Soil Horizons

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Editorial

I am pleased to have the opportunity to introduce this year's issue of Soil Horizons. Soil Horizons has been bringing you bite-sized updates on progress in soil and land research from Landcare Research since 1997. This year the National Land Resource Centre (NLRC) has partnered with the Soil Horizons team to widen the scope and authorship to bring you soil, land, and water research from across the CRIs.

The NLRC is a collaborative centre that aims to deliver more integrated research effort on land and the interface with freshwater; greater alignment of research activity with national priorities; as well as capacity-building to increase the uptake of scientific information and associated tools.

In this issue, we take the theme of the National Science Challenge 'Our land and water' to showcase research that aims to enhance productivity while maintaining land and water for future generations. This represents one of the most significant priorities for New Zealand.

So what will be required for the national science challenge to make an impact?

- Collective science effort at farm, catchment and regional scales – the potential for which is nicely demonstrated in '*CIBR: Putting waste to work*' (see page 7).

- Development of, and access to, robust data on soil, land and water variability as described in '*Meeting the demand for quality soil information*' (see page 4) and '*Instant access to 3D geology and groundwater information*' (see page 3).

- Science and tools that can be more easily 'consumed' by those driving decision-making processes, best practice, and innovation, a sentiment reflected in '*Where to for nutrient management science*' *"*Increased translation of science into more useable form, simplification of management software tools, and increasing the numbers of experienced advisors for land managers would be beneficial" (see page 6). Customising the way science is provided to specific communities or stakeholders is one method of 'translation', highlighted in '*Convenient access to Maori land information*' (see page 5).

The work progressing in each of these areas indicates positive contributions to the national science challenge and reinforces the value of initiatives such as the NLRC.

ALISON COLLINS
Director. National Land Resource Centre
E: collinsa@landcareresearch.co.nz

NATIONAL LAND RESOURCE CENTRE

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Landcare Research
Manaaki Whenua

Instant access to 3d geology and groundwater information

GNS Science have developed an interactive portal that provides instant access to information on groundwater systems and geology in three dimensions in the Bay of Plenty. Simply by entering a street address, map coordinates or a smart phone's GPS, it is instantly possible to call up relevant information.

The initiative, believed to be the first of its type in New Zealand, is the result of a partnership between Bay of Plenty Regional Council and GNS Science, with both organisations funding the development of the product. The Council provides its groundwater information, such as borehole data and groundwater consents, on a web site. GNS Science supplements this with information on aquifer characteristics, also available to the public. The product we initially developed was too large to serve over the internet, so we developed a simpler package for internet use.

The product is part of a larger project in which our scientists are developing three-dimensional subsurface geological models of the Taupo Volcanic Zone to better understand the geometry, fluid flow pathways, and layer properties of the geological units in this part of New Zealand.

Called 'Earth Beneath Our Feet', the model shows the main geological units down to bedrock plus a range of information about groundwater in Bay of Plenty. This includes the depth at which groundwater is most likely to be found. Landowners and contractors can use this information to help with drilling decisions without initially having to involve the Council. These 3D subsurface models can also be used to assess geothermal resources. In particular, they can be used to identify the large-scale water flow 'cells' associated with geothermal fields.

The information can be accessed by computer or by a smart phone app (Figure 1). The data served up on the smartphone app are a stripped-down version of the 'Earth Beneath Our Feet' website. Features of the app include access to geological model profiles below a point on the ground surface identified via a cell phone's GPS.

Senior Environmental Scientist at the Council, Janine Barber, says when the product goes live, in December 2013, landowners, consultants, and students will have information on geology and groundwater at their fingertips. She sees it as a win-win, with the public having ready access to the Council's data and GNS Science models, which frees up Council staff from responding to routine inquiries.

PAUL WHITE — GNS SCIENCE
P: 07 376 0128 E: p.white@gns.cri.nz

FIGURE 1 Groundwater Scientist Connie Tschritter uses her cellphone to access geological information directly beneath her feet in the Bay of Plenty.

Meeting the demand for quality soil information to underpin critical decision making

Data that characterise land resources are fundamental to improving both agricultural productivity and environmental quality. Knowing the spatial variability in how much water soils can store has a significant impact on the water-use efficiency of irrigation developments. Soils also vary greatly in their natural abilities to buffer and filter contaminants, and the value of accurate and accessible soil information has heightened as the need to manage the impacts of intensive land use on fresh water has become a national priority.

