

# Soil Horizons



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

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Manaaki Whenua  
Landcare Research

## Soils portal launch

Landcare Research is launching a new soils information portal on its website on 31 March. The portal will provide on-line access to New Zealand soil maps, data, fact sheets and background information held by Landcare Research and can be found at <http://soils.landcareresearch.co.nz/>. The following articles describe some of the initial features of the new soils portal and also provide information about what is planned for release later in the year.

## Landcare Research's GeoSpatial Data Integration Portal

Significant amounts of New Zealand's soil information will be made available through Landcare Research's new Geospatial Data Integration Portal. The Portal, part of Landcare's public web site, provides visitors with a simple means to discover what spatial data Landcare Research has, display it on a map in their web browser, ask simple everyday questions using the information, and obtain simple reports. The GeoSpatial Data Integration Portal, designed to be the centerpiece of Landcare Research's data access strategy, brings together the many different types of scientific information about New Zealand's

natural environment held by Landcare Research. These include such diverse resources as fungi, insects, plants, climate, soil, land resources, environment and satellite imagery. A number of these data resources have had their own dedicated portals (e.g., NZ Fungi at <http://nzfungi.landcareresearch.co.nz/> and NVS at <http://nvs.landcareresearch.co.nz/> and NZ Flora at <http://nzflora.landcareresearch.co.nz/>) for a while, but these have lacked mapping capabilities. When the portal for soils was planned, mapping was seen as a fundamental part of the portal's capabilities, providing a capability to integrate many combinations of these diverse data types.

Visitors will be able to explore the following soils information: locations of all soil pits and samples described in the National Soils Database (NSD; see article on the new national Soils Repository, page 2), digital versions of most published soil surveys and a rich suite of soil parameters from the Fundamental Soil Layer (FSL), including soil name and measures such as pH, permeability, carbon, rooting depth, profile available water. Other information closely allied with

**New Zealand Soils**  
Manaaki Whenua - Landcare Research DATABASES

The NZSC has an Hierarchical Structure with Four levels

- 15 ORDERS**: Soil orders are the highest, most generalised level of the classification and provide the national overview of New Zealand soils.
- 73 GROUPS**: The orders are divided into soil groups based on variation in factors such as drainage status, parent material, chemical and physical properties.
- 272 SUBGROUPS**: The soil groups are divided into subgroups which provide more detail about the range of soils included in each soil group.
- SOILFORMS**: The soil subgroups are subdivided into soilforms which provide more detail about the soil parent materials, texture and permeability.

**An Example**

ORDER	GROUP	SUBGROUP	SOILFORM
Oxic	Perch-Gley Oxic	Nodular Perch-Gley Oxic	Typic Perch-Gley Oxic, stoniness, clayey, moderate over slow
		Typic Perch-Gley Oxic	
	Nodular Oxic	Nodular Oxic	
		Typic Oxic	Typic Oxic
Orthic Oxic	Medial Orthic Oxic	Medial Orthic Oxic	
	Brown Orthic Oxic	Brown Orthic Oxic	



soils data is also being made available through the geospatial portal, including rock type, erosion and land use capability, primary features from the NZ Land Resource Inventory (NZLRI) and the more recent Land Environments of NZ (LENZ).

The real power of combining mapping with the web comes from the ability it gives the visitor to follow links, and good use is made of that in the integration of the mapping with other parts of the Soils Portal. Soil names from the Fundamental Soils Layer are linked to descriptive pages about soils, soil nomenclature, soil profile photographs, and so on. The links go both ways, so a visitor reading about soils can follow a link in the description of a particular soil to produce a map showing the distribution of the soil in New Zealand. Links will also be available to Manaaki Whenua Press's catalogue where traditional printed maps and reports are available for sale.

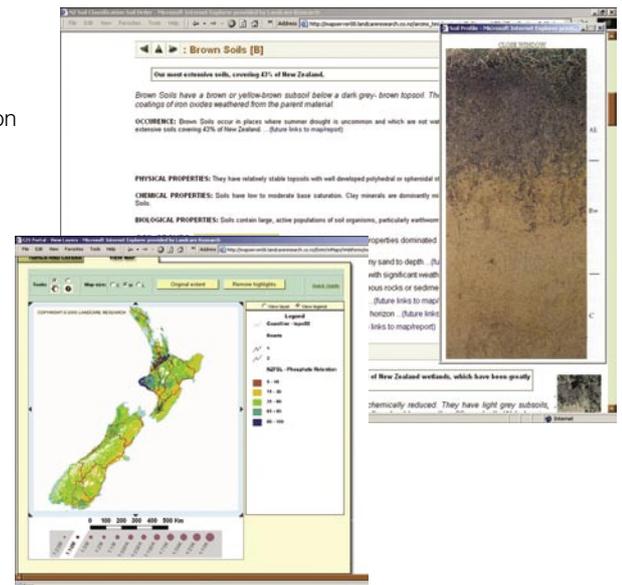
### **NZ Soils Repository – a radical new development in managing New Zealand field and laboratory soil data**

The National Soils Database (NSD) has for many years been the authoritative source for measured data about NZ soils. Started in the '80s by DSIR Soil Bureau, it is now looking a little long in the tooth. The NSD can only store information about soils that has been gathered in one defined way. Over the last decade a number of significant bodies of soils information have been gathered in ways that differ fundamentally from the data in the NSD: the standards used for field and lab measurements may differ from these used for the NSD and the field sampling regime may be depth-based rather than horizon-based. The demands of modern landscape modelling mean we need ways to

access all available soil information irrespective of its source.

