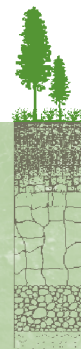


# Soil Horizons



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

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## Soil: our natural capital

In this issue of Soil Horizons we revisit the achievements of our soils and landscapes research over recent decades to show where we have really made a difference. The snapshots that follow highlight some of the real, tangible outcomes of our soil science.

Soils underpin food and fibre production, degrade pollutants, drive nutrient cycles, and regulate trace gas emissions. Soil's value in providing environmental services and in protecting the environment has been estimated at 40–70 times greater than the value of agricultural production, yet soil services are viewed as public goods that accrue to humans without regard for their real monetary value. Current land use and intensification, against a backdrop of climate change, are putting increased pressure on our vulnerable soils and landscapes.

Without healthy soils New Zealand would not be able to sustain current or anticipated agricultural productivity, or ecosystem health and integrity. The only way to protect soil resources—and ultimately the productive capacity that depends on them—is through research. Despite this, soil science has been subject to significant funding cuts over recent years, risking our ability to use and manage our soils to sustain the 'grass root' services we take for granted. As Federated Farmers President, Charlie Pedersen recognises 'we badly, badly need soil scientists again' (August 06).

Like most scientific disciplines, soil science is rarely blessed by 'eureka moments'. Our research focuses on

unravelling highly complex systems both temporally and spatially, where change is gradual but decidedly significant, such as landscape evolution or soil quality changes. We need to communicate to our investors the complexity and challenges we have overcome, and those that still remain. Soil science is making huge impacts, but as scientists we need to break through funding paradigms to build more stability and space into our research.

Minister for Science, Steve Maharey, remarked that investment in agricultural research has produced an average return of 17% per year in the past 75 years (June 06). An impressive figure, bearing in mind 53% of New Zealand's export receipts depend on our soils and landscapes. But whilst it is easy to calculate the return on investment of, for example, a disease-resistant wheat strain, or annual increase in milk solids, putting a value on the environmental services that soils provide is more challenging.

If we are to improve public awareness of the value of soils we must raise the visibility of this 'hidden' resource, and put real dollar values on the ecosystem services that soils provide. Public engagement should become part of our everyday scientific practice. By finding new ways of talking about and defining the public value of soil science we can play a central role in securing New Zealand's future.

**Alison Collins**

Phone 06 353 4809

CollinsA@LandcareResearch.co.nz



**Landcare Research  
Manaaki Whenua**



## Soil conservation – is the renaissance coming?

New Zealand loses over 200 million tonnes of soil every year to the oceans, and erosion is severe to extreme on 10% of the country. As a consequence, over the last 40 years or so, New Zealand has invested a considerable amount in soil conservation measures to protect and maintain farming predominantly on hill country landscapes. Has this investment been worth it and how have these practices fared in the light of a number of recent devastating storm and flood events? What role has science played and do we have the answers to future-proof our hill country against damaging storm events?

Research on the economic impacts of soil erosion in New Zealand has focused on the on-site costs of soil loss in the form of production loss and storm damage. Subsidies and implementation of soil conservation measures have primarily been justified through maintenance or improvement of farm productivity levels. However, while soil conservation measures have contributed to on-going, on-farm production, international estimates of soil erosion-damage in recent decades have indicated off-farm damage may be greater than that on the farm.

Soil conservation as both a word and a practice has largely dropped from popular use in New Zealand. Modern practices formerly ascribed as "soil conservation" can be found in terms such as sustainable land management, integrated catchment management, and so on. However, many of the physical practices of soil conservation themselves are still employed on the ground, though it might be argued that in many areas these too have declined. What has happened, though, is that attention has been focused to some degree away from individual properties and back to catchments where it all began between the 1940s

and '60s. Taking a larger view of the nature of the problem and its range of solutions is now providing the renaissance of soil conservation. Some might argue it's been a bit slow in coming as evidenced by significant damage during several recent severe storms, the impacts of which might have been less drastic if the soil conservation "ball" had not been dropped in some regions.

However, it is clear that attention is now refocusing on research, policy, and action "on the ground" in terms of soil conservation. Research initiatives such as SLURI (Sustainable Land Use Research Initiative), ICM (Integrated Catchment Management) at Environment Waikato, SLUI (Sustainable Land Use Initiative) at Horizons Regional Council, and a general move to conduct land-use planning at farm and catchment scales across the country, all point to a renewed interest in dealing with what is a "protection at source" issue rather than a focus on downstream effects, which has been the primary focus of many RMA (Resource Management Act) issues over the last decade.

Research carried out in Taranaki in the '80s and early '90s has resulted in a landscape that has a range of land uses suited to maintaining productivity on those parts best suited for that purpose and retiring and planting those parts that were steep, unproductive and at risk of failure. The result is a mosaic of land uses and vegetation cover seen across individual farms and catchments. Another example is the East Coast Forestry Project where research into understanding erosion process



*Storm damage at Ngatapa Valley, Gisborne, July 1985, after 200 mm of rain fell in 24 hours (Gisborne Herald)*

dynamics and the value of blanket afforestation in treating severe erosion and reducing sediment load to rivers and coast helped elevate this to a national priority requiring a central government response.

So where to next? There is still a need to understand the intrinsic nature of many erosion processes and the generation, transfer and storage of sediment in our landscapes. There is a need to move towards integrated modelling tools that incorporate and represent the nature of the actual processes rather than rely heavily on off-the-shelf models developed for other places with different sets of processes from those found in New Zealand. There is also a need to improve the uptake between research and policy formulation and to bring back a national perspective to what has become a series of regional issues. Soil conservation is not dead – it has just been quietly hovering in the background. The renaissance is nigh!

