THE NEW FACES OF SOIL RESEARCH

In 2006 the *International Union of Soil Sciences* challenged 55 of the world's leading soil scientists with the question 'what is the future of soil science?[1] Originating from 28 different countries, with varied careers and research areas, the responses these soil science 'superstars' provided were startlingly similar.

Their answers paint a picture of an evolving field of science that includes emergent themes such as:

- *Understanding the complexity of the soil ecosystem and all its dynamic interactions*
- *The increasing use of sophisticated technologies to understand, measure and manage soils*
- *The interaction of soil science with other science fields necessitating cooperation, effective communication and data sharing with other disciplines*
- *The socialisation and humanisation of soil science, including how soil relates to society and its goals*
- *The opportunity of the science to contribute to resolving real problems in policy, regulation and practice*
- *The requirement for soil scientists to coalesce, synthesise and disseminate knowledge effectivel*

In this issue of Soil Horizons we explore how, 10 years on, some of these 'faces of soil science', predicted in the IUSS 'Future of Soil Science', manifest in New Zealand science and application. The articles that follow highlight new and ongoing research to understand system complexity, including a previously unknown nitrogen cycle pathway that may help reduce greenhouse gas emissions and improve aquatic ecosystems; a holistic Maori view of forest resilience within a tukutuku o te ora (web of life) and how this might be enhanced using trees own naturally occurring microbiota (mahi ngātahi – resilience through collaboration); and some emergent research showing soil carbon may increase on intensively farmed and irrigated dairy pasture.

Several articles demonstrate how new technologies can contribute to resolving science conundrums, including quantifying riverbank erosion; development of a phone app to allow instantaneous remote monitoring of soil moisture status and control of irrigation equipment; and cost-effective scanning of soil samples through the use of vis-NIR spectroscopy that will provide insight in soil processes and properties on a global scale.

This issue also provides an update on an MBIE-funded programme on Innovative Data Analysis, which aims to develop better tools and infrastructure to facilitate use of existing soils data to support environmental reporting and decision making. The recent adoption of global interoperability standards for soil research data leaves us poised on the brink of a new era in global collaboration in soil research.

Finally, and critical according to those soil science superstars, we review new efforts in knowledge transfer and capacity-building. Development of a Pacific Soils Portal that would centralise soils knowledge across the Pacific and make it available for all land users looks more likely after many years working with Pacific Island countries and territories to understand knowledge needs. Within New Zealand, we showcase a collaboration with Hawke's Bay Regional Council to run training workshops on understanding soils and using 'S-map Online'

[1] IUSS International Union of Soil Sciences 2006. The Future of Soil Science / edited by Alfred E. Hartemink. Wageningen: ISBN 90-71556-16-6

NEW MBIE RESEARCH PROGRAMME PREVIEW

Landcare Research has been successful in obtaining long-term MBIE funding in the latest round, including investment for three soil-related research programmes. We briefly preview the research below:

Science to underpin next-generation S-map and smarter land management

Soils are one of NZ's most valuable and strategic resources, but they are highly complex and variable. Understanding soil variability and behaviour is fundamental to smarter land use and land management decision-making, including on Māori land. In a new programme of research, Sam Carrick, Linda Lilburne, and their team will focus on developing the underpinning science for a next-generation S-map. The research will include the:

- development of a spatial framework and a flexible technical infrastructure that supports the use of 'digital soil mapping' techniques
- quantification and predictive modelling of soil hydrological attributes that control water flow through soils
- development of tools and outputs to support different decision-making needs that are more culturally responsive, interactive, and relevant at a range of scales.

Research results will be delivered through S-map Online and facilitated by capacity-building programmes with users. Once completed, this research will substantially reduce uncertainty in soils information and play a valuable role in guiding decision-making. It is envisaged that the improved soil information will underpin regional economic growth and Māori land productivity; inform irrigation development; and support better nutrient management.

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Soil ecosystem health and resilience – a pathway to prosperity and well-being

Healthy soils are essential to sustain primary sector production and unlock the potential of Māori land, but pressure on our soils is increasing under agricultural intensification and land use change. In response, the Crown has set a national goal of healthy, resilient soils by 2020. NZ currently lacks agreed ways to assess and quantify long-term soil health, and urgently needs a unified national framework to monitor and enhance long-term soil health and resilience. Current soil health measures focus on short-term soil characteristics, and do not include soil resilience or Māori values.

Bryan Stevenson's team will use innovative methods to test long-term land use sequences on different soils to determine if land use intensification affects soil characteristics thought to be stable over human lifespans. Understanding whether soils are subject to thresholds from land use intensification beyond which abrupt changes occur, is vital to assessing long-term soil health at local, regional, and national scales. Concurrently, co-project leader Garth Harmsworth will work to define concepts of soil health within a Māori cultural context.

Defining long-term soil health from a Māori perspective and integrating cultural value systems with western science and policy needs will deliver a nationally consistent universal soil health framework. Primary industry, iwi/hapū, landowners, and central and local government can then use this framework to enhance long-term soil health and resilience, ensuring that landowners can increase the productive capacity of soils and meet community and market expectations, while still operating within environmental limits.

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Innovative ways to reduce farm nitrogen losses by manipulating carbon inputs

Transforming dry, eastern areas of the country into highly productive farming regions can be achieved through water storage schemes and irrigation. However, as these soils are typically shallow and stony, irrigation and nitrogen inputs need to be managed carefully to avoid increases in greenhouse gas emissions and decreases in groundwater quality. This is crucial to ensure the health of rivers and lakes and meet the cultural expectations of Māori in their efforts to sustain their relationships with te taiao (the natural environment).