Enter the NZ Soils Repository (NZSR). NZ Soils Repository can be thought of as a database of databases – it knows about the things that are common to all its constituent databases and where they differ. And, most important, it knows how to cope with the differences without the user needing to know the details. So a user might ask “find me all the soils with a topsoil pH < 6” and the NZSR would make all those records available for further analysis irrespective of whether the data were originally in the NSD, were a small collection of project-specific soil data or were any other collection of soils data that might have been contributed for inclusion in the NZSR. Our vision is that not only scientists but also members of the public such as farmers, fertilizer companies or students will have the opportunity to enter into data sharing and management arrangements so that their data will also become available for use with the NZSR.

Purists may initially object, saying that such data might surely be of very low precision and not up to the standards demanded by rigorous scientific scrutiny. But in fact part of the skill of a data modeller is to know how to manage data of varying quality – the trick is to make sure one knows the source and precision of each piece of data and to take them into account. Keeping track of the quality of each measurement in NZSR is therefore one of the repository's fundamental functions. Statistically, a thousand low-precision data values can be more important than one or two relatively



expensive high-precision data values. To take advantage of this, Landcare Research will in future offer a service to members of the public, other research agencies and companies for them to contribute soil data to NZSR and in return get access to it through the Soils Portal.

NZSR is currently under development and is expected to be available with NSD data around mid-2006. Following that we will enter into negotiation with the owners of a number of other soils datasets to develop protocols for use of the data, including who would be able to use the information and for what purposes. New services using the NZSR, such as receiving contributions from others, will be developed and introduced during the following year. In the meantime the NSD is available within the Soils Portal to be browsed, queried and shown on an interactive map – have fun.

### **On-line Soil Fact Sheets**

Ever wanted a quick summary description of a soil? Not all the detailed lab data but a summary of what it means to a farmer, horticulturist or home gardener .... well, try the on-line fact sheets on the Soil Portal. Soil Fact sheets or Soil Information Sheets have had a chequered history



– the early ones were written reports of the capabilities of a named soil and were written as a collaborative effort between regional soils specialists and farming advisors. These sheets were obviously expensive to produce and consequently focused on the highest producing soils. Historically, there has never been a strategy to produce national fact sheets. Southland and Dunedin have recently prepared on-line Information Sheets for their soils. These sheets were written first as text files and presented via the web as PDFs, linked to on-line soil maps (Environment Southland: <http://map.es.govt.nz/Departments/LandSustainability/> and Dunedin City Council [http://www.cityofdunedin.com/city/?page=searchtools\\_gis](http://www.cityofdunedin.com/city/?page=searchtools_gis) ).

When we designed the S-map project we wanted to include fact sheets

as an automated byproduct of the S-map soils system. Contributing to the Southland and Dunedin series of information sheets that had similar content and layout gave us an excellent starting point for designing automated fact sheets. The first of these has been created for the Otago region through the growOTAGO project. These automated soil fact sheets are generated on-the-fly directly from the S-map database and can be automatically updated as data and models in the S-map database improve. Since these are delivered from a database, they can be linked to a map in the GeoSpatial Data Integration Portal (see above) or in future to a query on the NZ Soils Repository (see above).

The first automated Soil Fact Sheets limit themselves to summaries of soil

facts – i.e. those things that can be measured. As our experience grows we plan to improve the models behind the fact sheets so they can also include inferences about soil versatility and suitability for growing particular crops – whether field crops, horticultural crops or grass.

Meanwhile, with S-map, the portal will provide a link to both the old-style soil information sheets and the new-style automated fact sheets.

Please send feed-back on any aspect of the Soils Portal to:

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## Will We Wiki or Won't We?

### On-line Soil Fact Sheets to NZ Soil Wiki?

Not heard of a 'wiki'? Well it's what you and I can do to organize information from the bottom-up instead of waiting for a top-down centralized solution. Still confused – try Googling 'wiki' or browse to <[wikipedia.org](http://wikipedia.org)>, and you will find an encyclopedia with contributions from all over the world mediated by anybody and everybody who feels they have something to offer. Every new entry, update or edit is signed by an individual – so you can assess who you are prepared to believe and what to discard. A parallel is TradeMe. Now you may not have used it, but the millions of successful transactions far outweigh the few rogues.