### **Chris Phillips**

*Phone 03 321 9775*

*Phillips@LandcareResearch.co.nz*

### **Michael Marden**

*Phone 06 863 1345*

*MardenM@LandcareResearch.co.nz*



## HEL – Highly Erodible Land – how do we assess it?

Landcare Research scientists were recently commissioned by Horizons Regional Council to provide definitions and guidelines for the assessment of erosion to help Council staff identify Highly Erodible Land (HEL). The necessity for this assessment has become apparent since the February 2004 storm that struck the Manawatu, Rangitikei, Wanganui and Taranaki Districts, causing erosion in hill country, and flooding, sedimentation and stream course changes in the lowlands. Damage during this storm event is estimated to have cost \$355 M.

The unsustainable use of hill country was a major factor contributing to this damage, and is now one of four major issues identified by the Regional Council in their draft Horizons OnePlan. The council is currently examining options to reduce hill country erosion risk – and one of the first tasks is to better define and identify Highly Erodible Land.

The present assessment by Landcare Research uses and builds on knowledge gained by them over recent decades. Definitions of erosion

severity were set out in the 1970s in the Land Use Capability Survey Handbook; and definitions of erosion type were developed in the 1980s in The New Zealand Land Resource Inventory Erosion Classification. Criteria for assessing erosion severity were developed, standardized and documented in the 1990s. This laid the foundation for a rapid response by Landcare Research scientists to address the effects of 62 000 landslides resulting from the February 2004 storm event.

From a scientific viewpoint, the February 2004 storm provided invaluable data to improve existing models of landslide susceptibility. It highlighted the fact that incidence of landsliding does increase with slope angle. The new data confirmed that forest reduces landsliding probability by 90%, and scrub reduces it by 80% compared with land under pasture. Analysis of the February 2004 storm was carried out using SPOT5 satellite imagery (with a resolution of 10 m) of the affected area. Assessment of storm damage by inputting this digital information into existing models was rapid – about 1 week.

Horizons Regional Council and Landcare Research are working together to identify highly erodible land at both farm and regional scale. Farm-scale issues are being addressed through the Sustainable Land Use Initiative, which provides whole-farm plans to farmers and encourages sustainable management practices. Regional-scale planning has been facilitated by production of a regional map showing the distribution of highly erodible land within the region, together with a report that sets out criteria and guidelines for assessing erosion severity. A major development has been incorporation of a new method for readily quantifying the areal extent of mass movement and fluvial erosion. This gives an invaluable preliminary assessment of severity that is further defined using criteria set down in the report. Future work includes development of field guides and decision processes for recognition of highly erodible land at farm scale.

**John Dymond**

Phone 06 353 4955

[DymondJ@LandcareResearch.co.nz](mailto:DymondJ@LandcareResearch.co.nz)



*Catastrophic effects of hill country erosion in the Rangitikei River catchment, July 2006  
(photo courtesy of Manawatu Standard)*



*Downstream effects of flooding – Ngaturi Bridge on the Mangawhero River, July 2006  
(photo courtesy of Manawatu Standard)*



## LENZ – continuing the unexpected harvest

When former DSIR scientists set out to map New Zealand's soil resources over 30 years ago, they did not expect to be planting the seeds of knowledge that we would harvest today to help protect our native biodiversity. But that's exactly what happened.

LENZ – or Land Environments of New Zealand – is our best attempt to date to depict the range of native ecosystems within New Zealand and help us assess whether we are indeed halting the decline in native biodiversity. As described previously in Soil Horizons, LENZ is a quantitative, hierarchical, scalable classification of New Zealand's terrestrial environments that can depict the degree of environmental similarity (or difference) between any two points within New Zealand.

LENZ is based on a combination of 15 underlying climate, landform, and soils layers. Landcare Research scientists combined information from the Land Resource Inventory and National Soils Database to produce a map of soil parent material for New Zealand. Parent materials are the "stuff" from which our soils develop. Using that parent material layer, the scientists were able to estimate soil properties as they would exist naturally, i.e. without the effect of human disturbance.

The ability to estimate such undisturbed conditions, combined with the climate and soils data, enabled the depiction of the natural range of environmental variability that serves as a reference for assessing the changes we have made to our landscapes. Since its introduction

in 2003, LENZ has been used in a range of studies to help assess the representativeness of our protected areas. In other words, how well do we protect the full range of native ecosystems, which is a key goal of the Biodiversity Strategy.

While LENZ brings significant advances in conservation management, it is not perfect. Its effectiveness depends directly on the quality and resolution (scale) of its underlying data. Local-scale variation in edaphic conditions helps drive local-scale changes in biodiversity pattern and in some cases results in unique and distinctive environments. Nelson's Red Hills and associated ultramafic soils are one excellent example. Many users would benefit from an improved LENZ that captures finer scale environmental variation at, say, 1:10 000 or 1:20 000 scale, and thus helps identify rare or uncommon ecosystems, such as wetlands.

