Soil Horizons

Issue 17 September 2008

Landcare Research
Manaaki Whenua

Contents

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

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Soil phosphorus losses to rivers – an update

Landcare Research and SLURI partners have been using an erosion model, NZEEM®, and a nutrient budget model, Overseer®, to estimate the amounts of total and dissolved phosphorus generated within a large catchment (Upper Manawatu). Then, with Horizons Regional Council river monitoring data for this catchment (77% sheep and beef, 16% dairy, and 6% forest), we assigned the likely sources of soil phosphorus losses.

Most phosphorus comes down the rivers in eroded sediment from steeper land during major floods. Using these two models we estimated that about 511 tonnes of phosphorus per year goes under the bridge at Hopelands in sediment (Fig. 1). Ninety percent of the erosion occurs under pastures and 10% under forest. These particulate-bound phosphorus losses could be decreased to 280 tonnes by tree planting on highly erodible land. During low flows sediment on the bed of the river releases about 4 tonnes of dissolved P per year. This could be halved by decreasing erosion.

Dissolved phosphorus, most of which comes from pastures, causes blooms of periphyton in summer. For sheep and beef farms this could be decreased from 14 to 10 tonnes with targeted planting of trees. For dairy farms it could be decreased from 9 to 5 tonnes with changes to management of effluent, limiting soil phosphorus to the optimum agronomic range, and excluding cows from streams. Dissolved phosphorus from point sources such as milking sheds could be decreased from 7 to 2 tonnes with changes to management of effluent.

We have therefore recommended that Horizons Regional Council adopt two approaches: SLUI to reduce soil erosion and total phosphorus (see Fig. 2, overleaf), and the nutrient management FARM strategy to reduce dissolved phosphorus during low flow (see Fig. 3, overleaf).

***SLUI:** Sustainable Land Use Initiative, being implemented by Horizons Regional Council to address erosion from farms and sediment in rivers*

***FARM:** Farmer Applied Resource Management, a strategy to target reductions in nitrogen and phosphorus loss from intensive land uses in priority catchments*

Figure 1: Water sampling in the Manawatu River near Hopelands Bridge

Monitoring of phosphorus in the river should be carried out to define a more precise base line, and to monitor improvements to water quality as SLUI and the FARM strategy programmes progress. A method has also been developed to determine the potential for water quality improvement, and indicate whether erosion control or nutrient management should be the priority management target in a catchment.

Roger Parfitt
Phone 06 356 7154
ParfittR@LandcareResearch.co.nz

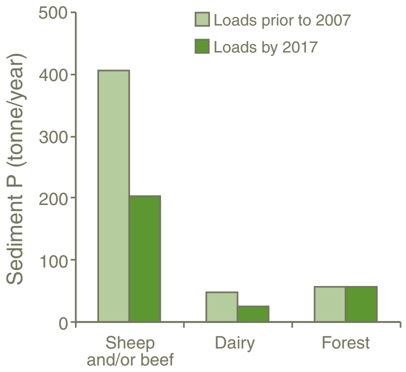


Figure 2: Estimates of sources of particulate phosphorus in Manawatu River at Hopelands in 2007, and loads achievable by 2017 if recommendations are implemented

Note: most of this phosphorus is generated during very large storms (e.g., 2004), and the tonnes per year are long-term averages from NZEEM

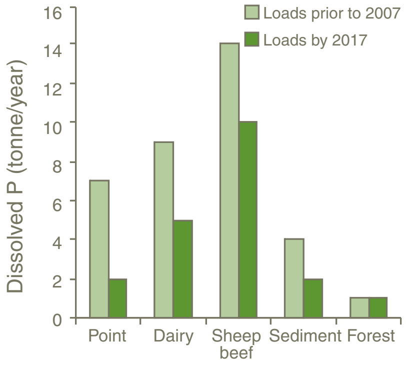


Figure 3: Estimates of sources of dissolved phosphorus in the Manawatu River at Hopelands in 2007, and loads achievable by 2017 if recommendations are implemented

Note: Some of the 511 tonnes of particulate phosphorus remains on the bed of the river and generates about 4 tonnes of dissolved phosphorus per year

Virtual soil cores

Fifteen intact soil cores collected from Waikato and Manawatu pastoral sites were recently hermetically sealed into special containers, and shipped off to the University of Abertay, Dundee, Scotland.

Landcare Research researchers, Marc Dresser, John Scott, and Malcolm McLeod are collaborating with Prof Iain Young who is based at the University's SIMBIOS centre. Their research is using a CT scanner to create a three-dimensional virtual model of the soil cores.

A CT (Computed Tomography) scanner is a real-time x-ray machine, developed for medical applications, that scans an object, wafer-thin slice by wafer-thin slice, to build up a 3D image of the surface and innards of the object.

The CT scanner takes readings at 2882 locations per 360 degrees of rotation, providing a resolution of 46.5 microns (1 micron is one thousandth of a millimetre) (Fig. 1). Each core took 3.5 hours to scan, then several hours of computing to assemble the data into a digital soil core image.

