Soil Horizons

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Landcare Research
Manaaki Whenua

Contents

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

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3D visualisation of erosion and sedimentation scenarios in the Manawatu catchment

Horizons Regional Council plans to reduce unacceptably high sediment loading in our rivers by encouraging conservation measures on highly erodible land. In hill country, where tree roots are important for stabilising slopes, the clearing of indigenous forest for productive pastoral farming since European settlement has led to increased soil erosion and consequent increased sedimentation in waterways. Anne-Gaelle Ausseil and John Dymond have developed a catchment-scale model to predict sediment concentrations at the catchment level, based on long-term average estimates of erosion rates and information relating to catchment hydrological processes (mean discharge).

The model is being used to evaluate the effect of land-use change and farm plan scenarios on the spatial distribution of sediment concentration in the Manawatu River of New Zealand.

Three land cover scenarios are considered:

- historic scenario where all the Manawatu catchment was covered in indigenous forest
- present land-use scenario where most of the hill country has been converted from indigenous forest to pastoral agriculture (this came from classification of Landsat TM imagery dated 1999–2002)
- farm-plan scenario where Horizons Regional Council are encouraging the implementation of farm plans, designed to reduce erosion and increase productivity. Previous work has identified priority farm plans in the catchment by ranking them in order of areas of highly erodible land. This scenario simulates the implementation of the first 500 farm plans with each farm plan reducing sediment load by 70%.

The results show that under the historic scenario, sediment concentration in the river is very low compared with the present land-use scenario. The farm plan scenario shows the potential improvements, with the sediment concentration at Palmerston North reduced by half from the current scenario.

The model is being used to predict changes in sediment concentration anywhere in

Figure 1: 3D Google Earth view of sediment concentrations in the Manawatu catchment.

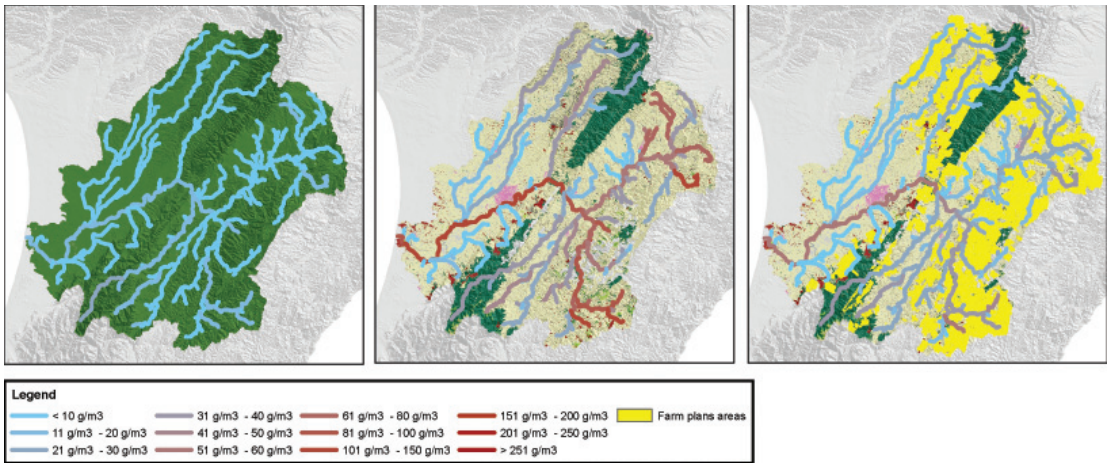

Figure 2: Comparison of sediment concentration (g/m³) at mean discharge using three scenarios: 1) historic scenario 2) present land-use scenario 3) farm-plan scenario (500 farm plans shown in yellow).

the catchment in response to land-use change. This model can be reconfigured quickly to explore new land-use scenarios proposed by management groups. The graphical output (see Fig. 1 & 2) acts as an aid to understanding and communication of the complex spatial relationship between land use and water quality. In particular, it provides a tool to assess how effective different land use or farm planning activities may be in delivering water quality improvements.

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The Land Use Capability Survey Handbook – revised and updated

New Zealand's goal of demonstrating robust environmental management and sustainable performance of our highly productive landscapes is driving a renaissance in land-use capability assessment, particularly at farm scale, in several New Zealand regions.

The Land Use Capability (LUC) Survey Handbook, which assesses such capability, was originally published 40 years ago. The second edition was published in 1971 and the third edition has just been published, with the help of Envirolink funding from FRST.

The new 2009 edition provides upgraded, nationally applicable LUC classifications and standards for on-farm, catchment and regional level planning, and is a step-by-step procedural manual for undertaking LUC surveys.

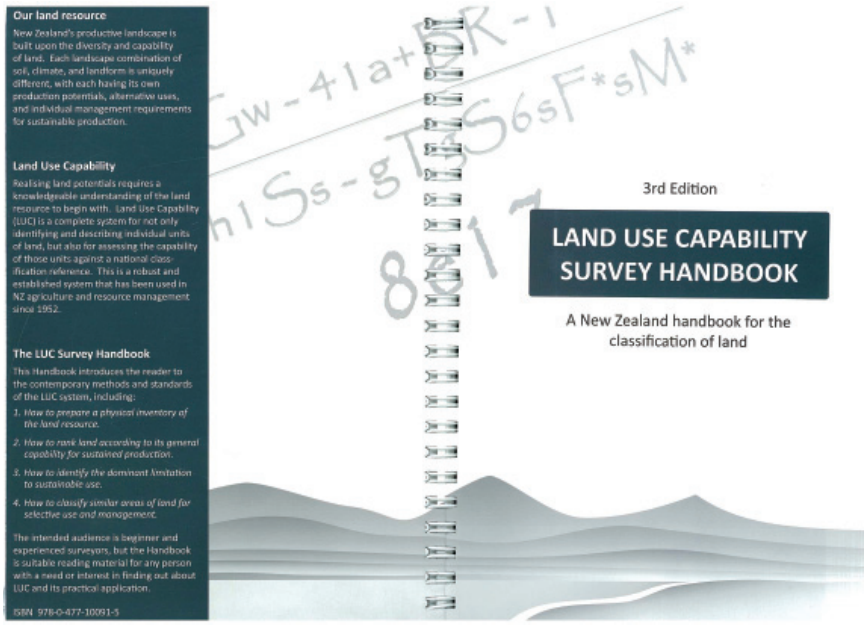
The rewriting of the LUC survey handbook provided an opportunity to:

- include more objective definitions and assessment criteria
- improve the LUC class and subclass definitions
- provide guidelines for the assessment of erosion severity
- add new reference and underpinning scientific information
- add links to key databases.