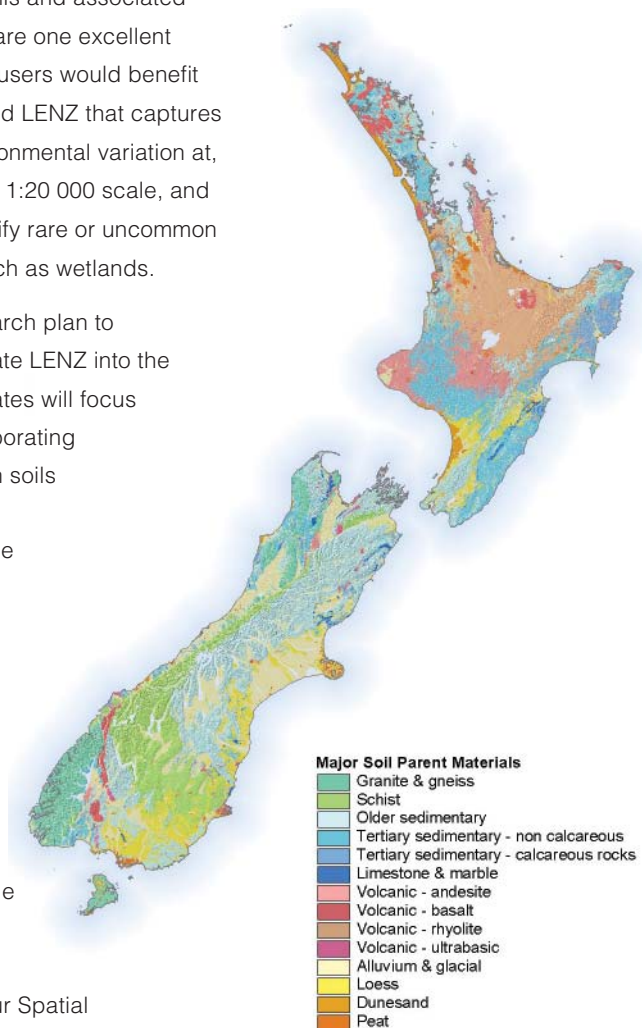
Landcare Research plan to continually update LENZ into the future. The updates will focus mainly on incorporating improvements in soils information that have arisen since the original development of LENZ. This will include localised improvements to the LRI and uptaking as much as possible the improved soils information generated by our Spatial Information Programme.

Ultimately our ability to improve LENZ – or any of the models and tools intended to deliver better economic, social, and environmental outcomes for New Zealand – rests squarely on improving our fundamental knowledge about our natural, productive, and urban systems. Continued investment in that knowledge will continue to yield new harvests of ideas and benefits – both expected and unexpected – for current and future generations.

**Daniel Rutledge**

Phone 07 859 3727

RutledgeD@LandcareResearch.co.nz



## Humping and hollowing or flipping

Humping and hollowing is a drainage technique that has been widely adopted for land development of pākihi soils on the West Coast, particularly for dairying. Similarly, flipping is another method of improving drainage of some of these soils.

Pākihi soils, naturally very poorly drained and infertile, are found in high rainfall areas (>2000 mm pa) extending from Golden Bay to Fiordland. The Maori term 'pākihi' has several definitions, the most applicable being "open country", "infertile land" and "place where fern root has been dug".

Pākihi land is generally flat or of low relief on river terraces or old sand country. It is normally very wet, very poorly drained, and underlain by soils of very low fertility with an indigenous vegetation of tangle fern, sedges, restiads, rushes, mosses and stunted manuka.

Soil surveys during the 1970s–80s identified significant variability in what was originally considered uniform pākihi soils (including Placic or Humose or Humose-ortstein-pan or Peaty-silt or Silt-mantled Perch-gley Podzols, Humose Acid Gley Soils, and Humose Densipan Podzols). Profiles range from relatively shallow (<50 cm) peaty or humic silts/fine sandy loams over

humus- and iron-cemented gravels (including boulders) to deep (>1 m) silty soils over cemented gravels, to humus- and iron-cemented sands.

Before modern soil surveys in the 1970s–80s, iron- and humus-pans were considered to impede soil drainage. For some pākihi soils, such as cemented sands or shallow soils on cemented gravels, this is indeed the case. However, conventional drainage by open ditches and/or pipe and mole drains was unsuccessful, as were attempts to drain these soils by disrupting the pans with explosives. Modern hydraulic excavators provided the economic solution of flipping. Flipping is deep cultivation of the soil to 2–3 m, semi-inverting it, breaking up the impeding pans, and allowing the water to filter through the soil to the groundwater. So far there are no signs of the pans re-constituting over 10 years after flipping.

Flipping was first pioneered in 1992 by dairy farmer Alex King in the Cape Foulwind area near Westport. Since then large tracts of land have been flipped to improve dairy production or for dairy farm development. One farm in the Cape Foulwind area has more than doubled milk production through improved drainage from flipping.

Poor drainage of the deeper silty or humus-clogged pākihi soils is a different matter. Research in the 1970s in association with the soil surveys, determined that the internal drainage through the soil profile was the main cause of poor drainage, rather than the underlying pans in the gravels. Studies of the physical properties of West Coast wet land soils by former Landcare Research scientist, Rick Jackson, found saturated hydraulic conductivities of <10 mm/hour in subsoil horizons. For these soils, re-contouring the surface to shed water was the solution, rather than trying to improve internal soil drainage properties. Shallow 'spinner drains' along natural low contours provided modest improvements. But again it was modern hydraulic excavators that provided the economic ability to re-contour the land into broad humps and hollows.

Thousands of hectares of West Coast pākihi have been humped and hollowed in the last two decades, significantly improving farm production or allowing previously waste or poorly utilized land to be developed into intensive dairy farms.