In a novel research programme, David Whitehead's team from Landcare Research, Lincoln University, Plant & Food Research, and AgResearch will investigate the biological processes that modify soil carbon and nitrogen cycling in stony soils, leading to nitrogen leaching and gaseous losses. Their approach involves experimentally manipulating carbon inputs into soils, measuring the impact on nitrogen losses, and using molecular techniques to reveal the biological drivers. This will provide land managers with improved management practices to reduce nitrogen leaching to groundwater and lower nitrous oxide emissions, ultimately enabling them to operate profitably within the nutrient discharge limits set by regional councils. The research will contribute to the government's 'export double' and water quality goals while reducing environmental risk by improving water quality, increasing soil biodiversity, reducing greenhouse gas emissions, and enhancing the exercise of kaitiakitanga (guardianship and protection of the environment).

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NEW WAYS OF REMOVING EXCESS NITROGEN FROM AGRICULTURAL ECOSYSTEMS

Fertiliser truck. Image - John Hunt

Adding fertiliser nitrogen (N) to soil is a common agricultural practice worldwide, but less than 20% is actually harvested in plants. The remaining excess nitrogen from fertiliser and livestock excreta is reactive and can have undesirable environmental consequences, such as increasing greenhouse gas emissions and detrimentally affecting aquatic ecosystems. A group of New Zealand and USA scientists, working together since 2014, recently discovered a previously unknown pathway for removing excess reactive N in soil.

They found that reactive N could be chemically converted to unreactive di-nitrogen (N2) gas without forming the greenhouse gas nitrous oxide (N_2O) as an intermediate product. Our atmosphere is 78% N_2, so when reactive N becomes N_2 in the atmosphere, this is considered a permanent sink. Atmospheric N_2 is not reactive and is not a greenhouse gas. The international team have applied new approaches and techniques developed by Dr Andrew McMillan (Landcare Research) and Professor Craig Tobias (University of Connecticut) to confirm chemical formation of hybrid N_2 under standard conditions of temperature and pressure. Hybrid N_2 is formed when organic N and inorganic N are combined. Current models of the nitrogen cycle indicate hybrid N2 is evidence of biological production by very specific bacteria or fungi in the absence of oxygen. However, this new pathway shows hybrid N_2 formed in the absence of biology and in the presence of oxygen. This exciting discovery may help explain gaps in the global nitrogen budget and provide new opportunities for mitigating excess reactive N in the environment. Preliminary data from investigations at the Virginia Institute of Marine Sciences provide additional evidence that hybrid N_2 is formed abiotically, particularly for deep sediments. These results are significant, as they demonstrate the potential for abiotic N_2 formation worldwide.

These research finding were made possible by a new analytical instrument capable of measuring atmospheric concentrations of both N_2 and N_2O. This instrument, owned by Landcare Research, is the only one of its type in New Zealand (Fig. 1). The technology facilitates new advancements in the field of soil N cycling in New Zealand that were not possible previously. Analytical instruments at the University of Connecticut, tuned to detect isotopes of N_2, utilised microbiological protocols developed by the New Zealand team (Figs 2 & 3) to provide independent data. An international team effort was then able to distinguish chemical formation of hybrid N_2 as completely independent of N_2O – a finding that has not been reported until now.

The team is now developing proposals for further funding that will allow them to investigate on-farm applications for transforming excess N from soil and water into unreactive atmospheric N_2 gas without producing N_2O. This may allow scientists to develop options to manage the fate of agricultural N while avoiding greenhouse gas emissions.

Acknowledgements: This work was partially funded by a USDA-NIFR grant [2014-67019-21614]; New Zealand's Ministry of Business Innovation and Employment, Royal Society of New Zealand International Travel Programme; and New Zealand Ecosystems and Global Change Fund. The authors are grateful to Veronica Rollinson at UConn, Trish McLenachan at Massey University, and Megan Peterson and Landcare Research Auckland for invaluable technical assistance.

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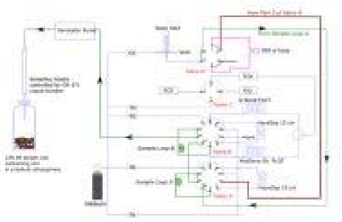

Figure 1: Schematic of the robotized instrument developed for simultaneous N_2 , N_2O, CO_2, and O_2 analyses at Landcare Research, Palmerston North.

Figure 2. Rebecca Phillips uses sterile techniques in the laboratory to quantify chemical and biological production of N_2O and N_2.

Figure 3. Thilak Palmada sets up the evacuation line for measurements of N_2 and N_2O by controlling headspace with either 100% helium or heliox (20% oxygen, 80% helium).

MEASURING BANK EROSION USING HISTORICAL AERIAL PHOTOGRAPHY AND LIDAR

Introduction


Bank erosion. Image - Les Basher

Bank erosion (Fig. 1) is commonly perceived as a significant contributor to river sediment loads but there are few measurements to quantify bank erosion rates. Landcare Research scientists have studied river bank erosion in the Kaipara Catchment in Northland to better understand the sediment dynamics of rivers and measure lateral migration of meandering channels. The extent of bank erosion is a function of multiple controlling factors such as storm and flood events, riparian vegetation, adjacent land use, bank material composition, and topography.