So what do 'wiki' have to do with soils? Landcare Research would like to provide a means for people to share their soils knowledge. One way to do that would be to provide a 'wiki' as part of its Soil Portal, but because the success of such an enterprise is so dependant on support and contributions from you, the soils practitioners of New Zealand, we are asking for feed-back on the idea before we proceed. To get you thinking here are some possibilities:

- The proposed concept is for a website where people can put information about soils – their use, management and limitations. **Is this a good idea or do you think it has no future?**
- The descriptions could be tagged to soil names, which would ideally be the latest NZ Soil Classification (NZSC)/S-map names. For soils that haven't yet been formally classified by the S-map team, other published soil names might be used and a name resolution capability could be included that provides the most probable associated NZSC soils. As an alternative people could just provide a GPS or other location on which their observations were based.

#### What do you think might work?

- The descriptions will be able to have links to any other part of the portal – so queries to the NSD or NZSR would be possible and map layers could also be linked.
- Regional Council staff, farmers, independent soils consultants, university staff and students, school teachers and their classes, and soil scientists could all potentially contribute. **Would you?**

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## Growing greenroofs in New Zealand

Greenroofs are a drought-tolerant, low-plant cover, growing in lightweight, thin (50–150 mm deep), manufactured 'soil' on a waterproof membrane on top of a building. They decrease the impact of stormwater runoff in cities by storing rainfall – working like sponges to reduce and slow runoff into stormwater pipes – cumulatively helping downstream flood impacts, streambank erosion, and stream degradation. Greenroofs also help filter pollutants from the atmosphere in cities, improving air quality. They provide wildlife habitat and add to the greening of central business districts and high-rise accommodation areas. Greenroofs are widespread in Germany and Norway, and are increasingly being built in England, Canada and the United States.

Lack of local information and experience are barriers to greenroof development here. It is difficult to promote greenroofs for New Zealand commercial buildings without sites where they can be seen. Also, the costs and benefits haven't been quantified under New Zealand conditions. Landcare Research soil scientists and ecologists have been working with Waitakere City Council and the University of Auckland to design and install a 500-m<sup>2</sup> 'indigenous' greenroof.

The media used in greenroofs need to balance the engineering requirement of light weight with moisture retention, suitability for sustaining plant growth, and cost. The two field-trial media pictured have dry bulk densities less than 0.70 T/m<sup>3</sup>, a fully saturated weight less than 250 kg/m<sup>2</sup> at 150 mm depth, store more than 20 mm of plant-available water, infiltrate more than 100 mm/hour of water, and are able to support foot-traffic without breaking down or compacting.

Plant species suitable for greenroofs need to be low-growing and adapted to the special environmental conditions. Sedums are often grown in overseas greenroofs. These are exotic succulent plants, some of which are weeds in the South Island. But our aim was to find native alternatives that would form a dense, weed-resistant cover while surviving frequent droughty conditions with little watering (after an initial establishment period). The ideal plants need to tolerate very windy, exposed conditions and provide habitat or food for native insects and birds. Fifteen native herb, shrub and



Two of the native candidate plants for 150 mm deep greenroofs have attractive flowers: Sand dune convolvulus (*Calystegia soldanella*) is growing in the mix dominated by coarse pumice, and NZ iceplant (right, *Disphyma australe*) is growing in the mix containing expanded clay balls.

grass species were planted on a 150-mm deep greenroof in November 2005 – by mid-January all had successfully established and irrigation was stopped. By autumn the entire 500-m<sup>2</sup> roof will be 'greened' and its performance quantified, particularly its impact on stormwater runoff.

Landcare Research is developing joint proposals with the University of Auckland School of Engineering to trial indigenous NZ substrates and plants for ultra-light greenroofs that are less than 75 mm deep and weigh less than 100 kg/m<sup>2</sup>. Light weight greenroofs need less structural support, so are highly desirable, as long as they meet stormwater mitigation targets.

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Semi-extensive greenroof 18 months after establishment, Chicago City Hall



## Long-term effects of ripping and mounding on forestry soils

Ripping and mounding are two common forms of cultivation used to prepare land for plantation forestry. Ripping aids rapid root development and mounding is used to concentrate topsoil into rows into which tree seedlings are transplanted. This helps to alleviate any potential water logging, or microclimate conditions such as frost. The practice, along with effective weed and pest control, gives seedlings the best possible opportunity to establish root systems in the first 12 months of growth.

Previous work established short-term benefits of increased seedling survival and growth from improved soil conditions – but Craig Ross and colleagues wanted to discover if these cultivation benefits extended through a full forest rotation. A series of cultivation trials, initiated by the Forest Research Institute (now Scion/Ensis) in the 1970s, were re-examined just before tree harvest, 24 to 31 years after planting. Long-term effects of cultivation on soil physical conditions and rooting patterns were evaluated

Trial sites were selected in Northland, the Central Plateau and Nelson area:

Region	Forest	Soil Group
Northland	Te Kao Forest	Humus-pan Densipan Podzol Typic Yellow Ultic Soil
	Utakura Forest	Perch-gley Densipan Ultic Soil
Central Plateau	Kaingaroa Forest	Typic Orthic Pumice Soils
	Karioi Forest	Typic Orthic Allophanic Soil
Nelson	Golden Downs Forest	Typic Firm Brown Soil

by Landcare Research in collaboration with Malcolm Skinner (formerly at Forest Research) and Douglas Graham (Scion) who measured *Pinus radiata* wood production. This study was funded by the New Zealand Forest Site Management Cooperative.