Clear and precise definition of the criteria used in LUC assessment is important to ensure accurate and repeatable application. It also ensures the process is transparent, sound, and able to withstand close scrutiny in planning hearings and at the Environment Court.

The 3rd edition retains a similar layout and content to past editions. It has a modern, easy-to-follow format with an abundance of embedded tables, figures and colour illustrations, and includes inventory factor

Land Use Capability Handbook – a New Zealand handbook for the classification of land, 3rd edition, 2009.



descriptions, extensive appendices, a comprehensive glossary, and a modern reference list. It strongly promotes the use of a minimum data set in the form of a land resource inventory (of rock type, soil, slope, severity and type of present erosion, vegetation cover), and an objective land-use capability assessment of LUC class, LUC subclass, and LUC unit (Fig. 1).

The generalised LUC class guideline criteria are now also provided in a single table as a quick reference for assigning or checking 'class' classifications (Table 1). The key criteria summarised include physical limitations, arable suitability, slope, soil stoniness, depth and workability, soil texture and drainage, erosion severity and erosion types, salinity, elevation, and annual rainfall ranges. The full 'class' descriptions are detailed in the text.

The new handbook is the result of a significant collaborative effort:

- *Ian Lynn* (compilation editor), *Garth Harmsworth*, *Peter Newsome* (both LCR Palmerston North) and *Mike Page* (ex LCR, now GNS) rewrote the text
- *Christine Bezar* (Lincoln) undertook the final edits
- AgResearch staff managed the project and publication as well as contributing to the science
- Fifteen regional council land management staff were also part of the project.

The new handbook will give planners, policy developers, land owners, and regulatory teams confidence that their land use and management decisions are evidence-based, informed by good science, and able to withstand close scrutiny through the legal system.

The waterproof book is available through Landcare Research or AgResearch. Contact Manaaki Whenua Press, email: mwpress@landcareresearch.co.nz or phone 03 321 9749 or shop on-line at www.mwpress.co.nz

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Figure 1: Example distribution of land resource inventory and land use capability units on the landscape – lower Awatere valley, Marlborough

Table 1: Summary of generalised LUC class guideline criteria

LUC Class	Physical limitations	Arable suitability	Slope	Soil stoniness, depth & workability	Soil texture & drainage	Erosion severity & erosion types	Salinity	Elevation & annual rainfall ranges* South Is.	North Is.
Arable land									
1	Minimal limitations for arable use.	Suitable for a wide range of crops.	0– <7°	Deep, >90 cm, easily worked & resilient.	Fine textured, silt loam, fine sandy loams, well drained.	Minimal erosion risk (negligible W, Sh under cultivation)	Nil	<200 m 650–1500 mm	<350 m 650–1500 mm
2	Slight limitations for arable use.	Suitable for many crops.	0– ≤7°	Moderately deep 45–90 cm, slightly difficult to work.	Wide range, loamy sand & clay textures are less favourable, well to imperfectly drained.	Slight erosion risk under cultivation, W, Sh, R.	Very weak to weak	<400 m <1500 mm	<500 m 800–2000 mm
3	Moderate limitations for arable use. Soil conservation measures required.	Restricted range of crops, intensity of cultivation is limited.	0– ≤15°	Shallow 20–45 cm &/or stony (5–35% in upper 20 cm), often difficult to work.	Wide range, clay loam, & sandy loam textures are less favourable, well to imperfectly drained.	Slight to moderate erosion risk under cultivation, W, Sh, R.	Weak	<650 m <2400 mm	<750 m 800–2500 mm
4	Severe limitations for arable use. Intensive soil conservation measures required.	Occasional cropping but reduced range of crops and intensity of cultivation.	0– ≤20°	Very shallow <20 cm) &/or stony or very stony (35–70% in upper 20 cm), often difficult to work.	Clay, loamy sand, sand, & very stony textures are less favourable; well to poorly drained.	Severe erosion risk under cultivation, W, Sh, R, G.	Moderate	<800 m <3000 mm	<1000 m 800–3000 mm
Non-arable land (assessed under perennial vegetative cover)									
5	Negligible to slight under perennial vegetation cover.	Non-arable, high producing.	0– ≤25°	Variable, deep to very shallow (<20 cm) &/or stony or very stony.	Variable texture, well to poorly drained.	Negligible to slight, Sh, Ss, R, T	Moderate	950 m[a] & 1050 m[b] 600–4000 mm	<1000 m 3000–4000 mm
6	Moderate, soil conservation measured desirable.	Non-arable, suited to grazing, tree crops, & forestry.	0– ≤35°	Variable, deep to very shallow (<20 cm) &/or stony or very stony.	Variable texture, well to poorly drained.	Moderate, Sh, Ss, Sc, T etc	Moderate to strong	<950 m[a] & 1050 m[b] <600–4000mm	<1000 m 3000–4000 mm
7	Sever, requires active soil conservation measures.	Non arable, with soil conservation measures suited to grazing and forestry in some cases.	0– >35°	Variable, deep to very shallow (<20 cm) &/or stony or very stony.	Variable texture, well to poorly drained.	Severe, Sh, Ss, Sc, G etc	Strong	<950 m[a] & 1500 m[b] <4000mm	<1100 m[c] & <1300 m[d] 4000–6000 mm
8	Very severe to extreme – conservation or protection uses.	Unsuitable for arable, pastoral or commercial forestry use.	0– >35°	Variable, deep to very shallow (<20 cm) &/or stony or very stony.	Variable texture, well to poorly drained.	Very severe to extreme Sh, Ss, Sc, G etc	Strong	<3700 m 420–10 000+	<2800 m 750–7000+

** regional variations occur*

[a]Southland, [b]Marlborough, [c]Wellington, [d]Gisborne

Wireless sensor networks (WSN) helping to improve the use of irrigation water

A prototype wireless soil moisture sensor mesh network (WSN) has been built by Jagath Ekanayake at Landcare Research, Lincoln, for real-time simultaneous monitoring of soil moisture at multiple locations. The ability of the network to monitor how soil moisture varies spatially, using affordable, low-power sensors, means it can be usefully employed to help improve our traditional methods of irrigation scheduling.