This work contributes to the collection of detailed data to improve SedNetNZ, a sediment budget model being developed by Landcare Research (see Soil Horizons issue 24, December 2015), which includes bank erosion as a core component.

Methods

We measured bank erosion for four different river reaches (Wairua, Mangakahia, Tangowahine, and Hoteo Rivers) with average lengths of 11 km, as well as one smaller (3 km long) reach of a tributary to the Tangowahine River. River bank positions were mapped using historical and modern aerial photography and a LiDAR-derived digital elevation model. We also used the LiDAR data to measure the height of river banks every two metres along both sides of the river channels. The results were in the form of polygons signifying either areas of erosion or accretion (deposition) which were combined with local bank height to calculate volumetric erosion and accretion rates.

Results

An example of the mapping is shown in Figure 2. Erosion rates varied widely but were usually greatest on the outside of river bends, particularly downstream of the apex of bends. Sites of accretion typically, but not always, occurred on the inside of bends and were frequently greatest upstream of the apex of inside bends. Straight stretches tended to alternate between erosion and accretion and were generally evenly balanced – in some instances with long stretches of erosion countered by similar stretches of accretion on the opposite bank. However, bank migration rates along straight stretches were not as significant as along river bends.

The average lateral migration of eroding banks for the Wairua and Mangakahia Rivers was found to be –0.139 m/year and –0.210 m/year respectively, with average lateral accretion rates of 0.165 m/year and 0.239 m/year (see Table 1; negative values denote erosion, positive values accretion). These rates are comparable to other measurements of bank migration obtained elsewhere in New Zealand, for example in the Waipaoa River, measured in 2011 by scientists Ron De Rose and Les Basher. Changes in bank height along a river reach can have significant influence on volumetric calculations and underlines the value of volumetric measurements of bank migration over planimetric measurements alone (as given above). The volumetric erosion rates for the Wairua and Mangakahia Rivers are –0.027 and –0.126 m3 per metre of river length per year respectively for the entire period of analysis. Rates of erosion and accretion can be quite different for each of the 4–5 periods assessed. Overall, the results reveal a relatively even balance between erosion and accretion at all sites over the entire period.

Table 1: Channel characteristics and bank migration rates for the five study sites

Study Site	**Wairua River**	**Mangakahia River**	**Tangowahine Tributary**	**Tangowahine River**	**Hoteo River**
Period	1960–2015	1961–2015	1961–2015	1956–2015	1960–2012
Average bank height (m)	2.9	4.5	1.2	3.1	4.9
Average channel width (m)	17.0	19.7	2.6	4.8	15.6
Sum of erosion (m3)	188,800	576,900	28,200	492,000	421,600
Sum of accretion (m3)	178,700	509,200	29,800	364,200	462,900
Average lateral migration (m/yr) at sites of erosion	–0.139	–0.210	–0.158	–0.144	–0.123
Average lateral migration (m/yr) at sites of accretion	0.165	0.239	0.177	0.146	0.125

Average migration rate (m/yr)	0.017	0.021	0.010	–0.009	0.010
Average volumetric migration rate (m3/m/yr)	–0.027	–0.126	0.010	–0.161	0.059

This study has provided detailed volumetric data on bank erosion for a number of periods over the past 60 years to help unravel the amount of sediment removed from a reach as well as that redeposited. To improve the bank erosion component of SedNetNZ, Landcare Research aims to collect additional bank erosion data from a diverse range of reaches and styles of river. These data will support the development of relationships between discharge variables, catchment characteristics, morphological characteristics of streams, and bank migration rates.

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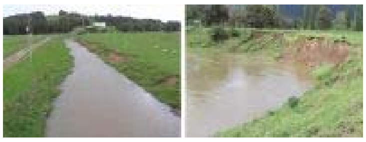

Figure 1: Photos show typical erosion processes at the Mangakahia River site. © Les Basher

Figure 2: An example taken from the Tangowahine River shows the river planforms mapped using historical aerial photography (1956) and recent imagery (2015). The bank migration during this period (1956–2015 is displayed as areas of erosion and accretion in the 2015 map.

FOREST HEALTH AND RESILIENCE MODULATED BY SOIL MICROBES

Forest soil microbes play a critical role in the modulation of tree health and disease expression. Tree disease is expressed when environmental conditions favour pathogens and insect pests. The kauri forests of New Zealand are being compromised by a novel soil-borne pathogen (Fig. 1), and radiata pine forests are being blighted by an exotic foliar pathogen.

Disease impacts on trees could increase in the future through a range of interrelated ecological processes, from individual tree scale to entire forest ecosystems. These changes include:

- increasing atmospheric CO_2 levels
- global temperature rise
- changes in global rainfall distribution
- increased deposition of nitrogen and sulphur generated by human activity
- habitat fragmentation and loss
- increased frequency of biological invasions and other processes threatening biodiversity

When viewed holistically, pathogens and plants exist within a *tukutuku o te ora* (web of life) – a wider environmental network of interacting species. In these networks, the interactions between species contribute to the natural regulation of disease. An intrinsic part of this web is the tree microbiota, which can be viewed as part of the tree's *whakapapa*.These microbial communities (Fig. 2), the outcome of millions of years of coevolution with their partners, play a key role in long-term tree survival by modulating resistance to stressors, including pathogens.