Mounded topsoil was very evident after about 30 years, with tree roots concentrated in the mounded layer. Soil physical properties reflected the extra volumes of topsoil in the mounded zone but had no effect on subsoil properties and root penetration into the subsoil, even when combined with ripping. Neither ripping nor mounding had any long-term effect on wood production at the Pumice Soil sites, despite initial reports of improved early tree survival and growth; however, wood production marginally increased by 36 m<sup>3</sup>/ha

(15%) with mounding and ripping of the Densipan Ultic Soil.

Residual ripping loosening was only evident in the Central Plateau and Nelson sites, and varied with soil type. Subsoil zones loosened by ripping had significantly lower soil strengths, bulk densities, and higher macroporosities at the end of the tree rotation. Root penetration into loosened subsoils was significantly better than adjacent non-ripped subsoils, particularly for the Pumice subsoil and clayey, stony Brown subsoil.

Wood production was marginally increased by ripping the Yellow Ultic Soil (+62 m<sup>3</sup>/ha or 14%), Allophanic Soil (+30 m<sup>3</sup>/ha or 6%), and Brown Soil (+55 m<sup>3</sup>/ha or 9%). Overall conclusions are:

- cultivation may or may not be beneficial to pine root development and harvestable wood volume production, depending on the soil type
- ripping and mounding effects on the soil profile can last at least for one tree rotation
- ripping gravelly soils with a clayey matrix lessens the susceptibility of mature pine trees to windthrow.

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A soil ripper

Ripping and mounding preparation for planting at Riverhead Forest, Auckland



## The Soil Carbon Monitoring System

New Zealand is obliged to report on greenhouse gas emissions and removals arising from land use, land-use change and forestry activities under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. The New Zealand Soil Carbon Monitoring System (CMS) is an integral part of the New Zealand Carbon Accounting System (NZCAS) and was designed to use historic soil databases as well as new data incorporated into empirical models to account for carbon fluxes in soils arising from land-use and land-use change activities. The CMS can be used to make national and regional estimates of carbon in New Zealand soils and to quantify soil carbon changes following land-use change, particularly those changes that have occurred since the beginning of 1990, the baseline year for carbon accounting. These post-1990 changes are principally from grassland to shrubland and from grassland to planted forest (afforestation). The Soil CMS is also designed to allow future land-use change (e.g., reforestation) effects on soil carbon to be predicted.

### Beginnings

Building the system involved stratifying New Zealand into soil, climatic, and land-cover classes. New Zealand soils, mapped at a scale of 1:1 000 000, were initially reclassified into six IPCC (Intergovernment Panel on Climate Change) categories based on clay activity, organic matter, wetness, texture and mineralogy. Podzols, widespread throughout New Zealand, were added to make 7 soil classes. Temperature and moisture stratification was based on the USDA Soil Classification System. Ten categories of land use/land cover were based on the 1:1 000 000 scale Vegetative Cover Map of New Zealand. After eliminating small areas, combinations of the 7 soil classes, 2 temperature and 5 moisture classes, and 10 land-use classes provided 39 combinations (cells) describing 93% of New Zealand (Table 1).

Georeferenced soil carbon data contained in existing databases were the primary data source used to estimate average soil carbon for each of the 39 cells. Historically,

most soil carbon data contained in these databases came from carefully selected 'representative' (or modal) soil pedons sampled and analysed as part of soil survey operations (Landcare Research National Soils Database) or from forest mensuration or trial plots (Forest Research Forest Nutrition Database).

Soil carbon information from about 350 sites contained in the Landcare Research National Soils Database (NSD) was used to populate the database. These sites were mostly pasture but included some data from forest, shrubland and cropping land. Additional data from forest sites were obtained from Forest Research's (now Scion/Ensis) forest soils database.

Early estimates of soil organic carbon stocks showed that some soil-climate-land use cells had large uncertainties in the predicted values due to relatively few data points. These uncertainties reflected the inability of the statistical analysis to correct for the sampling bias toward productive land without additional soil sampling.

Climate category	Climate classes		Soil classes	Land-use classes
	Moisture regime	Temperature regime		
Boreal	Udic	Cryic	Organic	Horticulture
Humid Boreal	Perudic	Cryic	Aquic	Arable crops
Very dry Temperate	Aridic	Mesic	High Clay Activity	Improved pasture
Dry Temperate	Xeric	Mesic	Podzols	Unimproved pasture
Moist Temperate	Udic	Mesic	Volcanic	Shrubland
Humid Temperate	Perudic	Mesic	Low Clay Activity	Indigenous forest (Mixed)
Aquic	Aquic	Mesic	Sandy	Indigenous forest (Broadleafed)
				Exotic forest
				Wetlands
				Alpine

Table 1: Soil-climate-land-use combinations representing 93% of New Zealand.