### Craig Ross

Phone 06 353 4807

RossC@LandcareResearch.co.nz



Recently humped and hollowed humus-clogged (or deeper silty) pākihi soils in the Grey Valley



Flipping sandy pākihi soils in the Cape Foulwind area, Westport



### What NZ-DNDC can deliver

There is concern in New Zealand about the environmental impacts of managed grassland and livestock production, particularly in relation to pollution of water bodies, and greenhouse gas emissions. With its strong agricultural base and relatively small amount of heavy industry, New Zealand has a unique profile of greenhouse gas emissions, dominated by the agricultural trace gases methane (37%) and nitrous oxide (17%).

As with carbon dioxide, New Zealand is required under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol to outline current emissions and changes of methane and nitrous oxide since 1990, and will face financial penalties if outputs in 2012 exceed 1990 levels. Landcare Research scientists are measuring these two greenhouse trace gases.

*Estimate nitrous oxide emissions:*

It is extremely hard to measure agricultural nitrous oxide emissions because amounts emitted vary due to the patchy nature of excreta deposition and the influence of environmental factors. Emissions vary from year to year depending on rainfall distribution, amount of time stock spend in paddocks, and soil type. Poorly drained, intensively farmed soils are particularly prone to high emissions.

Having started by measuring individual paddocks and identifying key processes controlling emissions, Landcare Research scientists developed a process-based model, NZ-DNDC, which simulates nitrous oxide emissions. We are now making progress to upscale these emission estimates to regional level and beyond (see Fig. 1).

This regional map shows where mitigation efforts should be targeted to help New Zealand fulfill its Kyoto responsibilities. Future research will target other regions with the ultimate

goal of providing robust national emission estimates and changes since 1990.

*Measure methane oxidation:*

Soils can consume or emit methane, depending largely on soil water content, soil properties, and management.

Reduction of methane emissions by manipulating soil management to enhance methane consumption would partially offset total emissions.

We recently used New Zealand data to improve the NZ-DNDC model, which enabled it to reliably predict rates of methane consumption (Fig. 2).

*Mitigate emissions:*

Knowing our nitrous oxide emissions is an important first step towards mitigating them.

Landcare Research scientists are also researching the effects of nitrogen inhibitors, sold to farmers to reduce nitrate leaching, and nitrous oxide and ammonia emissions. Our results suggest reductions in emissions of ammonia and nitrous oxide depend on the type of the inhibitor, and the efficiency of the inhibitor varies with soil type. The urease inhibitor reduces and delays the time of maximum ammonia loss from urine and urea, but does not reduce nitrous oxide emissions (Fig. 3). The nitrification inhibitor reduces nitrous oxide emissions but can increase ammonia

volatilisation and may enhance ammonium leaching.

Future research will uncover more about inhibitors, and further refine the NZ-DNDC model, which identifies management practices that reduce emissions, thus giving New Zealand the capacity to verify the efficiency of abatement strategies.

**Surinder Saggar**

Phone 06 353 4934

Saggars@LandcareResearch.co.nz

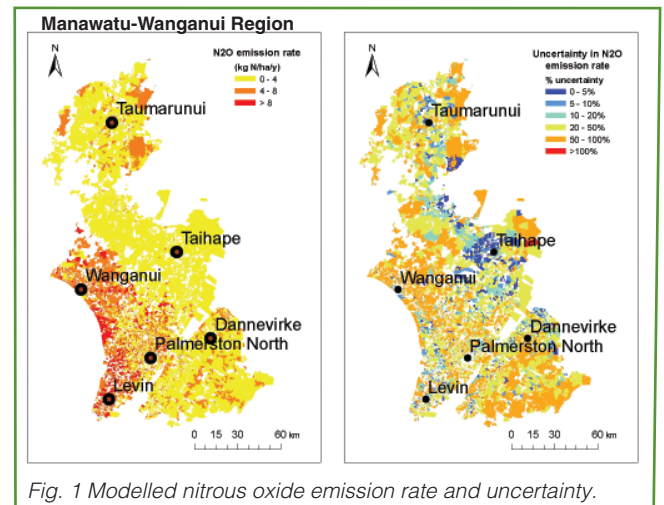


Fig. 1 Modelled nitrous oxide emission rate and uncertainty.

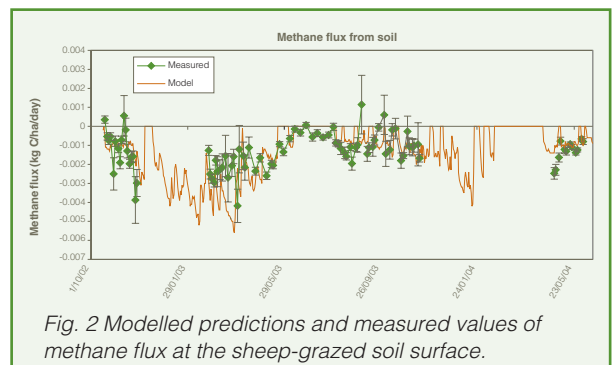


Fig. 2 Modelled predictions and measured values of methane flux at the sheep-grazed soil surface.