Plant and ecosystem health is controlled by complex interactions between the plant, the environment, and associated communities of organisms (termed the "phytobiome"). Management strategies that acknowledge these complex interactions are more likely to be successful than those that only focus on one part of the interaction. Advances in genetic technology are helping unlock the complexity that exists in nature and deliver a profile/inventory of the diversity of natural samples. This new technology allows us to establish quantitative linkages between species diversity and functional diversity. Understanding these linkages, enables us to begin deciphering how the genetic machinery of the entire soil–microbe–plant system responds to changes and expresses a particular phenotype (including resistance to disease) under a given set of conditions (e.g. drought, exotic/pathogen invasion).

With human-driven global environmental climate change occurring with unnatural rapidity, the concern is that the short generation time of pathogens will allow them to adapt quickly to changes in distribution (e.g. by accidental introductions) and/or rapid changes in physiology (with or without host switches), while trees will adapt much more slowly due to their longer generation times. This inconsistency is predicted to result in phenotype-environment mismatches, with the resulting *kaore i ōrite* (imbalance) leaving trees more vulnerable to disease. However, there is one facet of a tree's phenotype that may evolve as quickly as pathogens and thus have the ability to protect them – their soil microbiota. This raises two critical questions:

- Can the soil microbiota respond quickly enough to provide sufficient resilience to their tree hosts to maintain health when faced with pathogen pressures caused by climate change?
- If not, is there the potential to manage tree-soil microbiota in a way that will help them maintain the natural resilience to disease threats that their *whakapapa* provides?

These are questions best addressed by a Māori holistic viewpoint together with principles of ecology – notably that biodiversity increases the resilience and stability of ecosystem functions: mahi ngātahi – "resilience through collaboration" (Fig. 4).

STAN BELLGARD, MAJ PADAMSEE AND GWEN GRELET – LANDCARE RESEARCH

Fig. 1: Advancing collar lesion up trunk of kauri tree, Twin Peaks Track, Huia Dam, west Auckland.

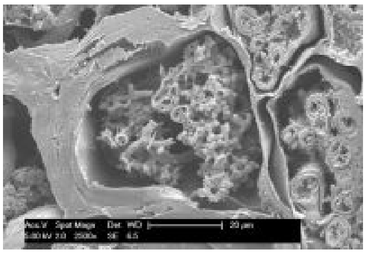

Fig. 2: Kauri nodule cortical cell colonised with arbuscular mycorrhizas (A. Turner, University of Auckland).

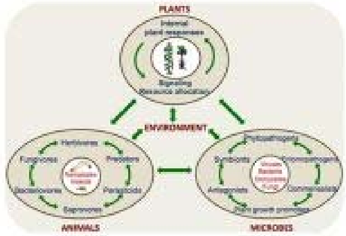

Fig. 3: Excerpt from the phytobiome (American Phytopathological Society) “roadmap” showing the interrelationships that are part of the complex factors modulating plant diseases, their expression, and management.

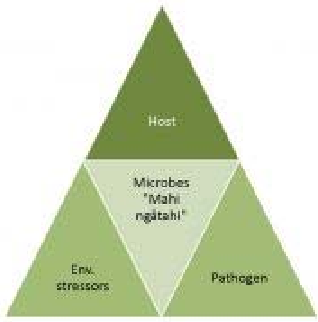

Fig. 4: The “holistic” disease triangle recognising the role of microbes in mediating the interactions between environmental stress, host responses and pathogen ecology and disease aetiology.

NET CARBON UPTAKE OF IRRIGATED DAIRY PASTURE CAN OFFSET ITS OWN NITROUS OXIDE EMISSIONS

Measurement setup to determine greenhouse gas budgets of irrigated pasture. image - John Hunt

Many managed grazed pastures around the world slowly accumulate carbon (C) over time. In other words, on average their uptake of carbon dioxide (CO_2) from the atmosphere plus other C imports (e.g. from animal excreta and fertilisers) exceeds the amount of C lost by respiration, grazing, and harvesting. The surplus C accumulates in the soil and belowground biomass. This is good for soil health and can also offset some of the greenhouse-gas (GHG) emissions associated with farm animals. However, this does not always hold for New Zealand's intensive pastoral systems.

Studies measuring soil C from the same pastures (flat or rolling) many years apart found either no change or decreases over time, while a NZ-wide study sampling neighbouring sites with and without irrigation revealed significantly less C under the irrigated pastures. The causes for observed losses of soil C are still unknown.

We have completed a 3-year experiment on a commercial dairy farm in mid-Canterbury, grazing 900 cows, in order to construct net C and net GHG budgets of an irrigated, intensively managed pasture on a well-drained stony soil (Lismore). The pasture was grazed 10 times per year and received fertiliser (mostly urea) after most grazing events, averaging 226 kg of nitrogen (N) per ha per year. A large pivot irrigator operated from late spring to autumn to ensure that soil volumetric water content did not fall below 30 %.

The GHG budgets include CO_2, methane (CH_4), and nitrous oxide (N_2O). We determined the net exchange of these three gases continuously with micrometeorological methods. To do this, we measured horizontal and vertical wind speeds and their short-term variations, as well as the gas concentrations at two heights above the pasture surface (Fig. 1). Combining these data, we determined the half-hourly net exchanges of the gases representative of a surface area of a couple of hectares. As gas measurements were excluded for periods when cows grazed within this area, the annual budgets of measured CO_2 and CH_4 represent the pasture only, and exclude direct cow emissions.