Landcare Research is custodian of the National Soils Database (NSD), the S-map soil survey database, and the National Soil Archive. The NSD stores analytical measurements and their meta-data for a wide spectrum of New Zealand's soils. This database is supported by the National Soil Archive, which is where physical samples from key soils are stored for future analysis. S-map is building a national soil survey database of the spatial variability of New Zealand's soils, drawing on the underpinning NSD to link analytical data to areas of the landscape with similar soil properties. The greater accuracy, richer information, and flexibility of the S-map system provide significant advantages over the coarser-resolution national-scale fundamental soil layers, which were derived from the Land Resource Inventory (LRI). Figure 1 shows the relationships between our soils datasets, and the services we provide to supply this information to users. We highlight key initiatives that are underway regarding these nationally significant databases.
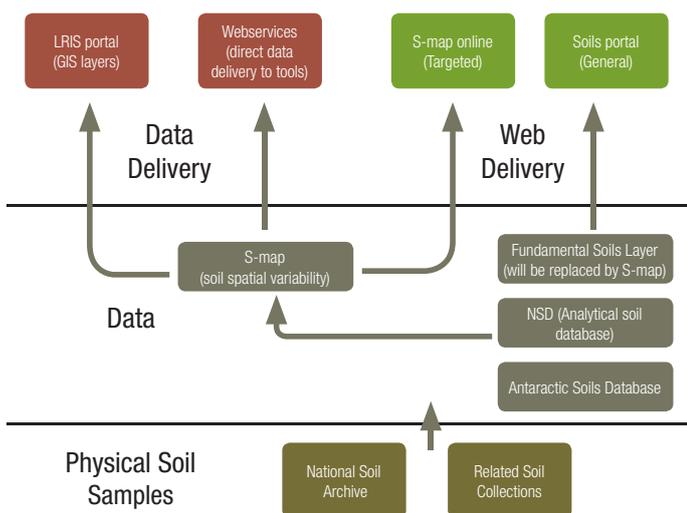

FIGURE 2 Soil mobile app displaying the Antarctica Soil Database.

slope). Last year S-map extended to include new areas in the Gisborne, Waikato, Canterbury, Auckland, Hawkes Bay, Bay of Plenty, and West Coast regions. Work continues in most of these regions, and also in large areas of Southland and Otago. Further progress in S-map coverage depends on the availability of funding.

Use of the S-map Online web service (http://smap.landcareresearch.co.nz/home) continues to grow highlighting the strong demand for quality and accessible soil information. The popular soil fact sheets, available for each soil through S-map Online, provide detailed soil data specific to land management tools such as Overseer and the Dairy Effluent Storage Calculator. Landcare Research continues to develop the delivery services for our soil information, with research this year focussing on development of an 'interoperability system' to enable soil data to be streamed directly from the S-map database into an end-user tool, with the first application being to link S-map to the Overseer model.

To support upcoming farm management environment plans we have added soil vulnerability assessments for nitrate and phosphorous contamination. Improved models have been developed to predict key soil physical properties, including important soil water storage attributes. These new hydrological pedo-transfer functions (generalised linear models) are based on a wider range of data, including percentage of sand, silt and clay, soil classification, soil parent material, and characteristics of the functional horizons (topsoil vs subsoil, stone content, structure size, and consistence classes). This has resulted in changes to estimates of profile available water, particularly for Pumice soils.

FIGURE 1 Relationships between Landcare Research soil datasets, and the services we provide to supply this information to users.

S-map

Thanks to Regional Council support, the coverage of S-map increases incrementally every year, focussed at this stage on the land with potential for intensive land use (generally <15°

National Soils Database (NSD)

Underpinning the soil information provided in the S-map fact sheets are the analytical data stored in the National Soils Database (NSD). This year Landcare Research has renewed investment in the NSD to modernise the design of the database and migrate the data from the existing NSD to a new database technology. At the same time we will enhance our capability to identify, capture, and store key new analytical data as they are generated. Over time the vision is to provide a repository for a range of publicly funded soil analytical data, enabling integration of data from a myriad of projects into a standard format that is readily accessible for re-use in future applications.

Soils Portal

During the winter we also upgraded the Landcare Research Soils portal (http://soils.landcareresearch.co.nz/), which provides access to maps and information on the New Zealand Soil Classification, the New Zealand NSD and Ross Sea Region soil sites, and the 16 class attributes from the Fundamental Soils Layers. During the re-engineering we created a version of the site that would work on mobile devices such as cell phones and tablets (Figure 2). This is available for testing at http://soils.landcareresearch.co.nz/maps/index.html.

SAM CARRICK — LANDCARE RESEARCH
P: 03 321 9663 E: carricks@landcareresearch.co.nz

Convenient access to Māori land information

Landcare Research has developed a Māori land visualisation tool online at http://whenuaviz.landcareresearch.co.nz. The work began in mid-2009 and was funded by Te Puni Kōkiri (Ministry of Māori Development).

The new tool, which combines updated Māori land block data (property and legal) from the Ministry of Justice (Māori land online http://www.maorilandonline.govt.nz/gis/) with environmental and land resource data from Landcare Research, has been designed specifically for Māori land owners and land managers searching for their land blocks, and wanting to know about the land resource characteristics of the land and its potential. The tool, however, is available to everyone who has an interest in Māori land.

The website can create a custom report of the environmental characteristics for any Māori land block in New Zealand. Māori land can be located by using either an interactive map or by searching for a block name or place name. The tool generates a series of resource maps, statistics, and descriptive information detailing land resource information and presents this to the user as an interactive webpage. To date, underlying data have been derived from two nationally significant databases, the New Zealand Land Resource Inventory (NZLRI) and the National Soils Database (NSD).

