conditions and lower nitrogen levels under pine also point to a slower, fungal-mediated nutrient turnover. The reduction in microbial C:organic C under *P. radiata* indicates decreased organic matter input.

This work suggests that the reduced biodiversity under *P. radiata* slows down carbon and nutrient cycling and is a characteristic of the landuse. As the soil microbial biomass and soil microfauna readily recolonize depopulated areas, we anticipate few problems in restoring the populations of soil organisms important in controlling nutrient cycling to sites after felling the *P. radiata* and returning the site to pasture or tussock-grassland.

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| | Manawatu | | Eastern Otago | |
|---|---|---|---|---|
| | Pasture | *P. radiata* | Tussock | *P. radiata* |
| Enchytraeids $m^{-2}$ | 18,700 | 38,100 | 38,600 | 4,050 |
| Tardigrades $m^{-2}$ | 0 | 0 | 6500 | 0 |
| Total nematodes $m^{-2}$ | 2,906,000 | 1,811,000 | 611,200 | 1,309,000 |
| Nematode diversity (H') | 2.40 | 2.08 | 2.33 | 1.68 |
| soil pH | 6.0 | 5.5 | 4.6 | 4.3 |
| soil carbon : nitrogen | 14.2 | 21.0 | 25.0 | 25.4 |
| mg microbial C:g organicC | 22.8 | 16.6 | 19.2 | 17.3 |

# Native plants and soil recovery

Large-scale ecological restoration of hydro-electric development sites at Aratiatia, on the Waikato River, provided an opportunity for Landcare Research scientists Craig Ross and Mark Smale to study the effect of vegetation on soil recovery. This revegetation began in 1962 and lasted until about 1980.

In a two-stage planting scheme aimed at simulating natural primary succession, koromiko, karamu, manuka, and rangiora were initially planted as a "nurse" crop, and kohuhu, black mapou, broad-leaf, kanuka, kowhai, cabbage tree and totara were inter-planted about 5 years later.

The man-made soils on restored sites had parent materials from the original soils (Taupo tephra), with admixtures of local pumice and ignimbrite. As a result, the restored soils were highly variable, ranging from skeletal profiles to profiles resembling those of the original (Atiamuri and Taupo) soils.

Most soils had 1–2 cm of surface litter; topsoil depth averaged 11 cm, with a range of 2 to 33 cm. B horizons occurred in 58% of cases. Bulk densities of mineral horizons averaged 0.89 Mg. $m^{-3}$, ranging from 0.30 to 1.72 Mg. $m^{-3}$. These compare with 0.63 to 1.31 Mg. $m^{-3}$ in natural soils under pasture. Soil chemical properties were variable, probably reflecting the nature of replaced materials rather than the fertilizer regime used 15–30 years ago. A few profiles have soil chemical properties approximating those of the natural soils under pasture. Total soil carbon buildup in 15–30 years averaged 8.29 kg.$m^{-2}$ (range 3.09 to18.63 kg.$m^{-2}$ ). This compares favourably with average values of 13.17 and 7.27 kg.$m^{-2}$ for local soils under pasture.

There was a general correlation between the quality of replaced soils and state of the vegetation, with plant health and diversity apparently better on deeper, non-compacted soils. An exception was totara, which has grown well on compacted, gravelly soils. Adventive grasses and broom tended to occur on skeletal soils of thin topsoils over pumice, sometimes mixed with ignimbrite stones. Interestingly, machinery compaction was still evident 30 years after planting, especially on benches and former roadways.

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## Cold, dry and dirty!

Antarctica is one of the largest and most pristine wilderness areas left on earth. No more than 2% of the continent's land area is ice-free. These regions are located mainly on the Antarctic Peninsula and in the McMurdo Dry Valleys Region. Human activities in Antarctica require fuel for transport and energy. Marine and the ice-free regions are considered particularly vulnerable to oil contamination, with petroleum hydrocarbons the most likely source of pollution. Very little is known about the impact of hydro-carbons on land, in particular on the ice-free regions.

Generally, the areas contaminated by terrestrial fuel spills are localised; however, runoff from soil has contaminated sub-tidal sediments. Landcare Research's Jackie Aislabie and her co-workers have detected petroleum hydrocarbons in soil from around Scott Base, the Antarctic Mainland and near the former NZ camp by Lake Vanda. When hydro-carbons are spilt on these soils they may move down through the soil column and have been observed to travel along the surface of the permafrost. Oil spills can result in shifts in the microbial community of the soils. In oil-contaminated soils significant increases in numbers of hydrocarbon-degrading microbes have been detected, and a number of bacteria which degrade oil have been isolated. The bacteria are not novel, they are similar to isolates from northern latitudes but they appear to demonstrate greater hydro-carbon degradative activities at lower temperatures. Work continues to determine their mechanisms for tolerance of low temperatures.

How oil spills modify *in situ* soil microbial diversity will be assessed using molecular techniques in collaboration with Dr David Saul of the University of Auckland. The work will also be expanded to determine how oil spills impact on soil physical and chemical properties. Measuring instruments which make continuous atmospheric and soil climate recordings will be installed in collaboration with USDA scientists. The knowledge gained from these studies will be used to refine recommended oil spill remedial actions and to contribute to our knowledge of how to avoid long term degradation of Antarctic soils.

Historical soil data, collected by Iain Campbell and

Graeme Claridge, and information collected as part of this programme will be incorporated into an Antarctic soil database being created by Robert Gibb (Landcare Research). This database, together with other information and knowledge, will form the nucleus of a decision-support system providing advice for visitors to the ice-free regions so that damage to particularly fragile soils can be avoided. The system will also recommend best practice remedial actions to deal with spills. The Antarctic Treaty requires all visitors to prepare environmental impact assessments (EIA) for their activities. Our goal is for the decision support system to be managed by Antarctica New Zealand and made available through the world wide web so that all intending Antarctic visitors can use it when preparing their EIA.

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## Are we up to date??

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