To construct annual C budgets, we also needed the C inputs from excreta and fertiliser, and the biomass removed by grazing. We measured the pasture biomass before and after some grazing events to accurately determine the dry-matter weight, and with these data calibrated a rising-plate meter that was then used for the other grazing events. From the amounts of grazed biomass, plus amounts of supplements fed during milking, we estimated the amounts of C returned as dung and urine to the pasture. Also from feed intake, we calculated the amounts of N in the excreta, in order to interpret the observed N_2O emissions. We further used the feed intake to calculate the direct CH_4 emissions of the cows. Since these two variables are tightly linked, this approach is more accurate than micrometeorological measurements during grazing events would have been.

In each of the 3 years, we found a net uptake of C by the irrigated pasture (averages in Fig. 2). The pasture emitted CH_4, throughout all seasons. These emissions were about 15 times greater than emissions expected just from cow dung, and similar to rates we measured from a nearby dryland pasture. This is a somewhat puzzling result as the soils are well drained and CH_4-producing microbes usually require oxygen-free conditions; however, similar observations have occurred in other intensively managed grasslands, grazed or harvested. The emissions of N_2O were roughly in line with expectations based on the N inputs from fertiliser and excreta. The global-warming potential of the N_2O emissions (expressed as CO_2-equivalent mass) was approximately equal to the C uptake. Hence, this irrigated dairy pasture was offsetting its own N_2O emissions. However, the CH_4 emissions directly from the cows were 2–3 times greater than the N_2O emissions, and about 6 times greater than the pasture's CH4 emissions. These cannot be offset by C uptake, therefore the dairy system including pasture and cows is a net GHG producer.

Acknowledgements: We thank Anitra Fraser, Matti Barthel, Tony McSeveny, Graeme Rogers, Rebecca Phillips and Gabriel Moinet for their contributions to this project. Purata (formerly Synlait Farms Co.) provided detailed farming operation information. This research was undertaken with CRI Core Funding from MBIE.

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FIGURE 1 Measurement setup to determine greenhouse gas budgets of irrigated pasture. Intakes for gas sampling from two heights are on the taller mast on the right, recognisable by the yellow and blue tubes. Instruments to measure fast changes of wind and CO_2 concentration are mounted on the smaller mast, rear left. Other visible instruments record radiation, temperature, humidity, and wind. (Photo: John Hunt)

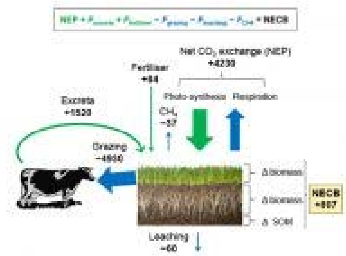


FIGURE 2 Net ecosystem carbon budget (NECB) of the irrigated dairy pasture, and the C exchanges contributing to it (means of 3 years), in kg C/ha/yr. Positive values indicate that the pasture system gains C.

MAXIMISING THE VALUE OF IRRIGATION

The MBIE Programme ‘Maximising the Value of Irrigation’ is undertaking research to support industry develop irrigation control systems that improve productivity, minimise wasted water, and reduce negative environmental impacts such as ponding and nitrate leaching.

The programme is led by Landcare Research with Plant & Food Research, and also includes researchers from FAR, Lincoln AgriTech, Massey University, and the University of Southern Queensland. The Programme is also financially supported by the Vegetable Research and Innovation Board, Hawke’s Bay Regional Council, ECan, and IrrigationNZ.

The Programme, now half-way through its 6-year duration, has gathered a wide range of soil data for modelling over two irrigation seasons from commercial farms (arable, mixed arable/pastoral, process vegetables, high-value seed crops, and fresh vegetable crops) and research trial plots (Massey, Lincoln, Chertsey). These data are being used for scenario modelling with APSIM software (Agricultural Production Systems Simulation model, www.apsim.info) to investigate (i) potential benefits of precision irrigation for different levels of soil variability, and (ii) soil management effects on irrigation water use efficiency (including mulching, cultivation, hydrophobicity). The model uses a specially developed spatial framework for sub-paddock scale modelling (Fig. 1) with a web processing service created to generate APSIM soil libraries from the S-map database.

An APSIM modelling exercise has been completed for one focus farm, where a 470-m centre pivot, with variable rate control, is used to irrigate a range of crops at any one time. The modelling was undertaken by Landcare Research scientist, Joseph Pollacco, for a 10-year period. Recent alluvial soils and older Brown and Gley soils are mapped for this site by pedologist Andrew Manderson and the modelling exercise compared the three alluvial soils (Fig. 2). The results showed that variable rate irrigation would reduce drainage and run-off by about 14% through reducing irrigation-related drainage events, and that these water savings vary from year to year depending on patterns of rainfall during the irrigation season. The modelling exercise also found that water savings for a shallow rooting crop (peas) was 11% and for a deeper rooting crop (maize) was 8%.

Modelling exercises are being validated by in-field soil moisture monitoring, using wireless soil moisture sensor network technologies, developed within this programme, by Jagath Ekanayake. Jagath has also developed a smart phone app, which is being developed and shared with participating farmers, to investigate how effectively real-time soil moisture monitoring can be used to improve irrigation scheduling decisions (see Apps for Irrigation Control).