The data, displayed over topographic maps, satellite imagery, and aerial photographs, provide convenient access to extensive information about Māori land. This information assists Māori land owners to access and visualise environmental data in relation to four questions:

1. Where is my land? This enables the user to see the location of their land on an interactive map that also shows the size of the land holding, the number of owners, and who manages the land (e.g. a trust).

2. What does it look like? The user can view a satellite image of their land, land-use capability and soils information.

3. What is around me? This shows what geographic features, infrastructure, other land blocks, etc., are on and around their land.

4. What can I do with it? This indicates land-use potential, i.e. whether it is suitable for cropping, horticulture, forestry, etc.

The tool has been shown at conferences and workshops and generated considerable interest around the country, especially from Māori landowners and organisations such as trusts and incorporations, as well as many Government departments. Māori have been waiting a long time to gain better and easy access to land resource and environmental data of their blocks. In future Māori land data can be linked to relevant data from many other sources. We have already linked the Māori visualisation tool to the National Library's DigitalNZ records, providing a wealth of historic and archival information for each Māori land block.

GARTH HARMSWORTH — LANDCARE RESEARCH
P: 06 343 4972 E: harmsworthg@landcareresearch.co.nz

MARINO TAHI — LANDCARE RESEARCH
P: 06 353 4969 E: tahim@landcareresearch.co.nz

Where to now for nutrient management science?

In 2013 the Ministry for Primary Industries (MPI) commissioned scientists from the Soil and Land Use Alliance (AgResearch, Landcare Research, Plant and Food Research, and Scion) to review research on nutrient management science for the primary sector between 1998 and 2013. The aim was to identify the current state of scientific knowledge, the use and uptake of this knowledge in the sector, and the 'knowledge frontiers' and gaps that needed to be filled.

A meta-analysis of the literature found over 1900 articles, which were then grouped by sector (arable, dairy, forestry, horticulture, and pastoral); soil processes such as leaching or mineralisation; soil order; geographic region; and nutrient (nitrogen and phosphorus).

The country was well covered by the research – Canterbury had the highest number of papers, followed by Waikato, Southland, Otago, and Manawatu-Wanganui. Most of the literature, however, focussed on biogeochemical responses with little or no attention to the economic consequences of nutrient management.

Despite the strong focus on soils (1600 references used the term) many papers did not explicitly identify the soil used in the study. Of those that did, gley, allophanic, and pumice soils were the top three (Figure 1). Of the papers where specific soil processes could be identified, leaching was the dominant focus (368 papers) followed by mineralisation (244), then de-nitrification (136), runoff/overland flow (131), and fixation (129).

Science advances have been numerous, and include development and adoption of best management practices – for example farm dairy effluent application and management, and forestry fertiliser management systems; rapid growth in paddock scale and whole-farm system models; development
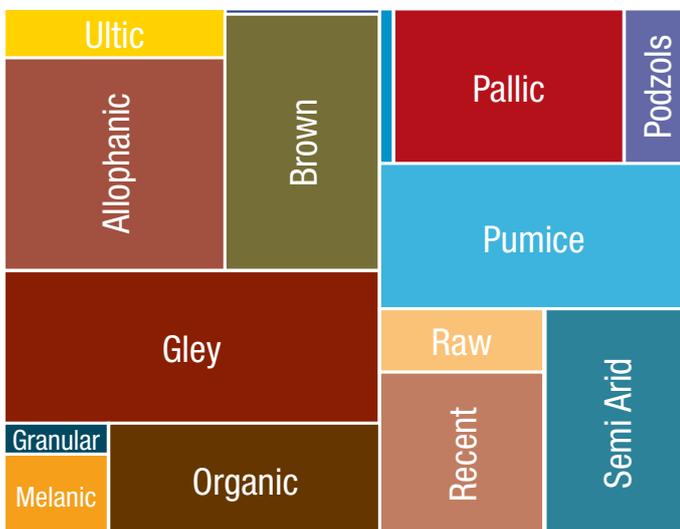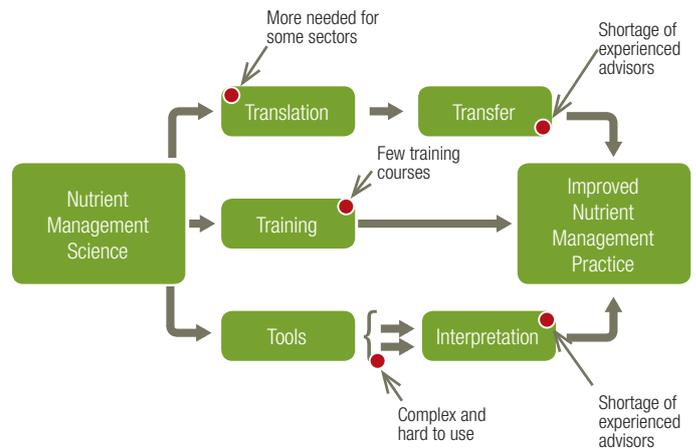

FIGURE 2 Science implementation pathway.

and adoption of a wide range of decision support systems across all sectors based on many field experiments; and inhibitors to manage N cycling and leaching loss.