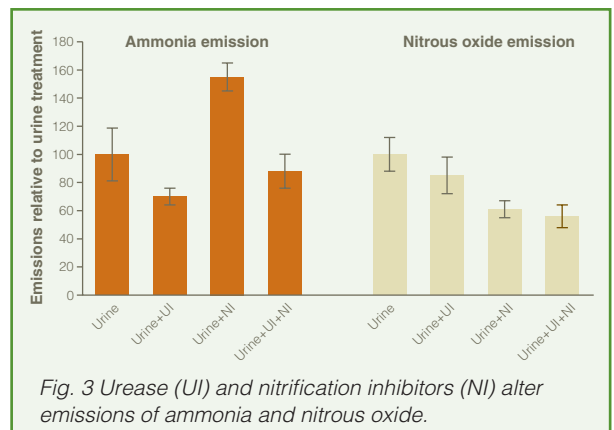


Fig. 3 Urease (UI) and nitrification inhibitors (NI) alter emissions of ammonia and nitrous oxide.



## Methane, soil and hungry enzymes

The concentration of the greenhouse gas methane in the atmosphere has risen by 150% since the Industrial Revolution. As methane has a global warming potential 21 times greater than that of carbon dioxide it is of particular interest. In New Zealand the agricultural sector is responsible for 49% of total greenhouse gas emissions. To be able to make progress towards our Kyoto obligations, New Zealand needs mitigation strategies to reduce our greenhouse gas emissions. One such process that could be developed further is using soil methane oxidation to consume methane from the atmosphere, i.e. using the soil as a methane sink.

Globally, methane oxidation first came to the fore in microbial studies in the 1970s but not until the 1980s, with the discovery of methane oxidation in swamps, did research into the subject begin to take off. Preliminary work on methane oxidation in New Zealand was done by Landcare Research scientist Kevin Tate and colleagues, initiating investigations by Sally Price in collaboration with Lincoln University in a *Nothofagus* forest soil in the Southern Alps. Here we found some very high oxidation rates, even on a worldwide scale. Other Landcare Research studies have investigated methane oxidation in agricultural soils and in newly re-established *Pinus radiata*.

As discussed in an earlier edition of *Soil Horizons* (Issue 11), methane oxidation is performed by soil bacteria called methanotrophs. While it is relatively well known that methane oxidation is carried out by bacteria, what is not so well understood is that the actual process is carried out by a

series of enzymes. Molecular biology has recently made good strides in understanding methanotrophs and how they work. In the first step of methane oxidation, methane is converted to methanol by an enzyme called methane mono-oxygenase (MMO). The enzyme can take two forms in methanotrophs: particulate and soluble. Particulate MMO is a membrane-bound enzyme, i.e. it is bound to the outside envelope of the cell, whereas the soluble MMO is found in the cellular fluid inside the cell. While in some methanotrophs both forms of the enzyme exist together, usually either one or the other is present. Methanotrophs use methane to make more biomass or produce carbon dioxide. While biomass production, is the more common endpoint, ultimately this depends on which type of methanotroph is present in the soil.

Sally's current research, again with Lincoln University, investigates the effect on methane oxidation rates of

marginal agricultural land reversion to kānuka. In addition, these researchers are investigating how long it takes for the soil under young kānuka to show a significant recovery in its methane oxidation rate compared with soil under rough pasture. Recent results show this recovery can take as little as 8 years. Allowing native scrub to regenerate may also be more economically feasible for farmers as demand increases for niche products with antiseptic properties such as kānuka/mānuka honey and essential oils.

Furthermore, current work suggests we can offset approximately 8% of methane emissions over and above New Zealand's Kyoto target – the 1990 baseline level. Overall, our research is progressing well, continuing to assess the potential of soil methane oxidation processes for mitigating New Zealand's methane emissions.

### Sally Price

Phone 03 321 9782

PriceS@LandcareResearch.co.nz



Methane oxidation measurements were made in a *Nothofagus* (beech) forest. (photo H. Betts)



### Fine sediment in the Motueka River

In the mid-1990s, trout numbers in the internationally renowned brown trout fishery on the Motueka River declined dramatically and remained low for almost a decade (Fig. 1). Many people attributed this to the effect of sediment in the river. Others went even further and suggested the source of this sediment was related to forestry activities on highly erodible granite at Separation Point (Photo 1). This material naturally breaks down to coarse sand particles that may be washed into the river. These particles fill the spaces among stones on the river bed, affecting the invertebrates and small fish living there, and can also fill deep pools, thus reducing adult trout habitat.

While trout numbers have recovered in the last 4 years (Fig. 1), debate continues about the cause of the decline. Other than anecdotal accounts, there are no data to support the claim that sediment from forestry activities caused the decline in the fishery. As part of the Motueka Integrated Catchment Management research programme, we have designed a low-cost method of describing variation in the amount of fine sediment in different parts of the river to see if the variations in trout numbers could be explained.



Photo 1. Impact of harvesting and roading on granite outcrops at Separation Point



Photo 2. Site with elevated levels of fine sediment

We first reviewed how other researchers tackled this issue and found a wide variety of measures used to characterise fine sediment abundance. These included detailed measurements of sediment particles sampled from the river bed, visual assessments of gravel embeddedness, analyses of bed stability, and surveys of the volume of fine sediment deposited in pools. Most measures were relatively time consuming and expensive, and there was considerable debate about their suitability for assessing the abundance of fine sediment.