CAROLYN HEDLEY, PIERRE ROUDIER AND JAGATH EKANAYAKE – LANDCARE RESEARCH

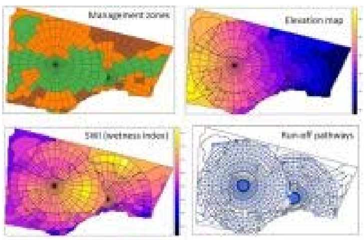


Figure 1 Soil maps are converted into (a) management zone maps for potential upload to precision irrigation control software, and for Spatial-APSIM modelling exercises. A digital elevation map (b) is used to derive a relative wetness index (c) for each cell, and potential water run-off pathways (d).

Figure 2: Farm-scale map overlaid onto EM map indicates the pattern of soils occurring under the centre pivot (soil map: A Manderson).

APPS FOR IRRIGATION CONTROL

Scientists at Landcare Research are developing apps for smart phones and tablets that monitor soil moisture status for irrigation scheduling, and allow control of irrigation equipment.

Satellite communication systems are being trialled with this product to overcome poor cellular coverage that would otherwise create problems in some rural parts of New Zealand. The app has been successfully tested on smart phones from different manufacturers, and can be used to control and monitor wireless soil moisture sensor networks over the internet. The soil moisture monitoring part of the app is being used at irrigation research trial sites this season, and the remote control of equipment component is being beta testing in controlled laboratory conditions.

JAGATH EKANAYAKE – LANDCARE RESEARCH

A GLOBAL SPECTRAL LIBRARY FOR SOILS

Visible–near infrared (vis-NIR) soil spectroscopy is a relatively new technology for rapid prediction of some soil properties. The reflectance of light in the visible and infra-red range of the electromagnetic spectrum relates to the bonding and stretching vibrations of molecules in the soil – primarily molecules containing carbon, nitrogen, oxygen, and hydrogen atoms. As a result, reflectance spectra recorded from the soil surface (Fig. 1) can be used to predict properties, such as soil organic carbon content.

A reference set of spectra, with associated laboratory measurements, calibrates a prediction model for soil properties of interest such as carbon or clay contents. The model is then applied to predict soil properties solely from collected soil spectra. Some attributes, such as iron oxides can be predicted directly by reflectance at specific known wavelengths, whereas others, such as soil carbon, require multivariate statistical analysis of the spectral dataset.

Our soil spectroscopy research group at Landcare Research has been collaborating with international collaborators since 2008 to develop a global spectral library of soil Vis-NIR spectra. This collaboration was initiated by Raphael Viscarra Rossel, CSIRO, Canberra, who provided method guidelines and measurement protocols for consistent measurement of soil spectra by laboratories. Contributors were asked to provide a minimum set of analytical data, geographic location, and metadata with the collected spectra. The global database has spectra from 92 countries, representing seven continents, including spectra from soils in the World Soil Information (ISRIC) collection.

This global initiative is addressing the need for more soil data to improve our understanding of soil processes at scales ranging from regional to global. The global spectroscopic database was found to accurately estimate soil organic and inorganic carbon, extractable Fe, and fairly accurately estimate cation exchange capacity (CEC), clay, and silt content and soil pH. The global soil spectral library is the largest of its kind and provides a unique snapshot of global soil diversity.

Traditional methods of soil analysis are very time consuming and costly, limiting the number of samples that can be analysed. In contrast, the collection of Vis-NIR spectra is rapid (Fig. 2) so that many more estimates of soil property values can be derived for the same cost, to drive down the degree of associated uncertainty.

Acknowledgement: Funding provided by The New Zealand Government to support the objectives of the Livestock Research Group of the Global Research Alliance on Agricultural Greenhouse Gases.

CAROLYN HEDLEY AND PIERRE ROUDIER – LANDCARE RESEARCH

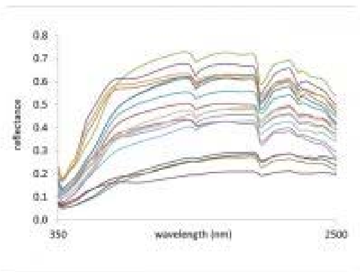
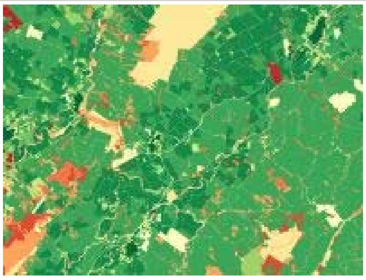


Fig. 1: The Vis-NIR spectrum of a soil is a unique signature for that soil reflecting its soil properties. Each line in this figure represents the spectrum of a different soil sample.

Fig. 2: Carolyn Hedley and Pierre Roudier with a new automated soil core scanner for direct measurement of volumetric soil organic carbon content

THE INNOVATIVE DATA ANALYSIS RESEARCH PROGRAMME: AN OVERVIEW AND PROGRESS TO DATE

The Innovative Data Analysis (IDA) programme is an MBIE-funded research project led by Landcare Research that runs for 4 years (2014–2018). The overall goal is to develop better infrastructure and tools to access and make use of existing data to support environmental reporting and decision-making.



Land use mapping.

The programme works in partnership with a wide range of stakeholders including regional and central government, and aligns with key initiatives such as the State of the Environment (SOE) reporting, Environmental Monitoring and Reporting (EMaR) and the National Science Challenges. There are three main test applications based on indicator domains: soil health, land use, and species occupancy. A key aspect of the project is developing techniques to characterise the provenance, quality, and uncertainties for each data source and recording workflows to enable an auditable process behind any reporting product.