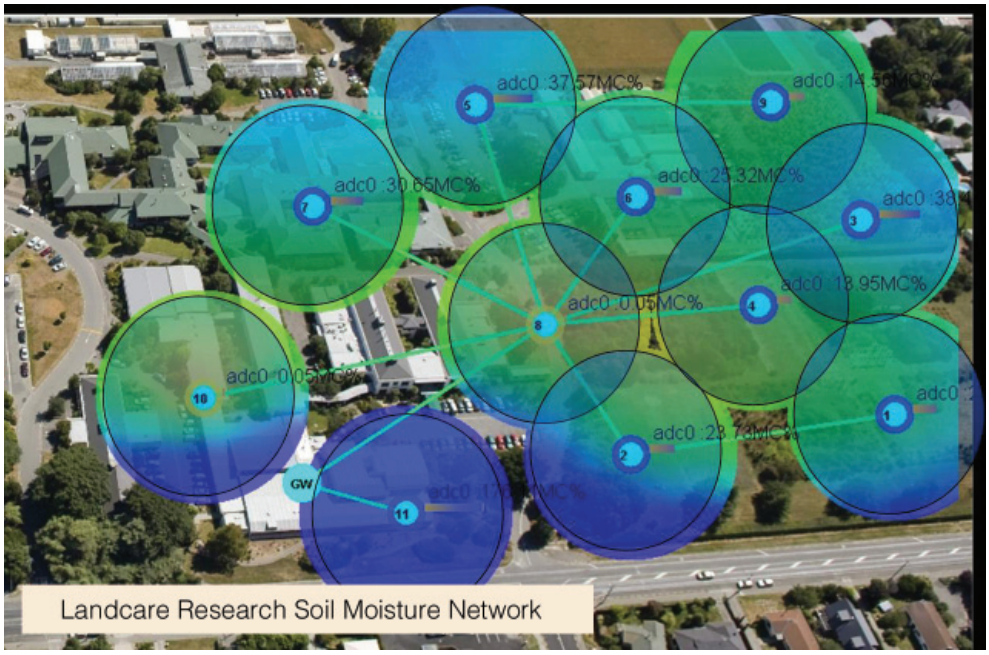

Figure 1: Prototype 'Landcare Research Wireless Mesh Soil Moisture Net' self-organizing and self-healing soil moisture sensors collect real-time soil moisture data. The prototype has been trialled at the Landcare Research campus at Lincoln. The diagram shows circles representing the representative areas for each sensor. Darker areas show soil near saturation.

Soil moisture is just one application for these wireless sensor networks. Affordable low-power, light-weight compact sensors are becoming available for a wide range of other environmental monitoring such as temperature, light, sound and rain. The WSN sensors are networked with nodes that transmit information using radio waves instead of wires. Each node has a transmitter and receiver, working on very low 10 mW power (equivalent to 1/1000th of a 10 watt energy-saving light bulb). The nodes contain their own power source, either solar or battery. They act like mini-computers, providing a smart, self-organising, self-healing network of sensors. If one sensor fails the nodes will reorganize to find the most efficient route to transmit logged environmental information to a base station. The base station acts as a link between the WSN and a remote computer so that information can be transmitted or received by the WSN.

Conventional irrigation practices apply irrigation while ignoring the spatial variability of the available soil water. Current irrigation scheduling models determine the timing and the quantity of water to be applied based on many assumptions, for example, a uniform soil moisture deficit and a uniform crop evapotranspiration demand under one irrigation system. In practice, we know that the soil moisture and crop stage might vary very significantly, which means the accumulated errors resulting from these assumptions cost water users and country dearly. For example, in the Canterbury region, 1 mm/day excess irrigation could cost over $15 million/year and leach 1.25 million kg of fertilizer per year to our ground water system and streams. In addition our conventional irrigation practices may not be able to meet future demand for irrigation water.

Jagath, working with colleague Carolyn Hedley, and Tim Davie of Environment Canterbury, believes that future efficient irrigation control can only be achieved by 'Direct Measurement and Control-type irrigation systems (see article p.5). Wireless mesh sensor networks with soil-water potential sensors allow us to obtain the fingerprint of the available soil-water potential across the land in real-time. Irrigation control is based on this direct measurement of soil water potential which eliminates the need for sensor calibration to match soil differences. Direct measurement and control also allow us to use **Reduced Deficit** or **Variable Rate** type irrigation methods for selected crops where the soil-water potential is maintained within the optimum narrow margin to increase not only water-use efficiency but also crop quality and production.

To help improved spatial irrigation scheduling, we plan to trial this WSN system under an irrigated cropping system over the next year.

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Variable-rate irrigation helping to mitigate our water footprint

Research conducted by Landcare Research and Massey University has shown that variable-rate irrigation saves between 9 and 26% of irrigation water, with accompanying energy savings, as well as reducing runoff and drainage by up to 55%, which reduces the risk of nitrate leaching. These mean annual estimated savings are based on a 4-year desktop study (2004–2008) of six irrigated production sites in the Manawatu, the Ohakune region, and Canterbury.

Variable-rate irrigation controls and places different depths of irrigation water under one irrigation system based on soil and crop differences. There are two components – first, a spatial soil and crop-based decision tool for spatial irrigation scheduling, using real-time soil water status mapping. The second component is an accurate irrigation system with variable-rate control. Centre-pivot and lateral sprinkler irrigation systems are ideally suited for variable-rate modification.

Variable-rate modification of an existing system fits each sprinkler with a valve, pulsing it on or off via a wireless node (www.precisionirrigation.co.nz). Each node controls four sprinklers and receives wireless inputs from a central controller to guide variable water delivery.

Sprinkler systems make up about 70% of all irrigation systems in New Zealand and cover an area of 460 000 hectares. These systems often occur on highly variable soils, such as the sandy and stony soils of the Canterbury Plains, applying uniform rates of irrigation to large areas. Therefore we investigated the potential benefits of variable rate modification of these systems. In addition to the benefits mentioned above, variable control allows complete flexibility for mixed cropping, site-specific fertigation and chemigation, the ability to shut-off irrigation to raceways (Fig. 1), water bodies, etc., and better control of irrigation application at either end of a centre-pivot.

The next stage of our variable rate irrigation research will be field-scale trials of these concepts.

Virtual water

The calculated virtual water content may be used to compare water use by variable rate irrigation (VRI) with a conventional (URI) system (Fig. 2). Virtual water content is the amount of effective rainfall (rainfall minus runoff) (green water) plus the amount of effective irrigation (irrigation minus runoff) (blue water) plus the amount of freshwater required to dilute any pollution occurring under the production system (grey water). In this case we have accounted for dilution of leached nitrogen to 11 mg/L. Fig. 2 illustrates that there is less runoff and better use of stored water under VRI.