### Data gap filling and the CMS Development Phase

To reduce these uncertainties in the soil organic carbon estimates, Landcare Research and Forest Research staff began filling data gaps in 1998–1999. The area most visited was a coast-to-coast 'transect' across South Island, just north of Christchurch, with sampling restricted to soils under indigenous forest and shrubland. Samples were collected for litter and FH horizons, and for 0–10 cm, 10–20 cm, 20–30 cm and 30–100 cm depths. Some areas of shrubland on volcanic soils in North Island were also sampled.

Around 2002–03 the number of data points from the NSD contained in the database was significantly increased (from c. 350 sites to c. 1120 sites) using a method developed by Allan Hewitt and David Giltrap to estimate fine-earth bulk density for NSD sites that contained no measured bulk density data.

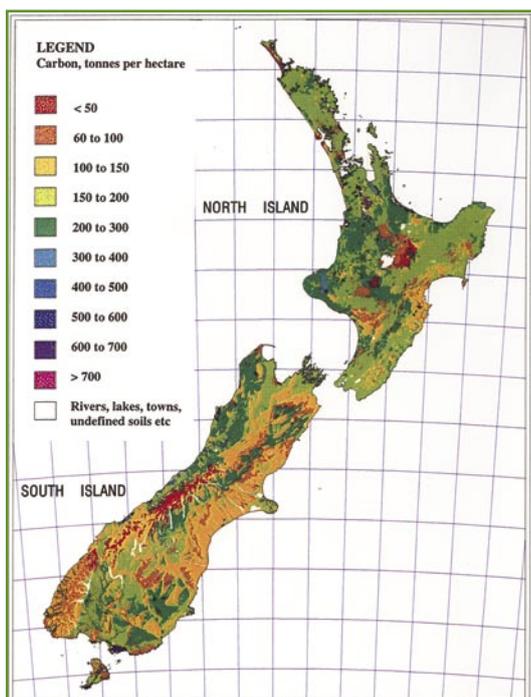


Figure 1: Spatial distribution of soil carbon to 1m depth

### CMS Implementation Phase

With the start of the CMS Implementation Phase during 2003–04, soils data from a further 113 forest and shrubland sites were acquired during this first year and from another 90 sites during the second year, 2004–05. The work will continue until the end of the Implementation Phase in 2007. In all, we should have slightly less than 2000 data points in the CMS soils database when the current sampling programme is completed.

### Estimating Soil Organic Carbon Changes and Uncertainties

We then investigated relationships between measured soil C in the 39 soil-climate-land use combinations and the main variables regulating soil carbon, to develop the best predictive model for each land use. This model takes account of soil-climate, land-cover, slope and rainfall, and produces a single soil carbon stock number (with uncertainty) for each land use, which can be used to

calculate the difference in soil carbon between any land-use and pasture. This number is the land-use effect (LUE) (Table 2). An assumption is made that soil C is at steady state for all land cover type, and changes over time can only be estimated if the land-use history is known.

We calculated national estimates for soil C stocks using these LUEs (Table 3 and Figure 1).

### Testing the Soil CMS

While our tests show that the Soil CMS predicts soil carbon stocks and changes reasonably

Land use	Land Use Effects (Mg C ha <sup>-1</sup> )
Reference (grazing land)	0 ± 4
Exotic forestry	-16 ± 7
Indigenous shrub	-12 ± 5
Indigenous forest	-1 ± 5
Cropland	-11 ± 8
Horticulture	-9 ± 7

Table 2: LUEs for 0–0.3 m soil organic carbon (± SE) relative to the reference land use based on Tate et al. (2005).

Depth (m)	National soil Carbon (Tg)*
0–0.1	1300 ± 20
0.1–0.3	1590 ± 30
0.3–1.0	1750 ± 70

\*Tg = Teragram = 10<sup>12</sup> g = 1 000 000 Tonnes

Table 3: Total national soil organic C

well, more comparisons need to be made to reduce uncertainties in our change estimates. Paired plot or chronosequence studies are used to verify the direction and magnitude of carbon fluxes predicted by the soil CMS. Paired plots and chronosequences have the advantage of providing immediate results, unlike measured changes in real time that may require years of monitoring.

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Tate KR, Wilde RH, Giltrap DJ, Baisden WT, Saggart S, Trustrum NA, Scott NA, Barton JR. 2005. Soil organic carbon stocks and flows in New Zealand: System development, measurement and modelling. *Canadian Journal Of Soil Science* 85(4):481-489.