In the first 2 years we have focused on integrating, harmonizing, and federating key land resource and biodiversity datasets in a standardised, statistically robust and transparent way, with some of the highlights including:

Federating datasets on soil

To support the development of soil quality indicators, data from the legacy '500 Soils' database was evaluated to establish whether it could be loaded into Landcare Research's new National Soils Data Repository (NSDR). The feasibility study showed that the NSDR is capable of storing the data; however, various initial data cleansing steps were required. As a result it will be important to look at defining national standards and procedures for the registration of sites and collection of data, so that monitoring datasets are recorded in a consistently organised way.

A linked project, the Open Geospatial Consortium (OGC) Soil Interoperability Experiment (IE), has recently been published as an approved OGC Engineering Report. This 6-month experiment successfully reconciled multiple existing soil data exchange models into a single draft standard that was then implemented as a set of internationally interoperable prototype data services and demonstration clients. Through its technical control of this project, Landcare Research was able to ensure that the IE work could subsequently be adapted for soil quality data.

Federating datasets on land use

Reliable and up-to-date land use (LU) information is important for the increased use of spatial modelling, for analysing and reporting trends, and for the development of fair and consistent land-use policies. Several independent LU classifications of varying qualities have been developed for New Zealand, all of which tend to draw on the same public and commercial datasets. However, classification methodologies are only occasionally documented and this can make it difficult to regenerate a given classification when the underlying source datasets are updated. The IDA programme produced a NZ Land Use Classification Regenerator based on spatial models and recorded workflows. The emphasis was on practical LU classifications, particularly those orientated towards rural and agricultural uses, e.g. land use classification for soil monitoring, and the Land Use of New Zealand (LUNZ). We have been successful in reproducing these classifications with a repeatable workflow using ArcGIS. We are now developing a platform-independent technology 'pyLUC' that provides a framework for defining and constructing LU changes that are automatically well-documented and easily reproducible. To enforce the use of well-documented and versioned input data, pyLUC can currently interact with datasets available on the LRIS portal. More development is planned to allow automatically generated reports for each classification, and additional usability features, such as creating a graphical user interface.

An open source linked data registry system was also deployed to test its suitability for the publication and management of land use classification systems. This registry software uses semantic Web standards and technology to store, describe, organise, search, and publish classification data on the web. Further work will use semantic web tools to infer equivalence between classes. Ultimately these pieces of research will unite, allowing pyLUC to have access to the registry and providing standardised definitions for the automatically-generated reports.

The final 2 years of this programme will focus on investigating different approaches to analysing, modelling, and visualizing indicators.

ANNE-GAELLE AUSSEIL, DAVID MEDYCKYJ-SCOTT, ALISTAIR RITCHIE, ANDREW MANDERSON, BEN JOLLY, JERRY COOPER – LANDCARE RESEARCH

Fig. 1: The IDA work programme follows the information supply chain from data to impact

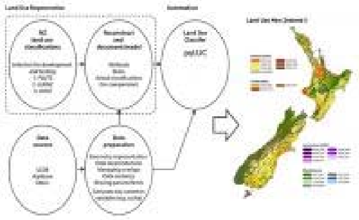
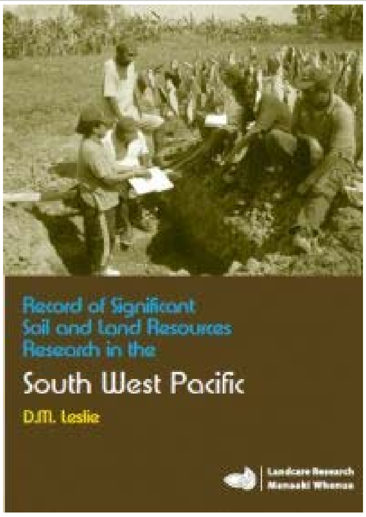


Fig. 2: Pipeline for land use classification (example shown here for LUNZ)

SECURING SOILS KNOWLEDGE FOR THE PACIFIC

Since the 1950s New Zealand soil scientists from DSIR Soil Bureau, and more recently from Landcare Research, have been visiting Pacific Island Countries and Territories (PICTs) undertaking soil surveys and capacity-building to help agriculture and primary sector agencies improve soils knowledge and land-management practices. The breadth and depth of that work has been summarized in Leslie (2010) and been largely funded via New Zealand Aid.



Book cover

Soil mapping in the Pacific has highlighted some significant challenges. In particular, populations are small, providing a limited pool from which to draw expertise, and many of the most able emigrate or are attracted to careers in international agencies. Institutional strengthening is, therefore, often short-lived and needs to be rebuilt before new projects can leverage past development work. As financial resources are also very limited, momentum gained during projects is often short-lived.

While valuable soils knowledge has been accumulated, it is clear that in-country capacity to use and understand that information is limited. Much of this soils data is still relevant but it is generally under-utilized and as a result land management decisions are not always as well informed as they should be.

Over the past 10–15 years, as Landcare Research has been developing its S-map Online and related web-based systems, we have also been promoting the concept of an on-line *Pacific Soils Portal* (PSP) through the Secretariat of the Pacific Community's Land Resources Division (SPC-LRD). The PSP aims to overcome the problems of retaining soils knowledge by centralising the existing knowledge base and improving its availability and relevance to land users through a simple point-and-click interface. Such an interface would enable individual users to link to interpretive knowledge of soils, their properties, and their suitability for agricultural uses for the location of interest. The *Heads of Government Departments* from 23 PICTs recognised the PSP as a good idea, subject to finding appropriate development funding.