While science findings are being widely used in practice, we identified areas where implementation of the science needed improvement (Figure 2). Increased translation of science into more useable form, simplification of management software tools, and increasing the numbers of experienced advisors for land managers would be beneficial.

There were some significant science and technology gaps on which future efforts should be focussed to improve nutrient management practice. Three major science opportunities relate to real-time predictions of N availability, manipulation of soil microbial systems, and crop biotechnology for nutrient use efficiency. All new science should be explicitly linked to 'place' (region, soil order). On the land, multifunctional and spatially based farm, forest, and orchard models will be needed to address the increasing complexity of land use. These models must better link to economics. Overseer ® needs enhancement and validation for more sites and crops, and there is a need to develop metrics to demonstrate the efficiency of NZ's production systems to consumers.

The report will be published by MPI on its website and used to inform policy development. MPI will also notify key organisations of the report including science organisations, regional councils and research funding bodies such as MBIE.

Reference: Payn TW, Beare M, Shepherd M, Bayne K, Botha N, Collins A, Curtin D, Davis M, Fraser P, Hedley C, Hoogendoorn C, Johnstone P, Lucci G, Parfitt R, Xue J 2013. Nutrient management science – state of knowledge, use and uptake in New Zealand. Ministry for Primary Industries Technical Paper No: 2013/XX. Soil and Land Use Alliance. 439 p.

FIGURE 1 Proportion of papers relating to NZ soil orders. The size of each soil's box reflects the number of papers in the literature database.

TIM PAYN — SCION RESEARCH
P: 07 343 5590 E: tim.payn@scionresearch.co.nz

The Centre for Integrated Biowaste Research (CIBR): Putting waste to work

In 2011, the two biosolids research programmes in New Zealand joined forces to create a more integrated and cohesive research effort – in April of this year the Centre for Integrated Biowaste Research (CIBR) was launched. Led by ESR, and in partnership with Scion, Landcare Research, and the Cawthron Institute, CIBR is a multidisciplinary collaboration between 10 New Zealand research institutes, universities, and research partners dedicated to developing appropriate and sustainable solutions that maximise the benefits and minimise the risks of biowaste reuse. Underpinned by Government Core Funding, this virtual research centre aims to address critical gaps in New Zealand strategies related to biowaste in recognition of the "national good" value of this research.

FIGURE 1 CIBR and local communities at hui in Kaikoura. Photo courtesy of the The Malborough Express.

New Zealand produces nearly 700 000 tonnes of biowaste each year, waste comprised predominantly of organic matter (that's approx. 2000 747s!). Biowaste includes the biodegradable parts of municipal wastes such as food and garden waste, paper, cardboard, some textiles, and wood. It also includes livestock manures and slurry, treated sewage sludge (biosolids), organic industrial waste (such as paper and textiles), and compost. Over 60% of this waste currently goes to landfill, more than half the total waste filling our landfills each year.

If biowaste is properly handled and treated, where required, it can be a valuable source of soil nutrients and play a useful role as a sustainable soil conditioner. New Zealand is falling behind other countries in the reuse of biowaste such as biosolids. In Australia, for example, only 15% of biosolids are sent to landfill, with more than 65% productively reused in agriculture and compost, and a further 15% stockpiled for use in the future. Currently New Zealand only reuses 17% of its biosolids.

Not only is this waste clogging our landfills, the cost comparisons are also convincing, with landfill costs far exceeding the costs of applying treated biowaste to land. In an agricultural context, biowaste may offset the cost of inorganic fertilisers, while improving soil quality.

For the past 3 years, the CIBR has undertaken work in two case-study communities (Kaikōura and Mokai) to help find alternative biosolids disposal/reuse options that satisfy social, cultural, economic, and environmental criteria (Figure 1). As well as the case-study approach, CIBR has been undertaking focused biophysical science into the fate and effects of emerging contaminants and mixtures of contaminants, which have been identified by the wastewater industry as critical knowledge gaps.

We have developed:

- a blueprint for successful community engagement
- an ecotoxicological platform that ranks contaminants of concern using chemistry and bioassays and also allows analysis of the impacts of mixtures of contaminants
- smarter ways of recycling biowastes such as vermicomposting, pyrolysis for energy production, and manufacturing biochar to mitigate potential environmental impacts of contaminants.

The CIBR is set to play a critical role in moving New Zealand to a more sustainable way of managing biowaste. With specialists in environmental microbiology and toxicology, forest ecology, soil science, molecular biology, soil chemistry and biochemistry, social sciences, and Māori issues-based research, the CIBR has a broad range of skills. It also has strong connections with universities, industry and local authorities and a strong focus on engaging communities to educate and empower.

JACQUI HORSWELL — ESR, CENTRE FOR INTEGRATED BIOWASTE RESEARCH
P: 04 914 0684 E: jacqui.horswell@esr.cri.nz

The greywater pipeline

Grey water is household water from kitchen sinks, dishwashers, washing machines, showers, baths, and basins. As such, it contains a complex mixture of chemicals used in household products, such as surfactants, detergents, bleaches, dyes, enzymes, fragrances, flavourings, preservatives, oils and greases, and antimicrobials. CBIR scientists are currently researching the environmental effects of some of the chemicals found in greywater. One potential effect of these chemicals is the loss of soil structure, which can lead to soil compaction and surface sealing. Another effect is the contamination of waterways. Phosphate, for example, while beneficial for lawn growth, becomes a pollutant in waterways, causing increased algal growth.