Information from the virtual soil cores will be used to determine if it is possible to model and quantify how soil structure (size and distribution of soil pores) affects soil processes such as soil nutrient dynamics, respiration, infiltration of water and nutrients, potential for contaminating ground-water, and the myriad of other soil processes that we take for granted. We expect soils to feed us and soak up rain. Well, a healthy soil does but a badly compacted soil does not.

This research aims to develop a more complete mathematical description of pore networks in soils, providing a more accurate model of the relationships between biological, chemical, and physical characteristics of soils, and what happens under various land management regimes. One of the many applications for this research is to assess risk factors for soil compaction. The research hopes to identify how soil characteristics and processes, including soil structure, texture, macropores, infiltration rate, and stone content, affect the susceptibility of a soil to compaction.

Marc Dressser
Phone 07 859 3712
DresserM@LandcareResearch.co.nz

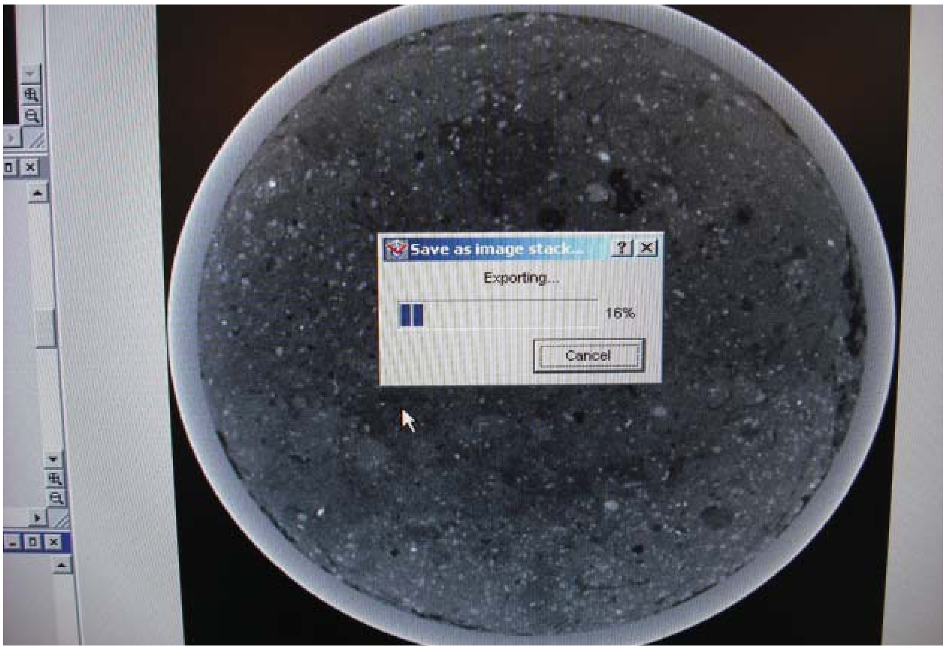


Figure 1: Soil slice imaging

Unravelling the secrets of soil respiration

The living soil respires – it inhales oxygen and exhales carbon dioxide. Measurements of soil respiration are straightforward and frequently used because they provide really useful information about the biological activity of that soil. However, scientists have always wanted to know more – what proportion of that total soil respiration is from the live roots and their associated microbes (autotrophic) and what proportion is from decaying organic matter (heterotrophic)? This question has been much harder to answer, but is essential to our understanding of how soil respiration will respond to changes in root-zone temperature and water content. Now a Marsden Funded team – Landcare Research scientists David Whitehead, John Hunt, and Margaret Barbour and colleagues Peter Millard and Andrew Midwood from Macaulay Institute, Aberdeen – have developed a new method that for the first time partitions soil respiration into autotrophic and heterotrophic respiration using the natural abundance of carbon isotopes (^{13}C and ^{12}C). This knowledge is essential for inclusion in models to determine whether soil in a particular ecosystem will become a net source or sink for carbon with changes in climate or land use.

Their study was possible because of increased resolution in the detection of natural abundance of these carbon isotopes in respired air samples resulting from careful collection of the samples and measurement using a state-of-the-art tunable diode laser absorption spectrometer.

Globally, soils contain more than two thirds of the total carbon in terrestrial ecosystems, and respiration from the soil surface accounts for up to 80% of annual total ecosystem respiration in temperate forest ecosystems.

The team measured soil respiration at 30 locations in an undisturbed native kānuka (*Kunzea ericoides*) forest soil at Lincoln (Fig. 1). They accounted for 29% of the spatial variability in soil respiration from the measurements of root length density and distance to the second nearest tree. They used natural abundance ^{13}C discrimination to partition soil respiration into autotrophic and heterotrophic respiration by measuring the ^{13}C signature of the soil surface respired carbon dioxide and respiration from litter, root and soil. At 23 locations the ^{13}C signature from soil respiration was between the values for roots or litter and soil, giving mean (± standard deviation) rates of autotrophic and heterotrophic respiration of 1.5 ± 0.69 and 1.4 ± 1.01 μmol m^{-2} s^{-1}, respectively. The team concludes that at this site total soil surface respiration comprised equal proportions from roots and soil organic matter. Partitioning would not have been possible using ^{13}C signature of solid roots, litter, and soil instead of their respired carbon dioxide.