VIRTUAL WATER *is the amount of water embedded in a product. It is calculated from crop water requirement plus yield.*

WATER FOOTPRINT *of a nation is more than food production. It includes domestic water use plus the balance of virtual water imports and virtual water exports. It indicates the annual volume of water required to sustain a population.*

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Figure 1: A variable rate irrigation system can shut off water as it passes over a farm track.

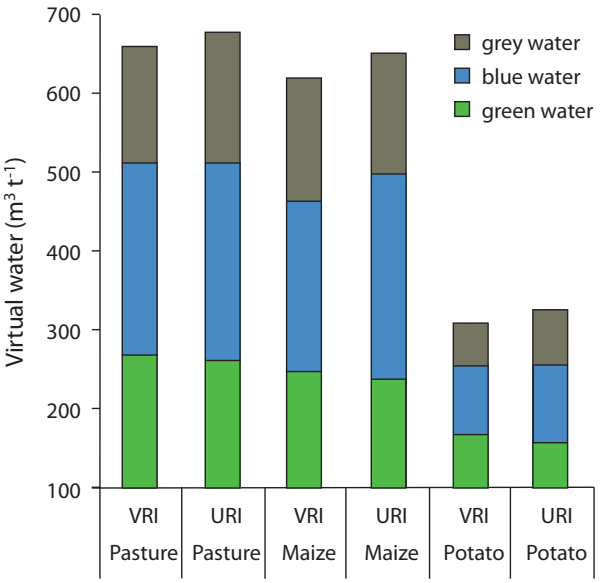


Figure 2: A comparison of the virtual water content of irrigated pasture, maize grain and potato crops using variable-rate irrigation (VRI) and uniform-rate irrigation (URI).

"Murray Jessen Memorial" doctoral scholar recounts...

Landcare Research "Murray Jessen Memorial" doctoral scholarship recipient Tanya O'Neill, based in Hamilton, last summer completed her first Antarctic field season in the Ross Sea Region.

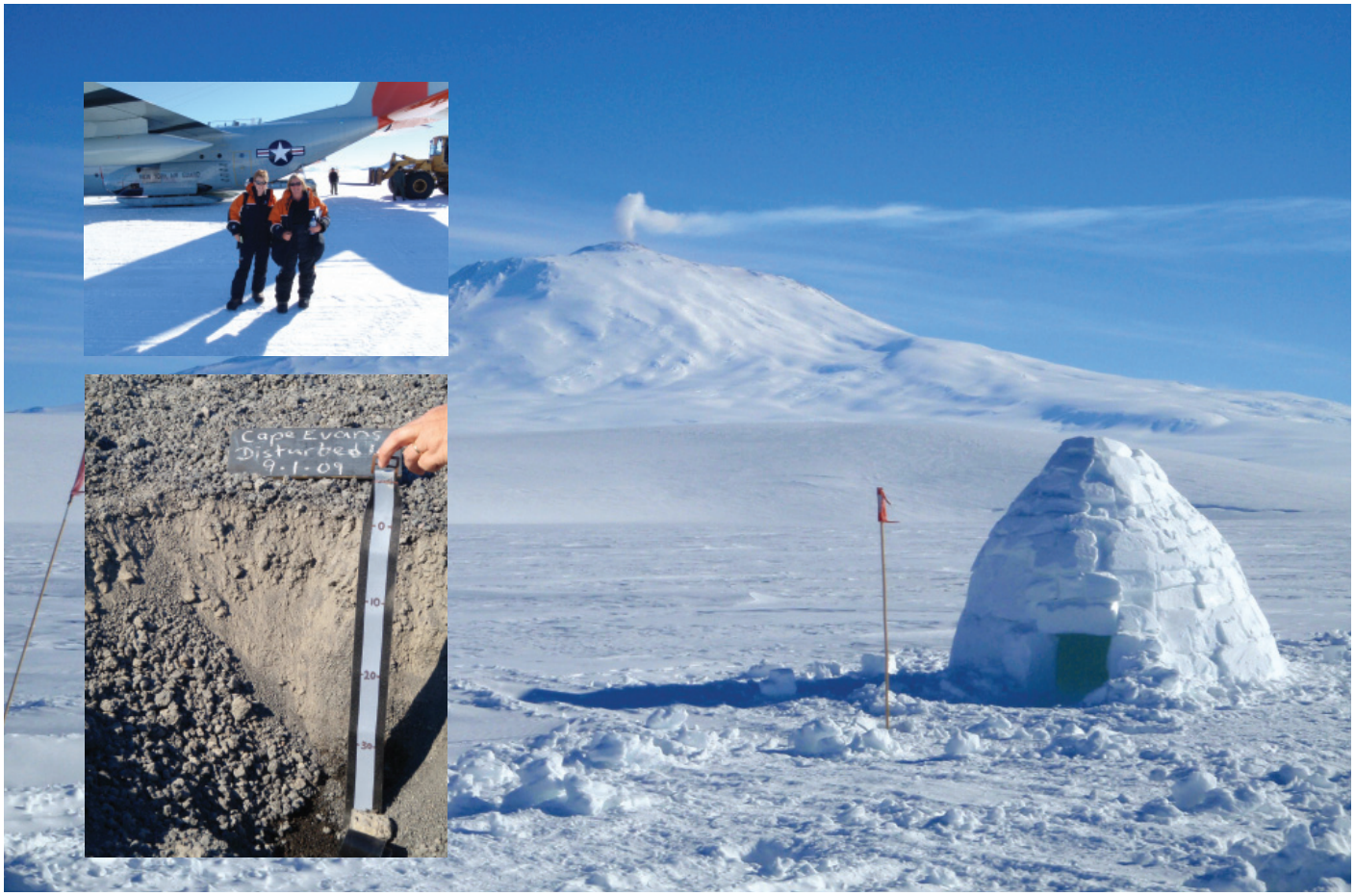
Tanya's doctoral programme seeks to bridge a gap in current understanding of the cumulative impacts of human activities on the Antarctic soil environment. Her work will build on the environmental impact-related work of Landcare Research's programme "Environmental Protection of Soils of the Ross Sea Region" led by Jackie Aislabie, as well as that of Malcolm McLeod (see Soil Horizons 17) and chief supervisor, Dr Megan Balks.