Scientists have paid particular attention to chemicals such as triclosan, an anti-microbial compound found in soaps, toothpastes, deodorant, and other personal care products, bisphenol-A, a plasticiser, and the pharmaceutical, carbamazepine. Triclosan can have toxilogical effects on soil organisms, particularly on earthworms and springtails.

Antimicrobials, also found in greywater, are another environmental issue currently being addressed. Antimicrobials kill both pathogen and beneficial microbes in soils, which can have adverse effects on microbial processes such as the decomposition of plant litter. Furthermore, enzymes in greywater can also upset the natural enzyme balance in soils.

FIGURE 1 Sampling soils under a greywater application site onto a household lawn.

Several new technologies are available that help scientists analyse the effects of contaminants on soil properties (Figure 1). For example, ESR, Landcare Research, Plant & Food Research, and Northcott Consultants are conducting lysimeter experiments to investigate the change in soil properties caused by zinc and copper in combination with tricolsan. Soil analyses conducted by Scion, Cawthron Institute, ESR, and Landcare Research are comparing the effects of applying biosolids on soil properties and on tree growth in pine plantations. To examine the overall effects on soil properties and the growth of native plants, Scion scientists are also applying different vermicasted and non-vermicasted mixtures of biowastes to degraded pumice soils.

CRAIG ROSS — LANDCARE RESEARCH
P: 06 353 4907 E: rossc@landcareresearch.co.nz

Movement of *E. coli* through stony soils

Irrigation of dairy shed effluent (DSE) onto land is an integral part of New Zealand's farming practice. The use of inappropriate soils can result in contamination of ground waters with microbes and nutrients. Animal wastes such as DSE contain microbes that cause disease in humans, including *Cryptosporidium*, *Campylobacter*, toxigenic *Escherichia coli*, and rotavirus. A gap in our knowledge is the ability of stony soils to treat DSE safely. The problem with stony soils is they have a limited water storage capacity compared with many non-stony soils, and pastures can rapidly dry out, which leads to low productivity. The reason for the limited water storage is that stones in the soil occupy space but are not available to store water. To compensate for their inability to store water, stony pastural soils tend to require irrigation for intensive use. However, as their soil water storage is limited, irrigation volumes need to match. Too large an irrigation volume, or rainfall after irrigation, can exceed the limited capacity of soil water storage, resulting in water draining from the soil. To maintain optimal soil

FIGURE 1 Selwyn very stony soil showing stones throughout the profile

water content for pasture growth, stony soils are irrigated frequently, which can result in topsoils frequently having high water content.

At high water content topsoils can be pugged by intensive stocking. In New Zealand stony soils are an extensive landscape in eastern regions of the North and South Islands, with 1.68 million hectares mapped that occur on slopes <15° and therefore have potential for intensive land use. Irrigated dairy farming has become a major land use on these soils, with 232 000 hectares under this land use in 2012. Over the last decade the Canterbury region has seen a doubling in dairy farm area, with 71% of dairy farms now located on stony soils with <400 mm of fines over stony alluvium.