This success opens the possibility of determining rates of soil organic matter turnover and soil respiration drivers in a wide range of undisturbed ecosystems. This will lead to new insights into the processes regulating respiration for individual soil components, as well as into predictions of changes in ecosystem carbon balance with changing climate.

David Whitehead
Phone 03 321 9862
WhiteheadD@LandcareResearch.co.nz

Figure 1: Chamber system used to collect respired air from the soil surface for isotopic analysis

Soil recovery on landslide scars in erodible, Wairarapa siltstone hill country

Our recent research supports previous findings that, when erosion occurs, total soil carbon and nitrogen levels might not recover to uneroded levels within a human lifetime.

The first New Zealand trial, by Lambert and others in the 1980s, examined some of the effects of this erosion on pasture dynamics and was conducted on seasonally dry Wairarapa hill country. The findings from this study were that pasture dry matter yields on young slip scars were about 20% of the yields produced on uneroded ground. However, while such scars revegetated rapidly over the first 20 years and could attain 70–80% of original productivity, further recovery was slow, and complete recovery might never occur. Much of the loss in pasture productivity was attributed to the slow recovery of topsoil physical and chemical characteristics on the landslide scars.

To determine whether soil biochemical properties on the landslide scars had further improved over the last 25 years, the original study site was relocated by Landcare Research scientists Brenda Rosser and Craig Ross (Soil Horizons Issue 16, p. 5). Landslide scars previously dated and sampled by Lambert and others in 1984, were relocated. Eight landslides known to have been initiated during storms in 1981, 1977, 1961, and before 1943, were chosen for analysis (two of each age). Soil cores were collected for soil analyses from each of the eight landslide scars and also from adjacent uneroded sites. This site had also previously been used by Graham Sparling, Louis Schipper and colleagues to investigate how quickly the soil biological properties recover following a landslip (Soil Horizons Issue 6, p. 9).

Total soil carbon (C) and nitrogen (N) showed a marked increase with slip age (Fig. 1), and conversely, pH showed a decline with slip age. Total soil carbon increased from 0.21% in 1-year-old erosion scars to 4% in 66-year-old erosion scars. The average total carbon for uneroded sites was 5.4%. There was no evidence in these highly variable soils to suggest total carbon was recovering towards a level lower than that found on uneroded sites. Total nitrogen increased from 0.03% in 1-year-old erosion scars to an average of 0.34% in 66-year-old erosion scars. The ratio of C:N correspondingly increased from 6 to 12 over the 66-year period. Soil pH decreased with scar age from 8.2 on 1-year-old scars to around 5.5 on 66-year-old scars, about the same pH of uneroded sites.

Topsoil and subsoil development with age was evident in the soil profiles. Figure 2 illustrates soil profile descriptions of scars described in 1984 by KW Vincent, and profiles described in this study. The profiles illustrate the development of an Ah horizon over time since slipping. On 2- and 7-year-old scars, there was virtually no soil development, and on 23- and 26-year-old scars, there was 5–6 cm of topsoil development.

Whiles some soil properties show signs of recovery (C/N, pH, Mg, Na, cation exchange and base saturation), our results show that soil carbon and nitrogen may not recover to uneroded soil levels within human lifetimes. There was no evidence in our study to suggest that in the long term total C was recovering towards a lower level than that found on uneroded sites.