We also wanted a technique that would enable a large number of sites to be characterised quickly, could be used by Fish & Game staff in conjunction with trout-drift dive surveys, and was suitable for documenting large changes in fine sediment abundance, rather than a

We chose 25 sampling sites throughout the catchment and made a visual assessment of the proportion of fine sediment at points along several transects across the stream at each site. The number of transects and number of observations per transect varied according to stream width. The start point of each transect was accurately located by GPS, allowing repeat measurements to be made at the same location in the future. We recorded the proportion of fine sediment using class intervals of <1%, 1–5%, 5–10%, 10–20%, 20–50% and >50%. A comparator chart was used to record the proportion of fine sediment accurately and consistently. At least 100 observations at each site were recorded directly into a datalogger connected to a GPS. All sampling was carried out under base flow conditions, and only the wetted area of the channel was characterised. Frequency of occurrence of each “% fines” class was then calculated.

At most sites, the proportion of fine sediment was very low: approximately 75% of observations exhibited <5% fine sediment, and only 7% showed >20% fines. A small number of sites, whose catchments drained areas dominated by Separation Point granite, had greatly elevated amounts of fine sediment. Repeat surveys were performed at all sites, and at Motueka

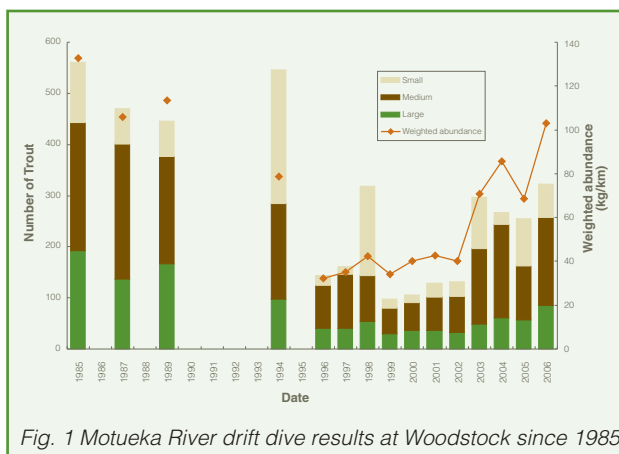


Fig. 1 Motueka River drift dive results at Woodstock since 1985

highly precise, time-consuming method. Most parts of the Motueka River have <5% fine sediment on the bed for most of the time, but as slugs of fine sediment pass through this proportion may rise to over 30% (Photo 2).





### Biosolids, trace elements and soil biota

Gorge a survey was repeated twice following a large flood in April 2005 that generated large amounts of fine sediment in that part of the catchment. Substantial changes in the proportion of fines in the river bed were recorded at that site indicating our survey method for estimating percent surface fines works well. The survey method is an efficient and effective way of providing information on the spatial and temporal variation in the proportion of fine sediment on the river bed. Although we may never be able to determine what caused the decline in the trout fishery in the mid-1990s, we are developing an improved understanding of sediment dynamics in the Motueka River, and over the next few years we will be able to establish how sediment affects the trout population.

#### Les Basher

Phone 03 545 7708

BasherL@LandcareResearch.co.nz

In previous Soil Horizons issues we reported results from biosolid\* land application trials. In Issue 12 we reported that biosolid addition to soils did not adversely affect soil microfaunal population indicators, including the microscopic roundworms, soil nematodes. In Issue 13 we showed that chemical availability, and therefore potential toxicity of the trace elements, copper, nickel and zinc, which can occur in biosolids, can be minimised by liming. We here report on the effect of these trace element-amended biosolids on soil microbial biomass, and nematode abundance and diversity. This FRST-funded research, conducted by Landcare Research in collaboration with Tom Speir of ESR, is required to help set national guidelines for safe land application of biosolids.

Approximately 0.1 million tonnes of biosolids (expressed as dry solids) are produced in New Zealand each year. Land application is a practicable option for recycling this organic material and its nutrients. Beneficial effects of adding this nutrient-rich organic material to soils include reduced fertiliser costs and improved soil structure and water-holding capacity. The USA and EU countries apply approximately half their biosolids to land, and in China the practice has been used extensively for thousands of years. Hand in hand with land application must be an awareness of the potentially toxic effects of biosolid contaminants. Trace element contamination arises from both industrial waste disposal into sewers and from domestic systems, for example, copper is contributed from domestic plumbing and zinc from cosmetics and galvanising.

We found that liming increased pH by 1.5 and produced microbial and nematode populations considerably different from the previous ones (Fig. 1). Likely causes for this are the reduced availability of trace elements with increasing pH, as well as indirect effects through other organisms in the soil food web. However, we conclude that soil microbial biomass activity and nematode diversity did not change during the whole sampling period, supporting previous findings that land application of biosolids is potentially desirable as a means of recycling nutrient-rich organic material to soils.