Replicates of four different stony soils were collected from Canterbury as intact soil lysimeters 460 mm in diameter and up to 750 mm deep. The soils had either stones to the surface or 300–600 mm fines over stones (Figure 1). To determine leaching characteristics of the soils a pulse of DSE (25 mm depth) was applied to the soil cores followed by continuous artificial rainfall, for one pore volume, at 5 mm h–1 (Figure 2). Leachates collected from the bottom of the soil cores were analysed for *Escherichia coli*. The lysimeters were then treated with hoof pugging using a mechanical hoof, and the *E. coli* leaching characteristics of the soil
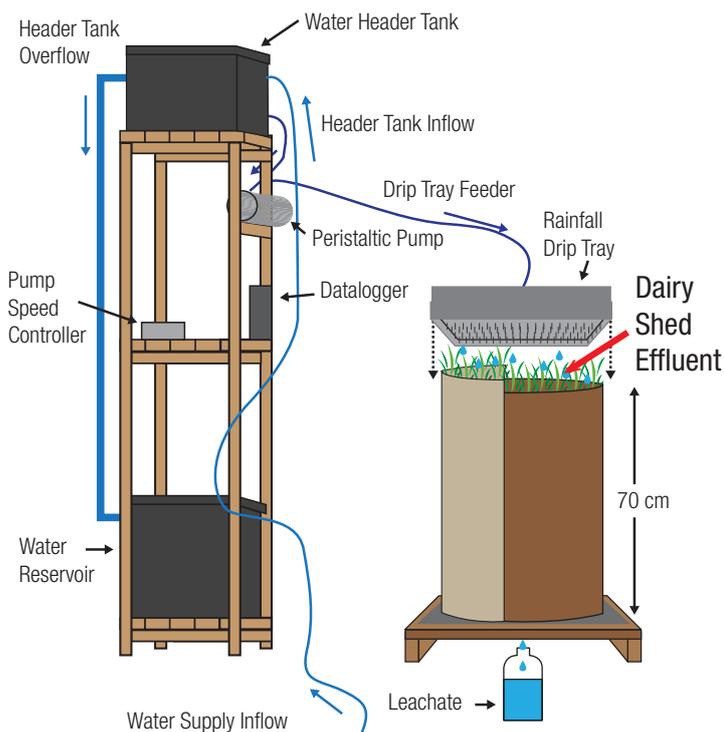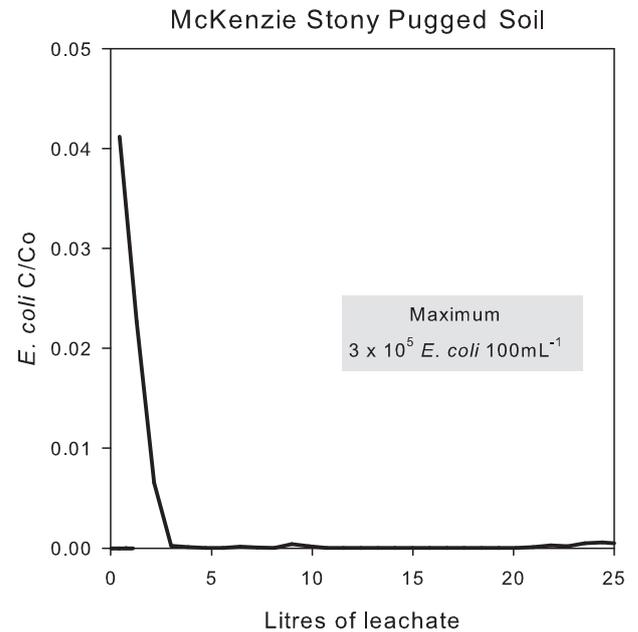

FIGURE 3 Ratio of *E. coli* applied to that in the leachate (C/Co) of a pugged Mackenzie stony soil core after a 25 mm application of DSE followed by rainfall at 5 mm/h. The peak at the start of the breakthrough curve indicates that some of the DSE is flowing through the soil via larger pores and not being filtered.

determined again. *E. coli* breakthrough curves revealed that the potential for *E. coli* to leach through the soils was high for Selwyn very stony soil and low for most other soils analysed that had silty material of varying depths over stones. After pugging, which disrupts the physical structure of the topsoil, *E. coli* leaching increased in Mackenzie soil, which has stones to the surface (Figure 3). Increased *E. coli* leaching likely occurs as effluent ponds in hoof pugs and may be transmitted via a worm hole or soil structural void. For most other soil cores *E. coli* concentrations in soil leachates were low.

This means that in stony soils with stones close to the surface (i.e. soils with small soil water storage), shallow groundwater is potentially vulnerable to microbial contamination as irrigation or rainfall can quickly induce water movement through the soil. Furthermore, the frequent irrigation practised on stony soils maintains a higher topsoil water content than in non-irrigated soils. At high water content, topsoils are more liable to pugging by stock, which increases microbial leaching. Therefore stony soils are best managed with shallow depth irrigations that retain the irrigation water within the soil profile. Furthermore, stocking following irrigation or rainfall should be avoided when there is increased potential for the topsoil to become pugged.

MALCOLM McLEOD — LANDCARE RESEARCH
P: 07 859 3704 E: mcleodm@landcareresearch.co.nz

FIGURE 2 Experimental set-up.

New guidelines for managing groundwater

Managing aquifers effectively requires sound understanding of capture zones – the area of land that feeds into the aquifer – as well as of the way land use can affect water quality.

Capture zones that surround a water body do not necessarily follow a simple rule. They vary greatly in size and shape depending on hydrogeology and terrain.

There has been no standardised and robust approach to delineate capture zones in New Zealand. So this year, GNS Science, in collaboration with ERS, produced a set of guidelines for councils on protecting water features, such as wells, streams, and wetlands that receive inflow from

FIGURE 1 To help protect the quality of groundwater flowing from wells, springs, small lakes and wetlands, guidelines are being developed to estimate where these features gather their water.

groundwater. Currently in draft form, the guidelines are designed to support the national environmental standard for human drinking water, implemented in 2008. The national guideline requires councils to know whether a proposed land activity will lie within the capture zone of a drinking water supply source.

Our guidelines provide a uniform and defensible approach for determining the size and geometry of the groundwater contributing area for a water feature. They are an essential management tool for long-term protection of the quality and quantity of New Zealand's freshwater resources.

To develop the guidelines, we reviewed techniques for measuring capture zones from several countries, and identified seven methods suited to New Zealand conditions. We then trialled these methods in different geological settings to ensure they are appropriate for New Zealand. Our guidelines lead the users through a stepwise process of deciding which of the seven methods are appropriate for their needs. A draft version of our guidelines has been circulated to several councils for comment and the feedback from users has helped refine the product substantially.