Brenda Rosser
Phone 06 353 4979
RosserB@landcareresearch.co.nz

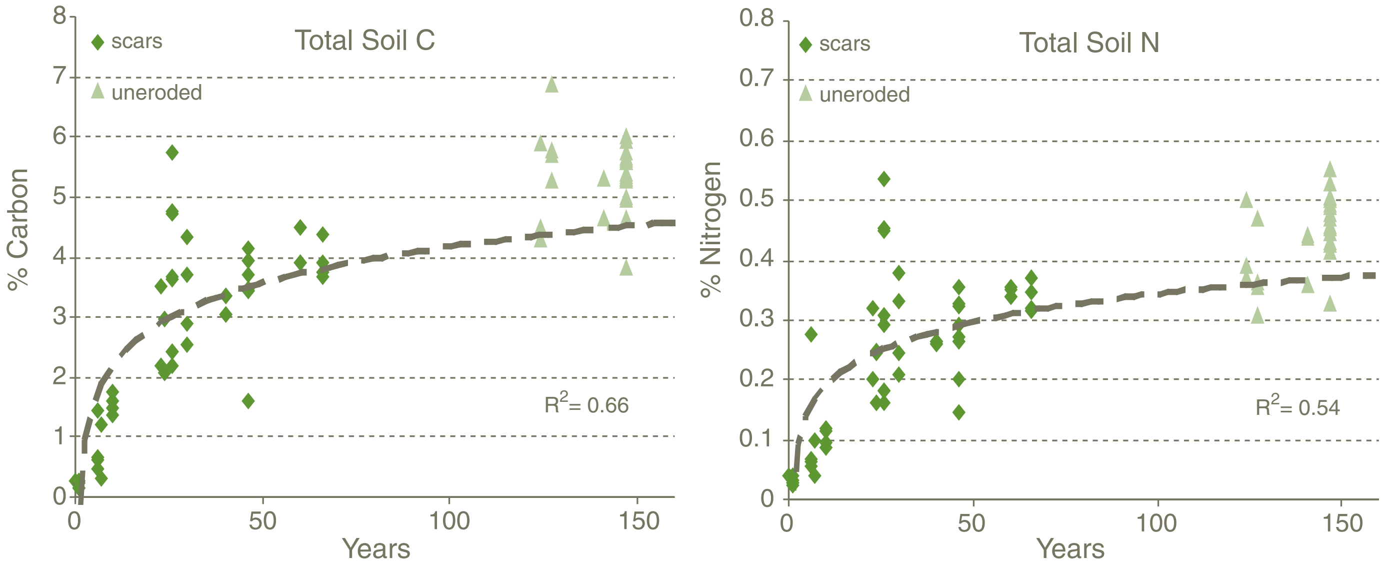
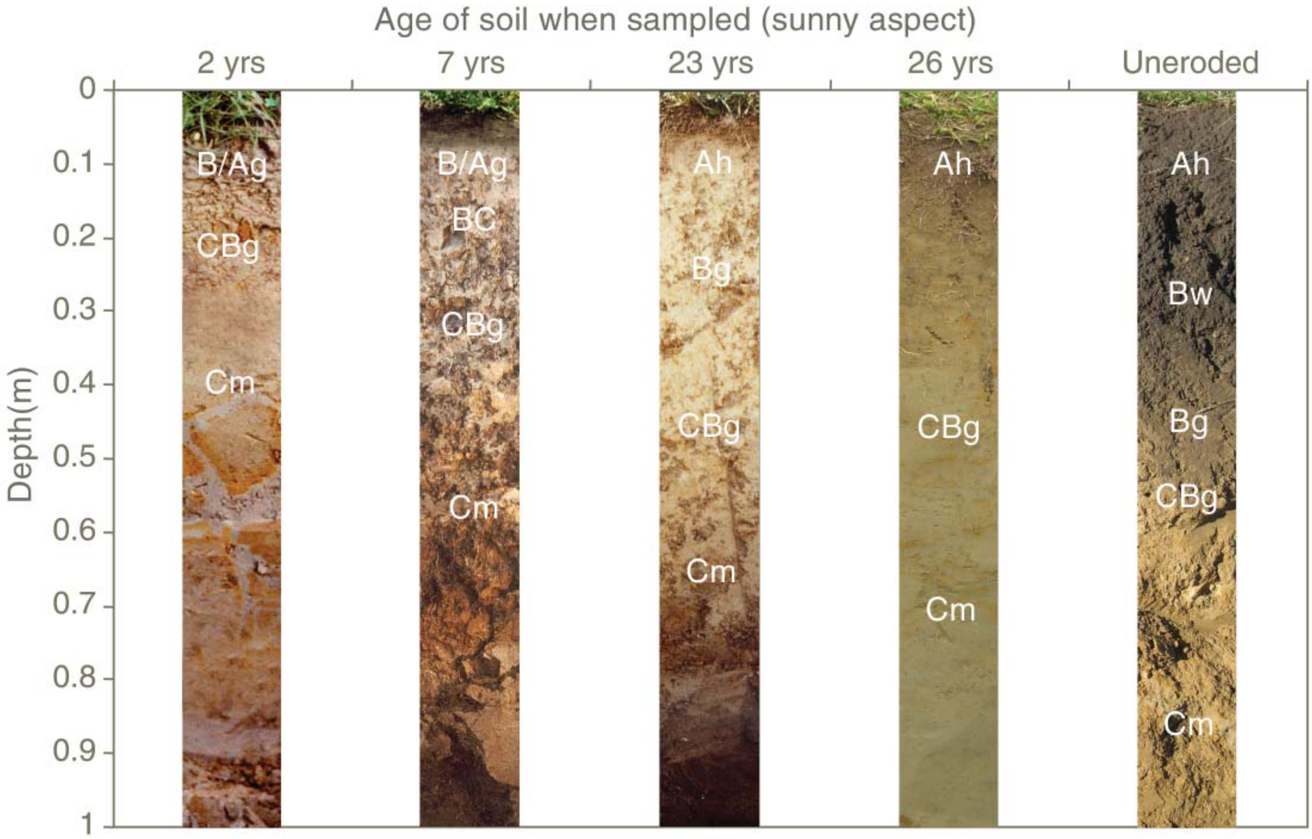


Figure 1: Recovery curves of C and N from the 66-year chronosequence of landslide scars (diamonds) at Te Whanga Station. Data from all years of sampling were used to derive the curves. The uneroded sites (triangles) were not used for curve fitting, and are shown for reference at the nominal ages assigned assuming deforestation and conversion to pasture in 1860



A = topsoil
B = subsoil
C = parent material

B/A = mixture of A and B horizon
CB = intermediate horizon

h = accumulated organic matter
g = imperfectly drained
m = cemented

Figure 2: Soil profile development in erosion scars compared with an uneroded site

Catchment Connections e-newsletter launched

Linking our soils knowledge to the wider landscape is fundamental to Integrated Catchment Management (ICM). Catchment Connections, re-launched as an e-newsletter in January 2008, is a Landcare Research publication addressing these linkages and summarizing results from the FRST-funded ICM programme.