Ice-free areas make up less than 0.4% of the total area of the continent, but are home to the majority of historic huts, research stations and biologically rich sites, thereby attracting a short sharp influx of tourists and science personnel each summer. With Tanya's only previous Antarctic experience being from the "other side of the fence" – a tourist running a marathon with 160 others on an island off the Antarctic Peninsula – the experience left her concerned about whether we could accurately predict how or to what extent the physical integrity of the soil landscape could cope with repeat visits, whether impacts were cumulative, and whether the most frequented sites were able to recover between tourist and science seasons.

During the 2008/2009 field campaign supported by FRST–Antarctica NZ, Tanya focussed her efforts primarily in the Ross Island area, investigating disturbed areas around Scott Base, Crater Hill (site of the Meridian Wind Farm), the scraped hillsides of Observation Hill (previously mined for road-fill), McMurdo Station, and Capes Evans and Royds. Specific objectives during this first season were to: 1) investigate the accuracy of the Antarctic Treaty enforced Environmental Impact Assessment system by comparing *predicted* versus *actual* impacts of past human activities; 2) quantify the relationship between soil vulnerability (based on McLeod's proposed Soil Vulnerability Index), cumulative impact, and soil rates of recovery; 3) explain a chronology of visible changes in the site "foot-print" at highly impacted sites; 4) investigate in detail the step-wise recovery of desert pavement after disturbance; and 5) install infrared track counters to quantify foot traffic along walking tracks in the region.

"Assessment of the impacts of

Main photo: Antarctic Field Training Masterpiece in front of a steaming Erebus; Bottom inset: Tanya's first Antarctic soil pit, Cape Evans, Ross Island, Antarctica (Photographs: Tanya O'Neill).



disturbances on the soil surface was carried out through ground-truthing and environmental footprint investigations, including a modified version of Campbell and others 1993 Visual Site Assessment (VSA) and McLeod's Soil Vulnerability Indices (SVI)," Tanya explained. "VSAs and SVIs were undertaken at all the sites, and at key sites we also conducted more detailed soil profile descriptions, bulk density measurements, and soil sampling.

"Another interesting part of this programme was to install infrared track counters across a number of recreational tracks in the region – to get some reliable data on users, and couple this with investigations into the physical attributes of the tracks themselves – particle size and bulk density differences between the tracks and adjacent undisturbed surfaces. Does it make a difference if the track has 100 users a day versus 2 a week? Do we keep tracks well-constrained, single file, or let people roam willy nilly? These questions are all a function of the material we are dealing with and its vulnerability or resilience to foot traffic."

Tanya is pleased with what was achieved in this first field season, – "We established, tested and fine-tuned our methodology for assessing the impacts of human activity, and also established some base-line data on sites we will monitor for recovery in the future. We are also formulating a new classification system for the step-wise recovery of desert pavement following disturbance – and this is very exciting: we have sites where you can actually see the desert pavement reforming! I can't wait to get to the Dry Valleys and see where these much older landscapes will fit into our system".

Next season's logistical requests are already underway, and the plan of attack for this coming year is in place. "This coming season we will visit new sites in the McMurdo Dry Valleys, disturbed sites such as Marble Point, the former Vanda Station site, and the Cape Roberts Project ice-free storage area, to build a much more comprehensive dataset."

Tanya hopes her outcomes will contribute to understanding the step-wise recovery rates of desert pavement after disturbance; highlight areas of landscape vulnerability, areas where future activity should be avoided; and pave the way for more informed decision-making on policy and management of activities in the Antarctic terrestrial environment.

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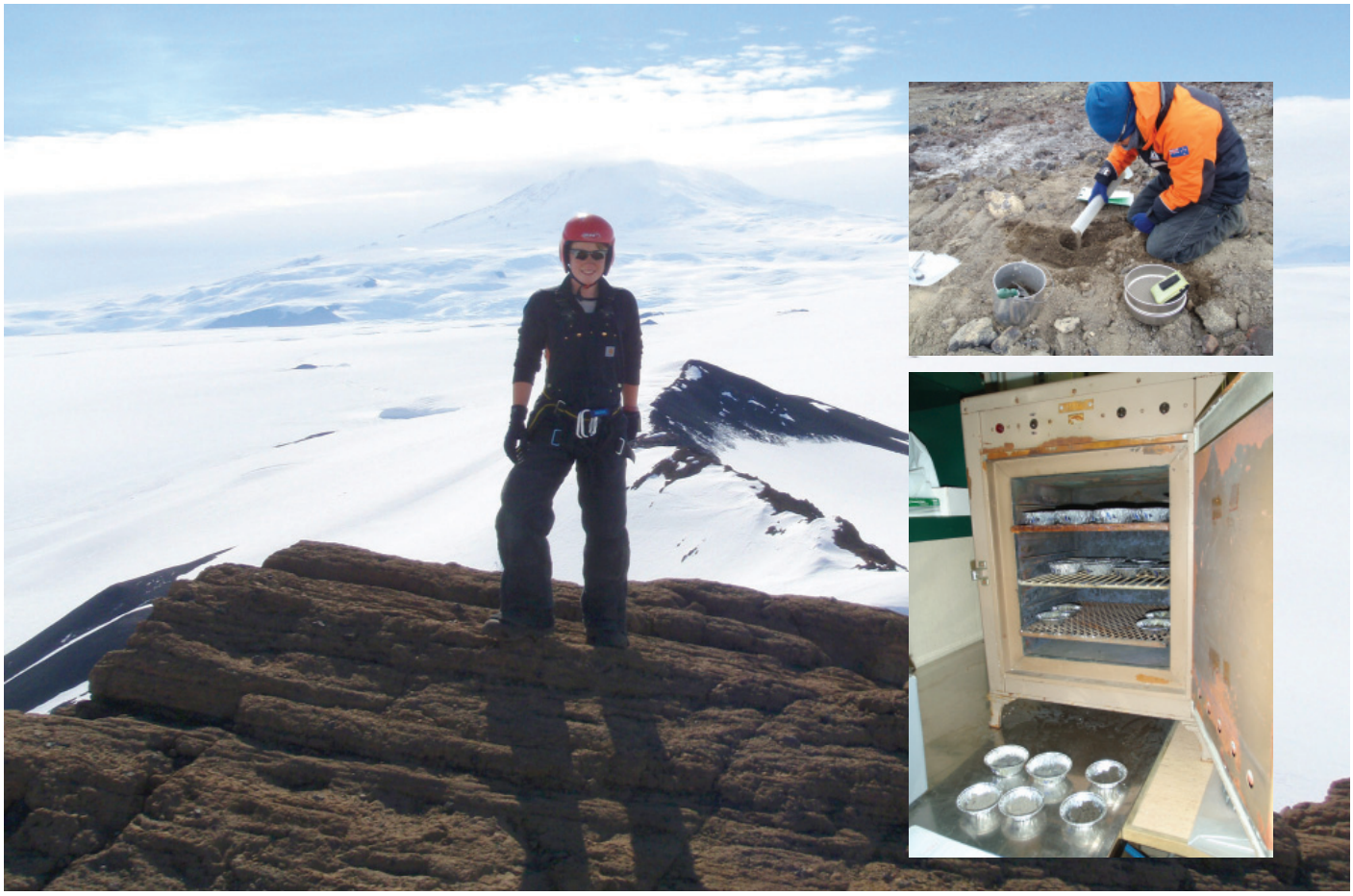
Main photo: Tanya on top of Castle Rock, Mt Erebus in the background, (Photograph: Renee Burns).Top inset:Tanya measuring soil bulk density – Sand Replacement method (Photograph: Megan Balks): Bottom inset: Graeme Claridge's historic oven for drying soils, Scott Base, (Photograph: Tanya O'Neill).