### Liming mitigates trace element toxicity in biosolid-amended soils

Land application of biosolids (sewage sludge and sewage sludge products) is a low-cost option for recycling this organic-rich material. Application amounts for New Zealand arable land are regulated, among other things by the total concentrations of trace elements in the soil and sewage sludge. However, availability, and therefore toxicity, of trace elements to plants and soil microbes has no direct relationship with total concentration. Instead, trace metal soil solution concentration and activity (a measure of free metal ions) are regarded as better indicators of metal availability.

As part of the FRST-funded programme 'Sewage biosolids – safe, beneficial and acceptable use on land', Landcare Research staff have been assessing the availability of these trace elements using a geochemical model to estimate copper, zinc and nickel activities in soil solution from a field-trial pasture soil amended with copper, zinc or nickel-spiked sewage sludge. This work parallels the research into the effects of biosolids on soil biological processes, reported by Gregor Yeates in Soil Horizons Issue 12. The aim of the trace element study is to establish safe-loading guidelines for sewage sludge, linked to local soil characteristics and

environmental conditions. Changes in soil solution chemistry over 7 years after application of metal-spiked sludge are reported here.

Copper is one of the least mobile trace elements. This is because it is sorbed strongly by humic substances, clay minerals, and iron and aluminium hydroxides in soil. As such, its concentration and activity in soil solution are low (Table 1). In contrast, zinc is a very mobile element. It can only be weakly sorbed by soil organic matter and clays. Thus, before liming, its concentration and activity in soil solution are high. Nickel is between copper and zinc in terms of its affinity to soil particles, and this is reflected by its moderate concentration and activity in soil solution.

An important soil management issue is to reduce the concentration and activity of trace elements where their toxicity to plants and microbes and their leaching to water are of concern. Our results show that keeping soil pH near neutral by liming is a very effective way to reduce the concentrations and activities of copper, nickel and zinc (Table 1). Lime was added to raise pH values by about 2 units to approximately 7 (from 4.6–5.2

to 6.9–7.1) and its effect was most obvious for zinc. The potential toxic effect of free metal ions (measured by their activities) on microbes and plants can therefore be minimised by liming. These results also show that a single lime treatment continued to be effective 4 years after application.

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#### Book Release May 2006

#### Handbook of Clay Science

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This book brings together up-to-date information on the varied and diverse aspects of clay science scattered in numerous journals, book chapters, conference proceedings, and scientific reports. Topics range from the fundamental structures and properties of clays and clay minerals, through environmental, health and industrial applications, to analysis and characterization by modern instrumental techniques. There are also chapters on clays and microorganisms, layered double hydroxides, zeolites, and cement hydrates as well as the history and teaching of clay science. No available modern work is as comprehensive and wide-ranging in coverage as the *Handbook of Clay Science*.

The target audience for this book includes newcomers and graduate students, research scientists, university teachers, industrial chemists and environmental engineers.

**The handbook is due to be released in May 2006. More information is available at <http://www.elsevier.com>**



Table 1: Concentrations and free metal activities (in brackets) ( $\mu\text{M}$ ) of copper (Cu), nickel (Ni), and zinc (Zn) in soil solutions from plots amended with sewage sludge in 1997

Year	Cu loading: 180 mg/kg soil	Ni loading: 58 mg/kg soil	Zn loading: 296 mg/kg soil
1998	3.97 (1.98)	13.20 (7.97)	476 (199)
1999	3.73 (1.75)	10.80 (6.61)	199 (110)
2000	3.93 (2.23)	8.52 (5.50)	214 (121)
LIME ADDITION			
2001	2.36 (0.008)	2.22 (0.84)	2.94 (0.99)
2002	2.08 (0.37)	1.30 (0.57)	1.52 (0.61)
2003	1.87 (0.54)	0.94 (0.56)	0.84 (0.50)
2004	2.75 (0.022)	0.77 (0.41)	2.91 (1.61)



### *Dissolved organic matter the main source of nitrogen in drainage waters*

The amount of dissolved nitrogen (N) in water is an important component of water quality. The nitrate ( $\text{NO}_3^-$ ) form of N has attracted much attention in the past as it is usually the most common inorganic form of N in soil and can be readily leached from the soil to water bodies. The World Health Organisation recommends a maximum concentration of  $50 \text{ mg NO}_3^-/\text{L}$  for drinking water, based on a possible link between nitrates in the water and methaemoglobinaemia in infants and stomach cancer in adults. However, recent studies have cast doubt on the link between human health problems and nitrates, but emphasise instead the large environmental problems associated with elevated concentrations of N in soil and water.

Even modest levels of N cause eutrophication and the development of algal blooms in rivers and lakes. This can be sufficiently severe to cause anoxia and kill fish and aquatic life. Organic forms of N have the potential to be broken down by microorganisms to ammonium and nitrate. Consequently, the total "loading" of N on the environment may be much greater than indicated by nitrate levels alone.