Topics discussed so far include:

- ICM as a process
- An influence matrix for assessing whole-catchment sustainability values
- Māori participation in ICM
- Social learning
- River plume ecosystems – some catchments extend offshore
- How do we establish what level of river gravel extraction is sustainable?
- How important are big storms for sediment generation?
- Modelling land-use effects on catchment water and nutrient fluxes

In addition, a regular item, 'ICM Out and About', highlights the application of ICM in various regions and projects around NZ.

You can access the last 3 editions of Catchment Connections or subscribe via this link to the ICM website: http://icm.landcareresearch.co.nz/about/newsletter/index.asp

If you missed the Country Calendar programme on Motueka ICM on 21 June 2008, it and a discussion with the producer can be viewed via http://tvnzondemand.co.nz/content/countrycalendar_2008_ep14/ondemand_video_skin?tab=CATCH UP

Or you can read about that 'Precious Water' episode at http://tvnz.co.nz/view/page/410965/1844944

How vulnerable are Antarctica soils to human impact?

A single footprint can blow out to a hole about half a metre wide in some Antartictic soils. This is one of the findings of Malcolm McLeod's research project, which has mapped soils and assessed their vulnerability to human impacts in the Wright Valley, McMurdo Dry Valleys Region, Antarctica.

At 485 square kilometres, Wright Valley is the third largest of the McMurdo Dry Valleys. The Valley extends 52 km from the Wright Lower Glacier to the Wright Upper Glacier, an outlet glacier from the East Antarctic ice sheet. Alpine glaciers also flow into the valley down the South wall. Soils of the Valley have developed over the past > 3.9 million years in response to fluctuations of the glaciers. The soils are distinguished on the basis of morphological properties such as the amount and distribution of soluble salts, the degree of chemical and physical weathering, and depth to ice or ice-cemented permafrost.

Wright Valley soils are cold desert soils. Although the mean annual surface soil temperature is about –20°C, the temperature is above 0°C for 10–11 weeks in summer. While soils of eastern Wright Valley may be relatively moist in summer, the soils of the central and upper Wright Valley are dry (the mean annual precipitation is less than 50 mm water equivalent). At Bull Pass on the valley floor in Central Wright Valley we measured only one week in three years when soils were moist. **Consequently, these soils are biologically among the simplest ecosystems on earth and in the virtual absence of plants they are dominated by microbes (bacteria and fungi).**

Although soils from many sites in the McMurdo Dry Valleys region are well described, with a reasonable understanding of soil-landscape responses, very little information on their spatial distribution across the region has been published.

Soil maps and underlying data can be used to:

- provide a spatial framework for environmental management including impact assessment and reporting
- define ecological habitats of soil organisms
- plan campsites and sites for fieldwork that minimize impacts
- define sites that require further protection

For example, while mapping soils of the Wright Valley, Malcolm identified a rare Hart Ash deposit that is now recognised as a special feature in the Management Plan for Antarctic Specially Managed Area

Figure 1: Lake Vanda in Wright Valley is permanently frozen at the surface but about 25°C at depth where waters are saline.
Inset: The Onyx River in Wright Valley flows for about 4 months a year inland from the Wright Lower Glacier to Lake Vanda

No 2, McMurdo Dry Valleys, Southern Victoria Land.

Before heading South, Malcolm compiled preliminary soil maps based on limited soil descriptions by Drs Campbell and Claridge (NZ) (deposited in http://gis.massey.landcareresearch.co.nz/rsr/soils), unpublished data of Professor Jim Bockheim and Dr Mike Prentice from the US, and interpretation of stereo-pair aerial photographs of the Wright Valley. Satellite and LIDAR (light detection and ranging) imagery were used as base maps. The preliminary soil maps were validated by fieldwork and soil analyses to test and refine predictions and to investigate soil variability.

In the field, soil pits were excavated to a depth of one metre where possible (i.e. no ice-cement) and soil colour, coherence, and the presence of visible salts recorded along with depth to ice-cemented permafrost. The active layer of the soils (that which thaws) varied between 20 and 50 cm; material below that depth that is not cemented by ice contains dry-frozen permafrost that may be unique to Antarctica. Soil samples returned to New Zealand are analysed in the laboratory for pH, salinity, water soluble cations (Ca, Mg, K, and Na), and anions (Cl, nitrate-N).