Some Regional Councils are already applying the methodology to wells and are looking to extend it to springs. They report that it helps significantly in understanding groundwater flow paths. More particularly, the methods described in the guidelines clearly identify where contamination might be coming from.

JOHN CALLEN — GNS SCIENCE
P: 04 570 4732 E: j.callan@gns.cri.nz

Soil organic matter decomposition depends on temperature, but interacts with seasonal variations in litter availability

Future biospheric carbon storage will respond to climatic changes, but different models diverge in their predictions of the biosphere's response by a massive 200 GtC. This divergence is largely due to uncertainties of the strength of the feedback between temperature and soil organic matter (SOM) decomposition.

Despite much work over many years, there is still no consensus

on the most appropriate temperature response function of SOM decomposition. The two most widely used response functions are those developed by Lloyd and Taylor (1994), based on soil respiration under seasonally varying temperatures, and that of Kirschbaum (2000) based on laboratory incubations, but which of these functions provides the better estimate of the true temperature response? The temperature sensitivity was stronger for laboratory than field studies. While laboratory incubations

are conducted under more artificial conditions, it is not obvious why this should increase the temperature sensitivity. On the other hand, field studies have to contend with less controlled conditions that might confound the derived temperature response function.

A huge range of SOM substrates decompose in soils, including plant litter, roots, microbes and humus. Such a range could reduce the measured temperature sensitivity of decomposition (or soil respiration) in field studies if substrate availability is lower in warm (and wet) seasons, which are favourable for decomposition.

This can be illustrated with a simple one-pool model, run with constant litter input, and with respiration dependent on pool sizes and temperatures. In the model, the recalcitrant pool decomposed slowly so that it had increased considerably before average respiration rates matched carbon input. With its large size, the relative size of the pool changed little throughout the year so that respiration had a unique temperature dependence. With more readily decomposable SOM, however, a larger fraction could decompose at each time step. In summer, respiration exceeded the constant input rate, depleted the pool, and reduced respiration. Highest respiration occurred before mid-summer and showed strong hysteresis, with autumn rates substantially lower than rates in spring.

These simulations were repeated with the CenW model with its more realistic multiple-pool structure. Patterns were similar to those of the one-pool model, with recalcitrant litter (e.g. conifer) having a unique temperature dependence. For labile litter (pasture), however, there was strong hysteresis, with autumn rates substantially lower than spring rates. Changes in labile substrate counteracted the effect of temperature, so that substrate pools shrank as a direct consequence of more favourable temperatures. This resulted in lower apparent temperature dependencies. It flattened the derived temperature response function compared with the underlying intrinsic temperature response.

Varying substrate supply shifted the temperature response functions in a direction, and of a magnitude, similar to the difference between laboratory and field-based observations. Temperature dependence based on laboratory incubations is therefore likely to be the best estimate of the true temperature dependence of organic matter decomposition.

References: Kirschbaum (2000) Biogeochemistry 48: 21–51.
Kirschbaum (2013) Soil Biology & Biochemistry 57: 568–576.
Lloyd & Taylor (1994) Functional Ecology 8: 315–323.

MIKO KIRSCHBAUM — LANDCARE RESEARCH
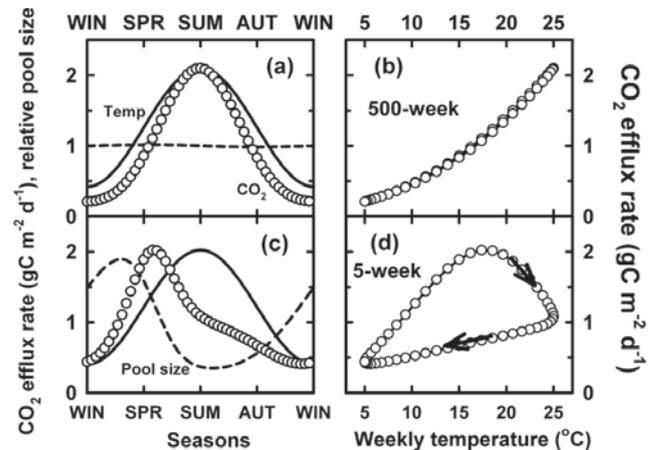P: 06 353 4902 E: kirschbaumm@landcareresearch.co.nz

FIGURE 1 Simulated respiration rates (o) using a one-pool model, as a function of time (a, c) or temperature (b, d) for recalcitrant (a, b) or labile organic matter (c, d), with turn-over times given in the Figure. The dashed lines in (a, c) show changes in relative pool sizes, and solid lines show relative temperature.
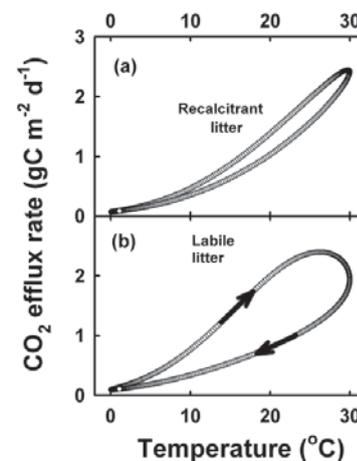