Just how much greater the additional N load might be was shown by

a 4-year experiment that allowed Graham Sparling and colleagues to measure the N compounds leached from soil cores in large barrel lysimeters located near Hamilton. These soil cores were planted with grass and clover, and either received natural rainfall or were irrigated with secondary-treated domestic effluent at the rate of 50 mm per week. Leachates were collected weekly and analysed for N content. Recent, Allophanic, Gley and Pumice soils were monitored.

Smaller volumes of leachate were collected from the soil cores receiving only rainfall (6–7  $\text{m}^3/\text{year}$ ) compared with those receiving effluent (23–27  $\text{m}^3/\text{year}$ ). The total amount of N in the leachate was 1–19 kg/ha from the cores receiving rainfall, and 11–77 kg/ha from those receiving effluent. The nitrate concentration in the leachate never exceeded the WHO guideline. However, most of the N draining from the soils was not

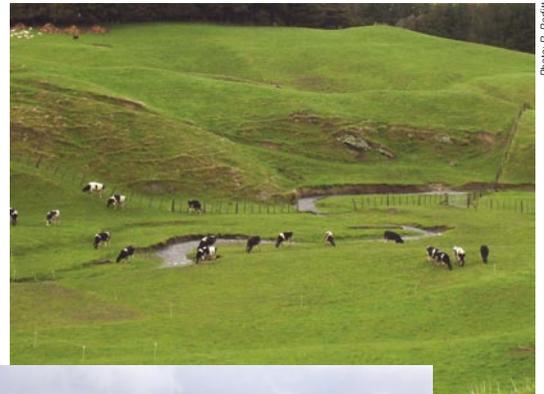


Photo: R. Parfitt



Photo: R. Parfitt

present as nitrate; instead, organic forms made up 43–87% of the total. This high incidence of organic N in the drainage water occurred both on the cores receiving only rainfall and on the effluent-irrigated cores. The total input of N in drainage waters was 5–10 times greater than that of nitrate alone.

We therefore consider it important to measure organic and total N in the sample rather than only inorganic nitrate and ammonia, when assessing water quality. The total N in leachate does not necessarily all reach receiving waters; under the right conditions denitrification in subsoil and streambeds can convert the nitrate to harmless nitrogen gas. Our current research seeks ways in which natural denitrification processes can be enhanced.

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Soil	Treatment	Volume leached ( $\text{m}^3/\text{year}$ )	Total N (kg/ha)	Organic N (%)
Pumice	Effluent	26	17	64
	Rainfall	6	5	43
Gley	Effluent	23	73	70
	Rainfall	7	7	63
Allophanic	Effluent	27	11	56
	Rainfall	6	1	79
Recent	Effluent	24	77	74
	Rainfall	7	19	81

## Precision agriculture tools for sustainable soil and land management

On 13 February 2006, Landcare Research and Massey University co-hosted a one-day workshop in Palmerston North to discuss innovative precision agriculture technologies for fine-tuning management of our natural resources – land, soil, water and air. These resources – which provide our nation with its competitive economic advantage in agriculture, horticulture and forestry, as well as in eco-tourism – are now under greater pressure than at any other time. Agricultural productivity has been increasing by 4% pa for the last 15 years – approximately four times the rate achieved by the national economy. This brings the dollars in – but the long-term price is paid by each New Zealander as an environmental cost, exemplified by water quality issues apparent in our Central North Island lakes.

International speakers gave an insight into a wide range of existing and emerging precision tools available for resource management. We also heard from our own practitioners who successfully use these tools. A concluding discussion, led by Morgan Williams (Parliamentary Commissioner for the Environment), John Caradus (Fonterra) and Brent Clothier (HortResearch and SLURI), provided some direction for future research, development and application of these technologies.

A report from the workshop follows.

explained how precision farming provides the technical platform for traceability, an increasingly serious issue in food quality and security, as well as enabling accurate spatial data collection for crop management by both farmers and contractors. Professor Godwin anticipated that this could also provide the system required for “local” carbon trading accounts, and concluded his talk by explaining that while maximizing yield has been a significant motivator for development and uptake of precision farming technology, future drivers will be crop quality, environmental factors and traceability issues.

James Taylor, of the Australian Centre for Precision Agriculture, described the development of a multi-sensor platform for conducting field and sub-catchment-scale soil surveys. This platform consists of two electromagnetic induction sensors, a gamma radiometer and an Omnistar HP dual frequency GPS. Simultaneous analysis of data from coupled sensors should improve the accuracy of site-specific predictions of soil properties, although there is need for more research into the handling of this simultaneously collected complimentary data.

We need more sophisticated ways to alter the way we cultivate, seed and fertilise, now that we know that different areas of a paddock need different management. Professor Scott Shearer, a visiting expert from University of Kentucky, USA, explained how microcontrollers were first introduced for engine control in the mid-1990s in USA to meet emission standards, and rapidly spread to tractors, combine systems and then to implements. Over the last decade the cost of differential GPS in the USA has dropped from \$5,000 (US), plus \$1,000 per year (for

differential correction), to today's price of less than \$100, with free correction signals, making GPS technology a US commodity item. In the near future manufacturers will introduce equipment with virtually unlimited control potential. This equipment will sense metering and position errors, and compensate immediately. Spatial management will be at the sub-meter level, with the capacity to move to individual plant level.