Soils in the Dry Valleys recover only very slowly from disturbance because of the lack of precipitation and vegetation that rehabilitates soils in more temperate climates. As environmental protection underlies much of our work in the Dry Valleys, a rapid method of assessing soil disturbance from foot traffic was developed and tested in the field. Soils in the Dry Valleys have developed a protective desert pavement of coarse fragments through the removal of fine material by strong winds. The assessment is made by walking 10 paces and rating each foot print for the amount of soil disturbance based on either complete, partial or no breakthrough into underlying finer material. We also have a preliminary scale to describe how different soil materials recover from disturbance. Recovery is based on the nature of the soil, for example, whether it is fine-grained and can be readily redistributed by wind or whether it is coarser, possibly desert-varnished stones with salt encrustations that would not be readily repositioned. When disturbance and recovery scales are multiplied, vulnerability to foot traffic is readily established.

These new soil maps and associated data will be deposited in our online Ross Sea region Geographic Information System (RSR GIS) by 2009.

Malcolm McLeod
Phone 07 859 3704
McLeodm@LandcareResearch.co.nz

Figure 2: Summer camping in the North Fork Wright Valley.
Inset: The Labyrinth in the upper Wright Valley was cut by catastrophic release of subglacial lake water from the polar plateau

The pros and cons of biosolid application to agricultural land

Land application of urban waste material biosolids (sewage sludge) could reduce greenhouse gas emissions and enhance soil carbon sequestration as well as providing a source of slow-release organic nitrogen and phosphorus to growing plants. But further research is required in New Zealand to investigate these benefits, together with the potential health and environmental effects of contaminants in biosolids.

Biosolids production in New Zealand was estimated at 240,000 tonnes per year (New Zealand Ministry for the Environment 2007), or about 60 kg per capita. This is expected to increase with urban expansion and upgrading of sewage-treatment technology. In Palmerston North, for example, a 50-metre-diameter clarifier has just been installed as a key part of a $13 million upgrade to remove phosphorus from wastewater (Fig. 1) before it is discharged to waterways. The majority of biosolids in New Zealand is disposed in landfills, run by local governments and paid for by property owners via rates. Thus, the cost of landfills is often not transparent, and the environmental effects are seldom taken into account.

Application of biosolids to land could recycle and utilize nitrogen and phosphorus as plant nutrients and reduce environmental remediation cost. Sixty kilograms of biosolids per capita is a noticeable amount of organic matter and nutrients. Assuming the biosolids contain 4% nitrogen, 2% phosphorus and 30% carbon, this translates to 2.4 kg of nitrogen, 1.2 kg of phosphorus, and 18 kg of carbon per capita per year. While the nutrient value at the current prices of nitrogen and phosphorus fertilisers is less than $10, the agronomic value of biosolids in providing organic matter to improve soil structure and water retention capacity is significant. Graham Sparling (Soil Horizons Issue 12, p. 9) estimated that the environmental value of organic matter varied between $23,000 and $91,000 per hectare. Further, a large part of the nitrogen and phosphorus in biosolids is in organic form, available to plants over a longer time period than soluble chemical fertilizers. Thus, they would be less likely to enter rivers and lakes through leaching and runoff. Remediation of eutrophic water bodies is very expensive. Environment Bay of Plenty, for example, trialed PhoslockTM (a lanthanum-exchanged montmorillonite) for inactivating P in lake sediment at a cost of about $1800/kg P.

The US Environmental Protection Agency estimated that emissions of methane from landfills accounted for 13% of total anthropogenic emissions of the gas (2002).

Biosolids use on agricultural land could produce lower amounts of methane and nitrous oxide than landfilling the same amount of biosolids because the carbon in biosolids can be stabilised by clay minerals in soil, and nitrogen can be taken up by plants. Research is required to quantify this benefit.

The potential detrimental environmental and health effects of biological and chemical contaminants (e.g., heavy metals, organic compounds, and pathogens) remain a major concern. This major concern should be addressed through guidelines and regulations based on long-term, robust scientific research. Such research must be relevant to local climate, land use, soil properties, and land management practices—it also needs further funding.

Guodong Yuan
Phone 06 353 4900
YuanG@LandcareResearch.co.nz

Figure 1: A 50-metre-diameter clarifier (for phosphorus removal) at Totara Road is a key part of Palmerston North City Council's $13 million upgrade of its wastewater treatment plant

Biochar

There is growing interest in the potential use of biochar to increase soil carbon, reduce emissions of the greenhouse gases nitrous oxide and methane, and enhance agricultural productivity. When used as a soil amendment, biochar can supplement the long-lived stable fraction of soil organic matter, as well as reduce nitrous oxide emissions and improve soil methane oxidation potential. Application of biochar, with some added nutrients, can improve the structure, water retention capacity, cation exchange capacity, and fertility of degraded soils.

Biochar is a carbon-rich solid by-product of biomass pyrolysis. Organic materials heated to moderate temperatures between 400 and 550ºC under complete or partial exclusion of oxygen release heat and gases. These are captured to produce energy; the residue left behind is termed 'biochar'.

To underpin the development of biochar as a climate change mitigation tool for economic growth and to achieve other environmental benefits in New Zealand, the New Zealand Ministry for Agriculture and Forestry (MAF) is funding two Professorships – in Soil Science and Biochar and in Pyrolysis Engineering and Biochar – at Massey University.