#### Gregor Yeates

Phone 06 353 4915

YeatesG@LandcareResearch.co.nz

\*biosolid = sewage sludge and sewage sludge products

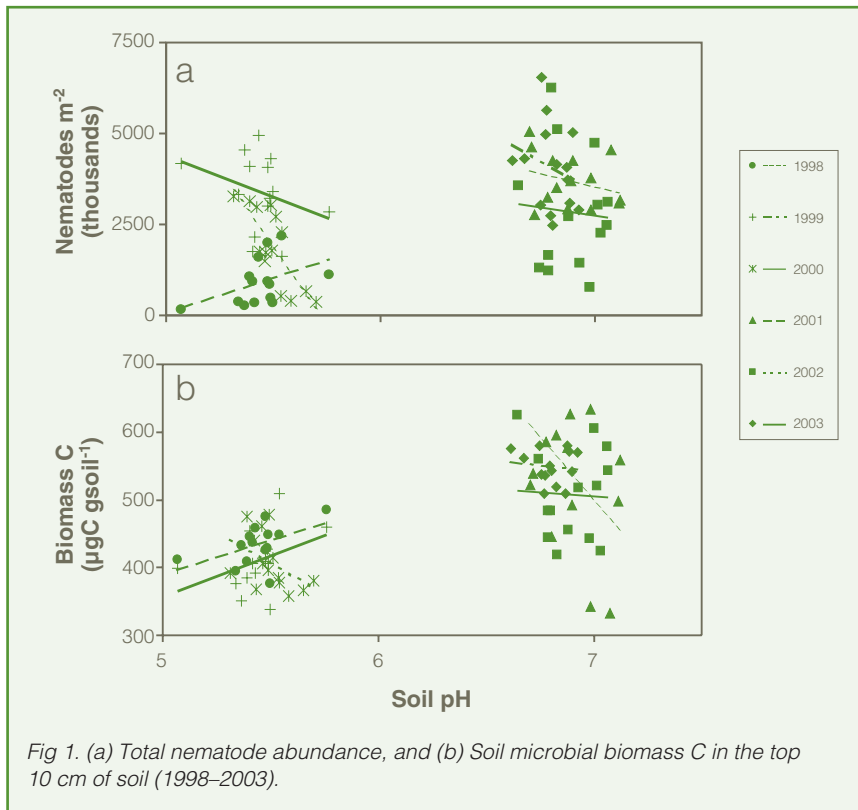


Fig 1. (a) Total nematode abundance, and (b) Soil microbial biomass C in the top 10 cm of soil (1998–2003).



## Progress in measuring soil quality

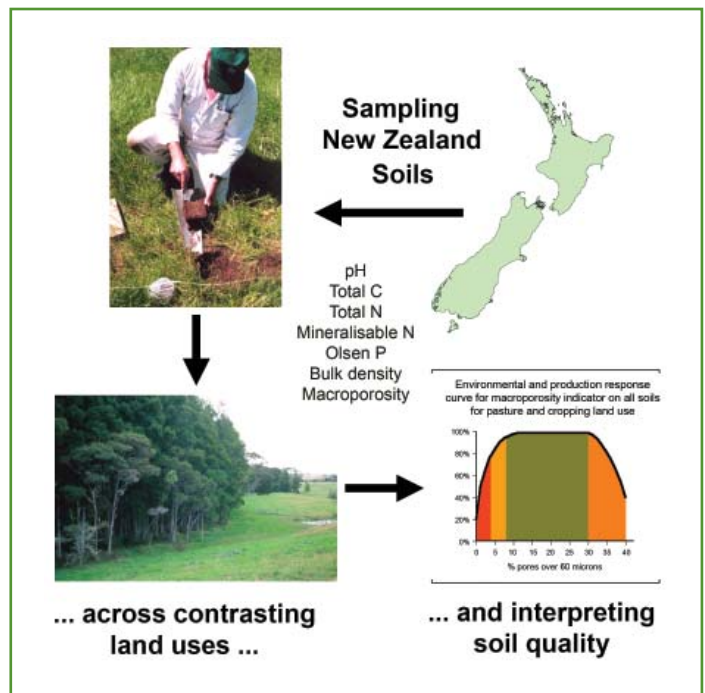
Soil scientists at Landcare Research have played a significant role over the past 10 years in developing concepts and practical approaches to measure soil quality. In the past, monitoring of soils primarily meant measuring soil fertility (generally acidity, nitrogen and phosphate content) to determine whether fertilizer or lime applications were needed to increase the production value of the land. That requirement still exists, but there is now a realization that soil physical condition (particularly the degree of soil compaction) is also an important component of overall soil health and quality.

The Resource Management Act (RMA), 1991, requires Regional Councils and Unitary Authorities "to promote the sustainable management of natural and physical resources to meet the... needs of future generations ...while safeguarding the life-supporting capacity of...soil and ecosystems". The concept of soil quality has grown to encompass not only the quality of soils for production, but also for sustainable use and environmental protection. The beneficial effects of retaining soil organic matter, which contribute to soil processes including microbial functioning, nutrient cycling, and pesticide adsorption (collectively examples of ecosystem services), are now recognized as essential for a healthy soil.

The RMA provides no guidance on what soil properties to measure, how to assess whether a soil is in good condition, or whether particular land management practices will be sustainable in the future. Indicators were therefore needed that would meet the dual roles of estimating soil quality both for production and for environmental protection. In some instances, the objectives may be in direct conflict – soil quality for aquifer protection generally requires

low nutrient levels to prevent eutrophication, whereas farmers intent on maximizing production often require high levels of available nutrient to meet plant demand. Soil quality indicators, however, can also benefit individual landowners in assessing land-use strategies that maximize the productivity of their land while minimizing soil degradation (which often leads to decreased productivity).

Landcare Research, with funding provided by MfE, Regional Councils and FRST, has established a minimum data set of soil indicators, and with colleagues in Crop and Food Research undertook a survey of soil quality in 10 regions covering all major land uses and soil groups. The initial minimum data set was refined and simplified from 20 to 7 key indicators: soil pH, total carbon, total nitrogen, mineralisable N, Olsen P, soil bulk density, and proportion of large pores (macropores). A provisional interpretive framework, specifying desirable target ranges based on the particular soil and land-use combination, was established. These key indicators and the interpretive framework are currently used by 4 large Regional Councils for their environmental reporting. In addition, a website (<http://sindi.landcareresearch.co.nz>) was set up allowing anyone with the relevant base data to be able to see how their soils compared with



the suggested targets and against samples held in the National Soils Database.