Can methane biofilters reduce agricultural greenhouse gas emissions?

In a project funded by MAF, Adrian Walcroft, Kevin Tate and Chris Pratt are investigating whether methane biofilters are a cost-effective technology to reduce methane emissions from point sources on dairy farms.

Biofilters are commonly used throughout the world to treat a variety of liquid and gas pollutants. They contain living material growing in a medium that also serves as the filter bed. The pollutant is biologically degraded into harmless end products as it passes through the filter. Biofilters have recently been developed that can remove methane from gas, such as that emitted from decomposing refuse in a landfill.

Methane biofilters use aerobic soil bacteria called methanotrophs, which consume methane as their sole source of carbon. Some carbon is retained and incorporated into new biomass, while the balance is oxidised and released as carbon dioxide. The conversion of methane to carbon dioxide has a greenhouse gas mitigating effect, since methane has a 21-times greater global warming potential than carbon dioxide.

Enteric fermentation by ruminant farm animals is the main source of on-farm methane emissions, but the anaerobic effluent pond on a typical dairy farm can account for 9–18% of total methane emissions. On large dairy farms (>800 cows), it is technically and economically feasible to install a digester and generator to recover energy, in the form of combustible methane, from the effluent. However, 95% of New Zealand dairy farms have fewer than 800 cows. It is on these farms that we believe methane biofilter technology could be cost-effectively utilised to lower greenhouse gas emissions. To reduce methane emissions from effluent ponds, it is necessary to capture the gas by covering the pond (Fig. 1 inset). Robust covers have been developed in recent years that can be retrofitted to existing effluent ponds .

Figure 1: Anaerobic dairy farm effluent ponds can account for up to 18% of total farm methane emissions.

A second point-source of methane on dairy farms has emerged in recent years with the increasing use of animal housing. Covered feed pads, wintering barns and herd homes are becoming popular as farmers recognise the production, animal welfare, and soil protection benefits of housing animals during winter months. When animals are housed, their enteric methane emissions accumulate and could potentially also be treated by oxidation in a biofilter.

So where does one find a source of active methanotrophs? Our early work showed that New Zealand forest soils have some of the highest rates of methane oxidation in the world. More recently we have been experimenting with soils that cover the decomposing refuse in a landfill. We expected high rates of methane oxidation since the soil methanotrophs will have been exposed to high methane concentrations. We sampled soil from part of a landfill that was capped eight years ago. The methane oxidation capacity was analysed in our purpose-built methanotroph laboratory. The results exceeded our expectations: as we increased the inlet methane concentration from 1000 to 35 000 ppm, the methanotrophs responded immediately by increasing their oxidation rate (Fig. 2). The removal efficiency was close to 100% across a 10-fold range in inlet methane concentration, and then started to decline at higher concentrations.

In subsequent experiments we observed similarly high oxidation rates for soil sampled from a part of the landfill that was

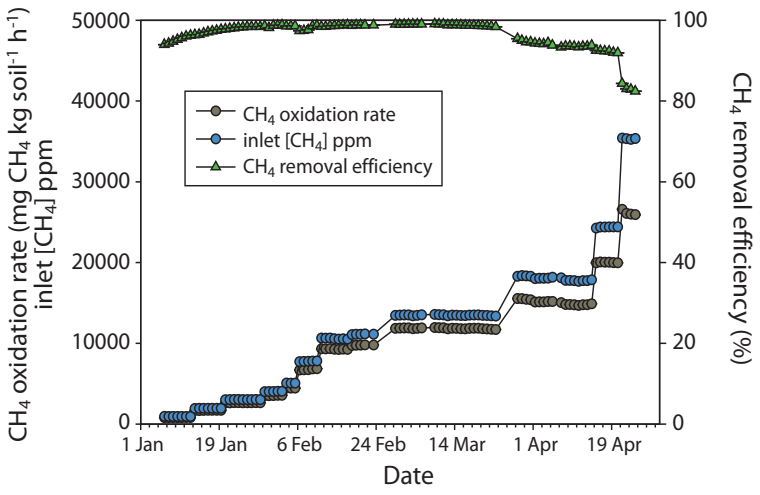


Figure 2: Inlet methane concentration, methane (CH_4) oxidation rate, and methane removal efficiency of soil sampled from a landfill cap.

covered only two years ago, but much lower oxidation rates for the same type of soil sampled from outside the landfill area. These data indicate that methanotroph populations can quickly respond to an increase in methane supply. A population of methanotrophs capable of rapidly responding to often wide changes in methane concentration is needed for developing an effective methane biofilter. We are using this landfill methanotroph population to build a prototype methane biofilter to oxidise methane piped from an effluent pond cover installed on a dairy farm at Massey University. Our colleagues at the University of Victoria, Canada, will use molecular methods to try to identify the methanotrophs present in the landfill soils, and will also attempt to culture them. We will use our biofilter laboratory to identify optimal conditions for methane oxidation and to provide performance data necessary to scale-up our laboratory filters to the field-scale.

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Can dairy cow urine decrease soil carbon?