This initiative will investigate the feasibility of biochar production from biomass, incorporation of biochar into soils, and its potential benefits as a soil amendment – including increased content of stable forms of soil carbon. As carbon and other greenhouse gas emissions trading systems continue to develop and emerge in New Zealand, agricultural capacity to participate and contribute to these systems may become more attractive to potential buyers and sellers of carbon credits.

Landcare Research through Professor Surinder Saggar, and Massey University through Professor Mike Hedley have initiated a joint research programme that involves the use of biochar produced from forest and crop residues, and from willow coppicing, to demonstrate the potential of biochar for soil carbon storage and greenhouse gas emission reduction. Specific objectives of this programme include:

- to characterise biochar materials and compare their performance under controlled conditions
- to determine the key soil factors influencing biochar performance
- to examine the cycling of carbon and nitrogen in this system
- to quantify the gaseous emissions of nitrous oxide and methane, and nitrate lost through leaching
- to develop tools to predict the carbon and greenhouse gas footprints to achieve sustainable management.

Dr Xinqing Lee, a Visiting Research Fellow from the Chinese Academy of Sciences has recently joined this research group, and he will initiate research to enhance our understanding of the processes regulating greenhouse gas emissions in grasslands, gaseous losses of nitrogen, and the effects of nitrogen transformation inhibitors and biochar in mitigating these emissions.

Surinder Saggar
Phone 06 353 4934
SaggarS@LandcareResearch.co.nz

Nitrogen inhibitor effectiveness

New Zealand's legume-based grazed pastures annually receive about 3 million tonnes of nitrogen from biological nitrogen fixation by clovers, fertilizer, recycled farm effluent application, and uneven deposition of animal excreta.

Nitrogen added to the soil is far in excess of immediate plant requirements and hence is susceptible to leaching and gaseous losses causing environmental degradation.

The use of nitrogen transformation inhibitors (Nitrification inhibitors and Urease inhibitors) is one approach fast gaining momentum as a mitigation strategy to reduce gaseous emissions of ammonia and nitrous oxide as well as the leaching of nitrate. The explanation for these effects is that the urease inhibitors retard the hydrolysis (decomposition by action with water) of soil-applied urea or urine and reduce the accumulation and emission of ammonia, while nitrification inhibitors reduce nitrous oxide flux and nitrate leaching from ammonium and urea-based fertilisers, organic manures, and urine spots.

A quantitative understanding of the interactions between (a) nitrous oxide and ammonia emissions, and (b) nitrate and ammonium leaching is therefore central to understanding how pasture systems behave and respond to these nitrogen transformation inhibitors and to determining the effectiveness of land-management strategies to reduce overall nitrogen losses.

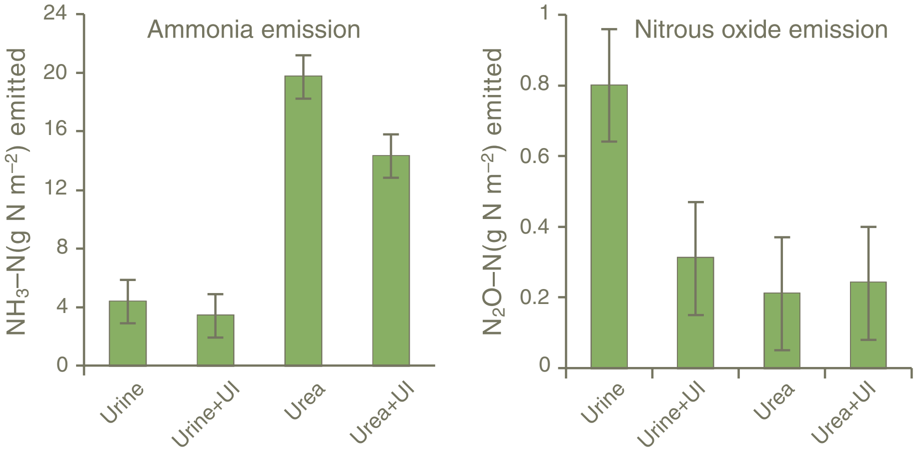


Figure 1: Comparison of ammonia and nitrous oxide emissions from untreated and urease inhibitor-treated (UI) soils

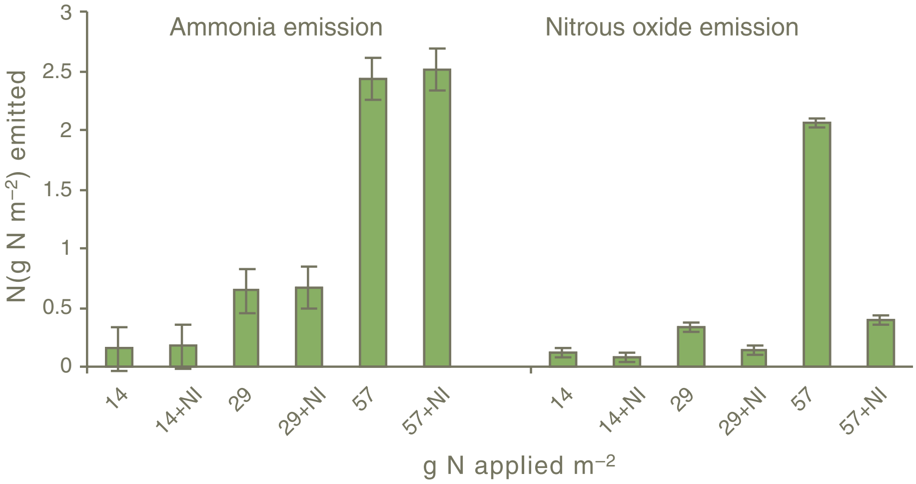


Figure 2: Comparison of ammonia and nitrous oxide emissions from untreated and nitrification inhibitor-treated (NI) soils