FIGURE 2 Simulated respiration rates as a function of temperature based on CenW simulations parameterised for conifer stands (a) or pastures (b).
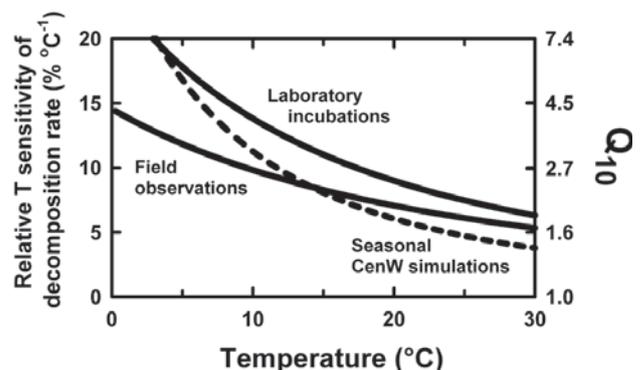

FIGURE 3 Relative temperature sensitivity based on field measurement, laboratory incubations, and CenW simulations with the temperature dependence from lab incubations but seasonally varying substrate availability.

A new spatial model for New Zealand soil carbon

Soil carbon is part of the life support system of the soil, and it is widely accepted that carbon content is a major factor in the overall health of soil. We know that humans increasingly influence the amount of carbon in the soil, through losses induced, for example, by tillage and erosion, and gains sustained by revegetation and adding manure.

The amount of carbon in soil is important for models in agriculture, as well as for components of global climate models. Landcare Research and AgResearch have recently completed a project that sought to build a model that estimates the total carbon content in the soil for every location over the landscape, as well as the uncertainty in the estimates (Figure 1).
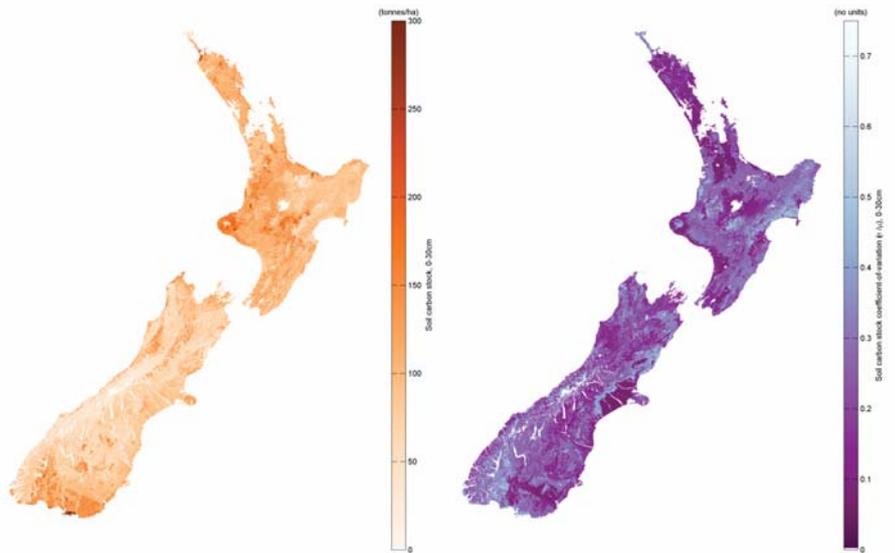

FIGURE 1 (Left) Soil carbon stock (0–30 cm layer), in tonnes/ha; (Right) Relative accuracy of the soil carbon stock estimate (standard error/mean)

To build the model, the researchers assembled all the major soil carbon data sources from New Zealand, as well as a range of map layers thought to be associated with soil carbon. These layers describe climate and terrain, as well as soil and landscape. The aim was that the map layers could be used along with the soil carbon sample data to build a model that describes soil carbon in terms of the various map layers. It would then be possible to estimate soil carbon over the landscape using the collection of layers.

There are several problems with this conceptually simple approach. First, the large number of map layers available for use as predictors, as well as their possible interactions, makes the problem of finding the "best" selection of predictors very difficult. Second, available soil data are patchy; some areas are well covered by field measurements while other regions and soil types are relatively sparse in coverage. The disparity in sampling over the landscape causes problems in building a model for soil carbon, especially in respect of the uncertainty.

The researchers used a method from data mining ("boosting") to find out the best set of map layers to predict soil carbon. Boosting is a method that can readily accept a large number of potential predictors of soil carbon, testing each predictor and their interaction in a systematic manner. Boosting has some disadvantages, however; the method can be quite slow and provides a model that is difficult to interpret. So the result from data mining was used as a starting point for a conventional statistical model-building exercise, but it was a crucial step that drastically reduced the time taken to develop the final model for soil carbon.

A critical step in the research was the development of a model for the uncertainty of the soil carbon estimates, which is the range of soil carbon values within which one might find the "true" value of soil carbon, given some set of climate, terrain, and other landscape conditions. Model uncertainty is essential if the uncertainty or confidence estimates are needed in downstream agricultural and climate change models.

STEPHEN McNEILL — LANDCARE RESEARCH
P: 03 321 9737 E: mcneills@landcareresearch.co.nz

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