Deposition of dairy cow urine onto pasture soils may accelerate soil carbon loss in these high productivity pastures by priming organic matter decomposition. Priming occurs when a carbon substrate added to soil increases the mineralisation of existing soil organic matter, which may lead to a decrease in soil carbon and a release of carbon dioxide to the atmosphere. Dairy cow urine contains up to 15 g carbon per litre and may act as a priming agent. To investigate this idea we measured the amount of carbon evolved from a soil as carbon dioxide above the amount of carbon added in urine.

A Rangipo sandy loam soil (0–50 mm layer) was collected from grazed pasture. Water or dairy cow urine was applied to repacked soil cores and incubated at 25°C for 84 days. Carbon in carbon dioxide was measured during the incubation period to determine if priming of soil carbon loss had occurred. Microbial biomass was measured using a fumigation-extraction method before and after incubation. Dehydrogenase activity was measured throughout the incubation to monitor soil microbial activity.

The amount of carbon added to the soil in urine was subtracted from the cumulative amount of carbon dioxide-carbon produced during incubation – the resulting difference was the amount of carbon dioxide-carbon presumably derived from soil carbon (Fig. 1). The amount of soil carbon lost by mineralisation to carbon dioxide-carbon after urine application was considerably larger than carbon lost after water application, indicating urine application caused priming of soil carbon decomposition.

Soil microbial biomass decreased in urine treatments to about half of the pre-treatment content after 84 days of incubation, but remained unchanged in the water control. If all the dead microbial biomass in the urine treatment was converted to carbon dioxide-carbon it would only contribute 15% of the carbon dioxide-carbon measured. Dehydrogenase activity in the urine treatment increased for the first 7 days of the incubation (Fig. 2), showing there was an increase in soil microbial activity immediately after urine application. Overall, degradation of dead biomass contributed only a small amount of the extra carbon dioxide-carbon that was measured after urine application. The remaining extra carbon dioxide-carbon was most likely from accelerated soil organic matter mineralisation, the result of increased microbial activity.

In our laboratory incubation experiment, the Rangipo soil lost about 5% of its total carbon after a single application of dairy cow urine. The extent to which losses of soil carbon following urine application occurs under field conditions needs to be determined. Future research on dairy cow urine will investigate the effects of repeated urine applications on soil in these intensively grazed systems.

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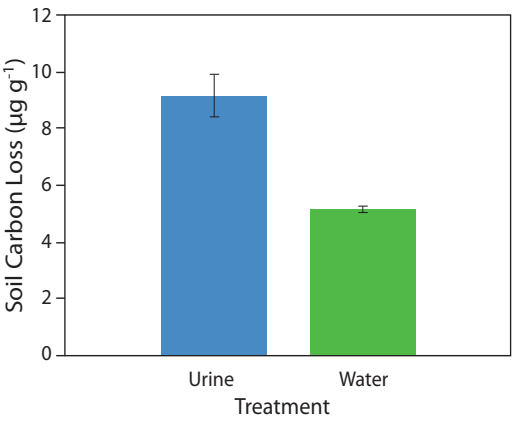

Figure 1: Soil carbon loss from a Rangipo pasture soil after an 84-day incubation with urine or water (with corrections for the amount of carbon added in solution).

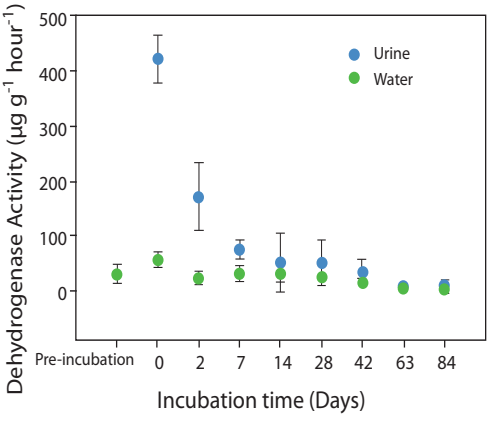

Figure 2: Dehydrogenase activity (microbial activity) in Rangipo pasture soil during 84-day incubation at 25°C after application with urine or water.

Long-term changes in carbon and nitrogen in New Zealand pasture soils: a re-analysis of archived data from 1964

There is renewed interest in the amounts of carbon (C) and nitrogen (N) stored in soil not only for the benefits that soil organic matter has on soil properties, but also because C and N stored in soil organic matter have significance for global C and N balances and national C accounting. In this study we re-analyse results reported in 1964 by Jackman on long-term soil C and N changes after indigenous vegetation clearance and following pasture establishment since 1900 or later. These provide a contrast to the current high intensity dairy grazed pastoral system reported by Lambie (p.9).

An alternative to carrying out long-term repeated measurements at a single site is to identify a "chronosequnce" of matched soils. Chronosequences have the same soil at different matched sites where a change in soil management has been in place for different lengths of time. The two papers by Jackman reported organic matter changes in chronosequences of 10 New Zealand soils under pasture. The soils had originally been cleared of indigenous native forest by settlers between 1850 and 1900 but these original pastures had reverted to scrubland. The establishment of new pastures involved clearing the scrubland, cropping for one year, and re-sowing to ryegrass and clover. Jackman identified sites on 10 matched soils between 18 and 66 years after pasture renewal but did not report on the change in C content although this was measured down to 30 cm along with bulk density. We reworked Jackman's data to provide estimates of the rates of C accumulation in these soils and also to assess how much longer the soils could accumulate N.

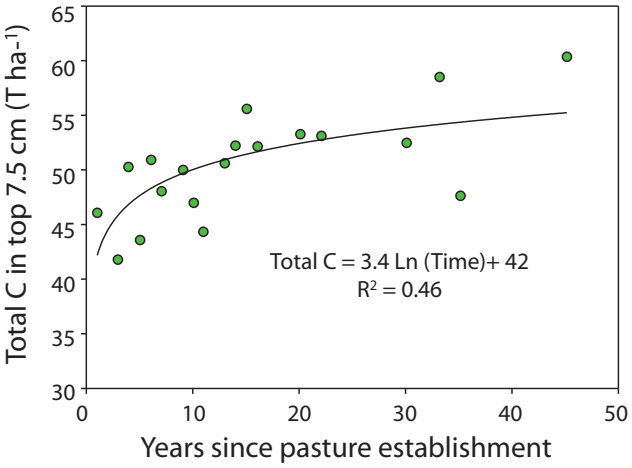

Figure 1: Accumulation of soil carbon in the top 0–7.5 cm of Waiotu chronosequence (based on research conducted by Jackman in the 1960s).