The work has been published in international journals, and because New Zealand was one of the first countries in the world to set up a soil quality monitoring scheme, Landcare Research scientists have provided advice to Ireland, Holland and the UK on setting up their own schemes.

Soil quality assessment is a major theme in the Sustainable Land Use Research Initiative (SLURI), and collaborative efforts derived from this initiative continue to develop new indicators as well as refine and provide a more robust interpretive framework for existing indicators. With the increasing pace of land-use intensification in New Zealand this work is ever more urgent.

### Bryan Stevenson

Phone 07 859 3797

[StevensonB@LandcareResearch.co.nz](mailto:StevensonB@LandcareResearch.co.nz)

### Graham Sparling

Phone 07 858 3734

[SparlingG@LandcareResearch.co.nz](mailto:SparlingG@LandcareResearch.co.nz)



## Stripping nutrients from glasshouse wastewater

Glass to the horizon – over the last 2 decades the glasshouse industry has been in a state of change. Large, professional operations, the great majority of which are hydroponically based, have replaced the small family operations of an earlier era. There are approximately 400 commercial hydroponics growers in New Zealand who produce lettuces, tomatoes, cut flowers, capsicums, strawberries, cucumber, herbs, and Asian vegetables. The international value of the hydroponics market was valued at \$6–8b in 2002, with the value of New Zealand's hydroponics market valued at \$160 million.

Water to support operations is largely drawn from bores under consents, and chemicals to support growth are mixed into this stream and fed through kilometres of channelling. The majority of operators are not currently recirculating spent solution due to cost and the risk of disease and infection, and prefer to irrigate adjoining farmland, allow absorption into soil below the glasshouse or discharge into the local drain.

The waste nutrient solution from these hydroponic operations is a major environmental concern that the industry is just beginning to address. It is very high in all nutrients, especially nitrate, and therefore presents a risk to ground and surface water quality.

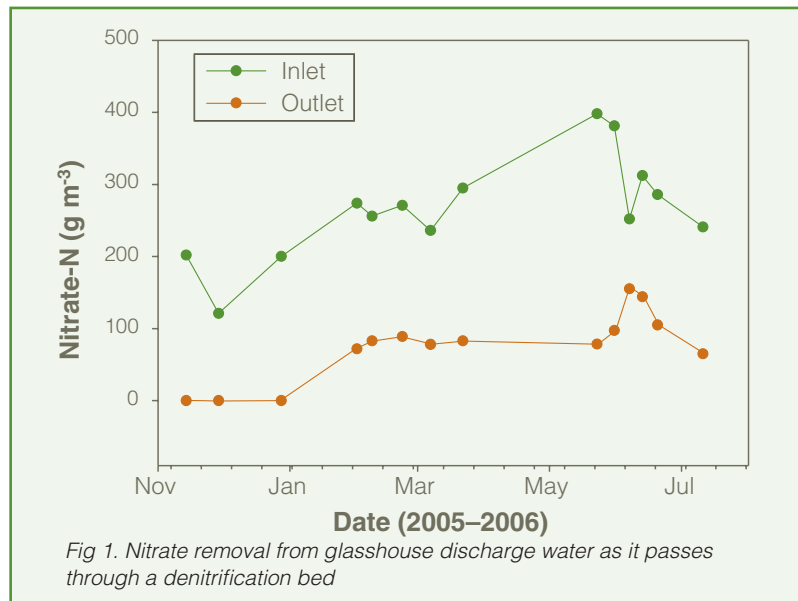


Fig 1. Nitrate removal from glasshouse discharge water as it passes through a denitrification bed

At present few glasshouse discharges are authorised by Resource Consent. Regional authorities intend to toughen their stance on control of discharge, at this stage working with the industry.

Enter the scientists. Building on FRST-funded research on denitrification walls for removing nitrate from shallow groundwater we designed a low-cost system for treating these discharges. Essentially, large, lined pits are filled with wood chip-based material that acts as a food source for denitrifying bacteria; these naturally occurring organisms convert nitrate in water to harmless nitrogen gas. In conjunction with NZ Hot House Ltd and Underglass Ltd (at Bombay, Auckland), the team constructed a large “denitrification bed” that in principle could eliminate nitrate from their hydroponic discharge. The current denitrification bed is a trench 50 m long by 4 m wide. Glasshouse discharge enters the bed at one end and migrates to the other end over a period of several days, during which time

microbiological conversion of nitrate to nitrogen gas occurs.

Results to date have been very promising (Fig. 1), with large amounts of nitrate being removed. It is planned to increase the size of the denitrification bed to remove the remaining nitrate once we have achieved a better understanding of maximum rates of denitrification. Other issues are also being addressed, such as changes in hydraulic conductivity of the beds, optimum inlet and outlet structures, and best carbon source.

These beds appear to be suitable for treating a wide range of effluent types that are high in nitrate. We have previously reported on a similar denitrification bed successfully treating domestic effluent from Kinloch, a small subdivision on the shores of Lake Taupo (Soil Horizons, Issue 11). We are continuing to develop and commercialise this promising technology through a joint venture under the banner of XN Solutions.

**Graeme Anderson**

Phone 07 859 3798

AndersonG@LandcareResearch.co.nz



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**Key contacts**

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