### New Zealand perspective

Ian Yule, director of the New Zealand Centre for Precision Agriculture (NZCPA), presented findings from the 2005 MAF review of precision agriculture in New Zealand, which identified the sheep and beef sector as having the greatest economic opportunity to benefit from these technologies, using variable rate application to zones of contrasting productivity potential. The NZCPA is a self-funding unit within Massey University, that researches, develops and assesses practical applications of precision resource management concepts, such as variable rate fertilizer application by ground-spreading and aerial top-dressing. New Zealand farming uses approximately 4 million tonnes of fertilizer annually (value approx \$600M to \$650M). Even a 5% improvement in use (using variable rate precision fertilizer application) would lead to an annual saving of \$30M and a reduction of 200 000 tonnes application of fertilizer to the environment. Efficient use of inputs such as irrigation and pesticide application would also deliver financial and environmental benefits. Tailored irrigation systems are being investigated in both the Canterbury and Marlborough regions that significantly reduce water requirement without reducing yield.

### Global perspective

Precision agriculture technologies can improve crop management linked to soil-plant-water-nutrient issues, providing significant economic advantage to the grower. This is the message of invited speaker, Professor Dick Godwin (Cranfield University at Silsoe, UK). He gave as an example increasing cereal crop yields with reduced nitrogen inputs, using satellite imagery to interpret crop density from NDVI (Normalised Difference Vegetation Index or “Greenness Index”) data. Professor Godwin also



John Austin Ltd Agricultural Contractors, based in the Waikato, are a leading user of precision agriculture technologies. Auto steer capability with RTK-GPS guidance, guide tractors in automatic self-steer mode to increase speed and accuracy while reducing labour costs. NIR sensors are being trialled to measure forage moisture and nutrient content. GPS-controlled sprayers have individual spray nozzles and planter units that can be turned on and off automatically when entering headlands or rows. David Densley, representing these leading precision farming providers, explained that the aim for the next 5 years is to produce multi-layered field information including EM maps, grid soil sampling, chlorophyll maps and yield maps. This information will then be used to produce a prescription map for pre-plant nutrient application, planting population, manure application and nitrogen application.

Landcorp, a state-owned enterprise and New Zealand's largest farmer, uses precision technologies to provide traceability from farm of origin to consumer, of importance in biosecurity and integrity (proof of origin) issues. Landcorp practises precision fertilizer placement and recording, and management and monitoring of water use, as explained by Landcorp General Manager, Bernard Card. These monitoring and measuring procedures enable Landcorp not only to achieve greater efficiencies but also to offer a quality assurance programme, FARMPRIDE™, which focuses on meeting/exceeding customer requirements, and also provides a means for environmental monitoring and management. This is a prime example of how precision technologies led to traceability of product and thereby quality assurance for the customer.



Photo: C. Aguilera

*Workshop delegates view the ATV-mounted pasture sensor, developed by Massey University's Centre for Precision Agriculture, for direct measurement and mapping of pasture dry matter yield in the paddock.*

A similar quality assurance scheme, EUREPGAP, initiated by Europe's leading food retailers aims to provide customers with more food safety assurance. Audit and certification of the standard within New Zealand is carried out by AgriQuality. EUROGAP's stated aim is to minimize detrimental impact on the environment, while conserving nature and wildlife, reducing use of agrochemicals, improving efficiency

**Precision agriculture** ..... relies on the existence of in-field variability. It requires the use of new technologies, such as global positioning (GPS), sensors, satellites or aerial images, and information management tools (GIS) to assess and understand variations. Collected information may be used to more precisely evaluate optimum sowing density, estimate fertilizers and other inputs needs, and to more accurately predict crop yields.  
[en.wikipedia.org/wiki/Precision\\_agriculture](http://en.wikipedia.org/wiki/Precision_agriculture)

of natural resource use, and ensuring a responsible attitude toward worker health and safety. These goals require an increasing adoption of precision agriculture tools to provide the means to monitor our natural resources spatially and to plan variable rate management methods, with cost benefits of less inputs.

Several speakers described precision agriculture as a philosophy, not just a tool, and its true effectiveness, therefore, is measured by end-user awareness of the issues of environmental variability and traceability, in addition to uptake and implementation of the technology. The final discussion highlighted an increasing requirement for our primary production sector to adhere to quality assurance schemes, and acknowledged precision tools as an integral part of this process. The traceability issue will involve a greater emphasis on "indicators" – both economic and environmental. The concern for New Zealand is that overseas markets will drive our practices (e.g., EUREPGAP) and we will lose the opportunity to combine performance and compliance tools of our own. Morgan Williams suggested that Landcorp's significant profits could be invested by the government to enable us to take leadership in this area. Precision agriculture tools and development of home-grown models such as FARMPRIDE™ will facilitate this process.

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