Averaged across all 10 soils, the rates of C accumulation in the 0–7.5 cm depth were 1.07 tonnes C ha^{-1} yr^{-1} in the first 5 years, 0.27 tonnes C ha^{-1} yr^{-1} between 5 and 25 years, and 0.09 tonnes C ha^{-1} yr^{-1} between 25 and 50 years. Very similar rates were obtained when calculated over 0–30 cm depth of soil, although in several cases for individual soils the changes in C contents were not significant. A typical pattern of C accumulation in the surface soil is shown for Waiotu soil (Fig. 1). Overall, the Jackman data support the idea that under traditional low intensity pasture management in New Zealand there was a gradual increase in total C that approached a steady state after 20–30 years.

The total N content of the soils increased at a more rapid rate than the total C content, resulting in a lowering of the soil C:N ratio. The rate of decrease in the soil C:N ratio of the Jackman soils suggests that after some 44 years the soils would have reached a C:N ratio of <10 and by now will have little further capacity to store more N.

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Land-use intensification and soil organic matter pools

Soil carbon may decline and soil nitrogen often increases when land use intensifies. These changes may adversely affect the nutrient storage capacity of soils, and consequently, a soil's ability to act as a buffer between intensification and its effects on the wider environment.

John Scott has been using the Johan Six soil organic matter (SOM) conceptual pools model to investigate land-use intensification, specifically a shift from dry-land to irrigated pastoral farming. The model uses 4 pools: (1) chemically-protected carbon, (2) silt- and clay-protected carbon, (3) micro-aggregate-protected carbon, and (4) unprotected carbon (see Fig. 1).

Using this model, John found some revealing differences between soils irrigated for about 50 years (the Winchmore long-term irrigation experiment) and dry-land soils, despite reported soil test results showing only small increases in C, N and phosphorus (P) concentrations under dry-land. John fractionated soils from the two sites into macro- and micro-aggregates and associated particulate organic matter. Micro-aggregates protect carbon and nutrients from the activity of micro-organisms better than macro-aggregates. Dry-land samples had a greater concentration of unprotected particulate organic matter, with associated C, N and P, outside the micro-aggregates. This is possibly due to lower biological activity in the dry-land soils compared with the irrigated soils.

Because there was no difference in C, N and P concentration within dry-land and irrigated micro-aggregates, this suggests that the micro-aggregates within each treatment may have possibly reached the limit of their ability to store C, N and P. However, there were greater total amounts

of macro- and micro-aggregates under irrigation compared with dry-land soils. This greater aggregation suggests greater physical protection under irrigation.

Greater hydrolysable N and organic P associated with micro-aggregate silt and clay under irrigation suggest N and organic P within irrigated micro-aggregates may be more available than under dry-land. In contrast the greater inorganic P found associated with dry-land silt and clay may represent greater concentrations of recalcitrant P. Under dry-land farming there is less break-up of existing aggregates by earthworms and less microbial activity providing a more stable environment for the stabilisation of inorganic P compounds.

Micro-aggregation increased with a shift from dry-land to irrigated pastoral farming, with other work showing an accompanying increased microbial and earthworm activity that may create more labile forms of soil N and P. Approximately 50 years after the change to irrigation, saturation of the C, N and P functional pools may have occurred. Further research is required to confirm if this is indeed the case.

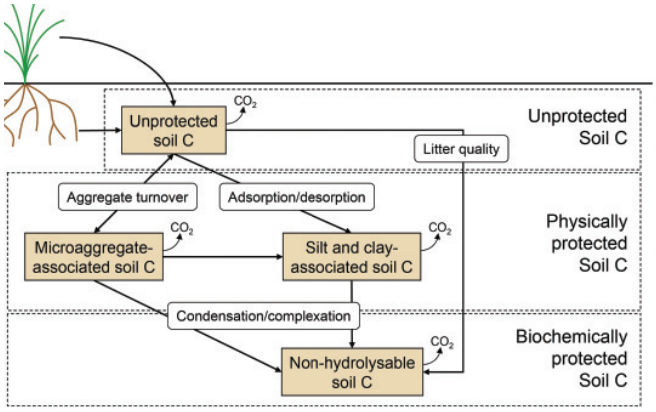

Figure 1: A conceptual model of soil organic matter (SOM) dynamics, determined by soil aggregate formation/degradation, SOM adsorption/desorption, SOM condensation/complexation and litter quality. Adapted from Six et al. (2002) Plant and Soil *241: 155–176.*

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CarbonNet

Last month, representatives of the New Zealand soil carbon research community met to formulate ideas for the re-establishment of a group who can coordinate and lead soil carbon research and identify key research areas appropriate to national policy imperatives. A teleconference of 18 researchers was convened by AgResearch's Alec Mackay and successfully drew up an agenda for action.

University and CRI representatives elected a group of six to go forward to a second meeting where the structure of the leadership group would be finalised. At the second meeting it was agreed that a widely representative leadership group would be an effective means to coordinate soil carbon research in New Zealand and Frank Kelliher was elected as Chair, Carolyn Hedley as Coordinator, and Tim Payn, Louis Schipper, Troy Baisden, and Brent Clothier as a support committee.

Our mission statement is:
CarbonNet connects New Zealand's soil carbon research community. CarbonNet provides expert knowledge and advice on the role of soil carbon processes and inventories to government and other parties interested in climate change mitigation.

We aim to act as a conduit for soil carbon research activities to policy. With the Copenhagen meeting in December and uncertainties about a national policy for carbon accounting we see the need for more data, better models, and development of ideas on how soil carbon research can contribute to the bigger picture of New Zealand's commitment to international carbon accounting. The Copenhagen meeting is the first meeting of UNFCCC parties and has an agenda to discuss a new international protocol to address global climate change beyond the final Kyoto Protocol commitment period of 2012. Representatives of 170 countries are expected to attend this meeting.

Troy Baisden points out that New Zealand's soil carbon changes and fluxes are potentially worth roughly $1B per 5-year commitment period, if we were required to account for all the net exchanges we currently think are occurring. However, only changes relating to Afforestation Reforestation and Deforestation (ARD) are presently accounted for and the future of accounting in any Copenhagen agreement is unclear. New Zealand currently does not have good quality information on soil carbon beyond ARD to support negotiating positions at Copenhagen, but could potentially benefit strongly from soil carbon management, including management of erosion recovery, and land-use change.

The CarbonNet focus on inventory will support the newly devised virtual Greenhouse Gas Centre announced by the government, to be established later in the year with an emphasis on mitigation.

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