Research by Landcare Research scientists, along with Massey University, shows that a urease inhibitor, Agrotain, alone, is effective in reducing ammonia volatilisation but has no consistent effect on nitrous oxide emissions from both urine and urea (Fig. 1). Application of the nitrification inhibitor DCD, under glasshouse conditions, is quite effective in reducing nitrogen losses via nitrous oxide emissions (Fig. 2) and nitrate leaching from urine. There was no adverse impact of DCD application on soil respiratory activity or microbial biomass.

However, this research also found that due to the ability of DCD to retain nitrogen in the ammonium form in the soil, it enhanced ammonia emissions from the urine and caused a 2–3.5-fold increase in potential ammonium leaching (Fig. 2). This aspect of DCD needs further research under field conditions to verify its efficiency in reducing total N losses.

Laboratory studies with three soils on the decomposition and effectiveness of the nitrification inhibitor DCD showed that its half-life and effectiveness to reduce nitrous oxide emissions depended on soil properties such as organic carbon content and mineralogy. The rate of degradation of DCD was highest (6 days at 25°C) in an allophanic Egmont soil with high organic matter content and slowest (15 days at 25°C) in a silt loam non-allophanic Tokomaru soil. In light of these results, our current research focuses on identifying other key properties of soils that may affect the efficiency of DCD.

Jagrati Singh
Phone 06353 4931
singhj@landcareresearch.co.nz

Extinction of New Zealand soils

Exploratory research by Landcare Research scientists, led by Daniel Rutledge, shows that due to urbanisation, New Zealand has lost 2.3% (Class 1) and 1.3% (Class 2) of its best soils (Table 1) over the past 25 years. This research addresses the question posed by Trevor Webb (Soil Horizons Issue 15, March 2007), who discussed the need for preservation of our best soils, and for determining how much prime land is being lost annually in New Zealand due to urban sprawl.

Urbanisation rates are estimated by comparing soils information from the national Land Resource Inventory (LRI) compiled from field surveys mainly conducted between 1975 and 1979 with the Land Cover Database Version 2 based on satellite imagery from 2001/2002. Results show that top-class soils were converted at much faster rates than lower class soils, which is not surprising given that humans tend to settle near areas of higher productivity. Furthermore, the research only considered urbanisation trends observable via remotely sensed methods like LCDB 2. It did not consider less obvious trends such as rural residential or coastal development. Including such lower density development could increase estimated conversion rates.

This raises the question of the effects of human impact on the long-term sustainability of some of our soils, particularly those top-class soils that best support agricultural production. The effects of urbanisation are particularly important because they decrease both the total area available for production and cause major and often irreversible alteration of soil properties.

If these trends were to continue, New Zealand's best Class 1 and 2 soils (see Table 2) would become "extinct" in about 1,100 and 1,529 years respectively. While this seems like a long time to us, it actually represents only a short blink compared with the geological time scales over which these soils developed.

Daniel Rutledge
Phone 07 859 3727
RutledgeD@LandcareResearch.co.nz

Table 1: Estimated extinction rates of New Zealand soils due to urbanisation by LRI land use class

Land Use Class	Original Total Area (ha)[1]	Proportion of Original NZ Stock (%)	Loss of Original Stock (%)	Urbanisation Rate[2] (%/yr)	Supply Remaining (Years)
1	187,103	1	2.3%	0.09	1,100
2	1,204,848	5	1.6%	0.07	1,529
3	2,437,285	9	1.0%	0.04	2,599
4	2,759,695	11	0.7%	0.03	3,718
5	209,774	1	0.4%	0.01	6,857
6	7,451,306	29	0.2%	0.01	11,646
7	5,723,586	22	0.1%	<0.01	23,391
8	5,780,544	22	0.0%	<0.01	103,473

[1] excludes urban areas not classified by the LRI
[2] over the last 25 years

Table 2: LRI land use class description

Increasing limitations to use ↓

Land Use Class	Cropping Suitability	General Pastoral & Production Forestry Suitability*	General Suitability*
1	High	High	Multiple Land Use
2			
3	Medium		
4	Low		
5	Unsuitable		Pastoral or Forestry land
6		Medium	
7		Low	
8		Unsuitable	Catchment protection land

Decreasing versatility ↓

* land use capability classes 4–7 that have wetness as the major limitation and those units in very low rainfall areas or those occurring on shallow soils are normally not suited to production forestry

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Q. Christie in Molloy, 1998

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