The Global Financial Crisis halted progress until the establishment of the Pacific Soil Partnership in 2014. The Pacific Soil Partnership united New Zealand, Australia, and 15 PICTs as a regional node of the *United Nations Global Soil Partnership*. Meetings of the Pacific Soil Partnership held in 2014, 2015, and 2016 have provided a vehicle for reinvigorating the PSP concept within a larger 3-year project "Soil management for resilient agriculture in Pacific Islands". In the last 3 months, the Australian Centre for International Agricultural Research (ACIAR) has funded both a scoping study and preparation of a "phase 1" project proposal. This phase 1 proposal has very recently been reviewed and passed on to phase 2 of the ACIAR funding process, requiring development into a full project proposal.

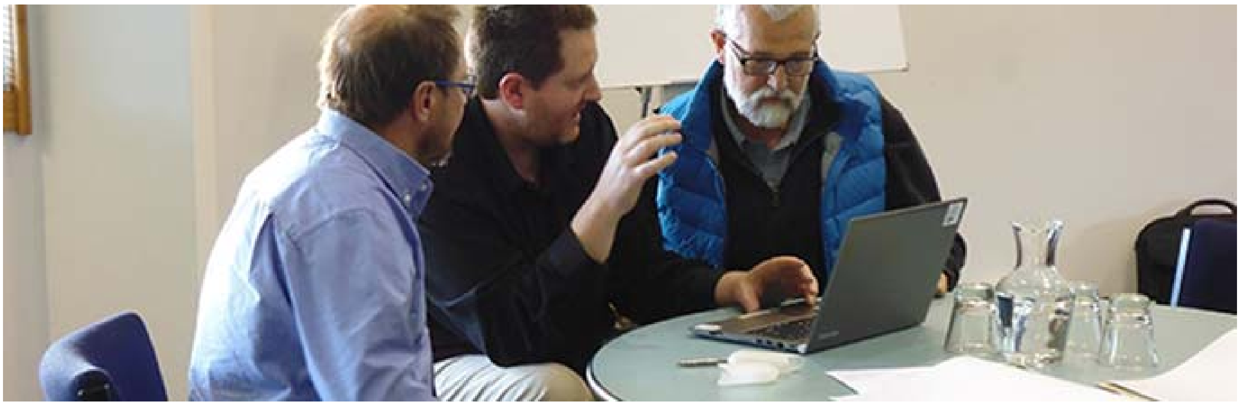
Leslie D 2010. Record of significant soil and land resources research in the South West Pacific, Manaaki Whenua Press, http://doi.org/10.7931/DL1KS3 .

JAMES BARRINGER – LANDCARE RESEARCH

Dr Siua Halavatau from the Pacific Community (SPC) looking at a sweet potato crop in a Tax Allotment on Ha'apai in the central Tongan group. The whole crop is affected by Rose Beetle and is also a little yellow – possibly reflecting macronutrient deficiencies of P or K (common on calcareous soils). This crop's small leaves may also indicate disease (a virus) or micronutrient deficiency of zinc.

Rohit Lal (Ministry of Agriculture Fiji Advisory Officer and Massey PhD student) and Dr Neil McKenzie (Intergovernmental Technical Panel on Soils Representative for the Southwest Pacific Region and Leader of the Australian Soil Research, Development and Extension Strategy) discussing soils and Taro cultivation on the south western slopes of Taveuni. There are concerns about unexplained declines in yield after storm damage caused by Tropical Cyclone Winston.

UNLEASHING THE FULL POTENTIAL OF S-MAP ONLINE THROUGH PRACTICAL TRAINING COURSES



Sharn Hainsworth explaining aspects of S-map online in a hands-on session.

S-map Online is a national soils database that aims to provide fast, simple access to New Zealand soil data. Earlier soil databases were patchy in scale, age, and quality and many maps did not adequately describe the underlying properties of the soil types they represented. In partnership with funders such as regional councils, existing reports and digital information are being integrated and soil maps updated where existing data are of low quality. New areas of coverage are being added as they are completed, with the aim of achieving nationwide coverage at a 1:50,000 scale by 2020. A recent update added data for an additional 7,000 ha in Canterbury, 351,000 ha in Hawke's Bay, and 376,000 ha in the Waikato.

The data provided by S-map Online allow users to explore interactive soil maps, view detailed information about soil classes or attributes, create custom PDF soil maps for printing, and download soil factsheets for specific locations. However, confident end-users are required for the data to be utilised to their full potential, and a recent survey revealed significant demand for more education about S-map, what it can be used for, and how it can be applied.

In response, Landcare Research teamed up with Hawke's Bay Regional Council to run two half-day pilot workshops in early August 2016. The Envirolink-funded workshops focused on building understanding of soils and general awareness of the value of Landcare Research's soil information.

After an introduction from Dr Alison Collins (Director, National Land Resource Centre) and Dr Barry Lynch (Team Leader, Land Science, Hawke's Bay Regional Council), Dr Malcolm McLeod began by presenting a journey through the NZ Soil Classification, with a subsequent session diving into S-map Online. This was followed by practical breakout sessions where participants had the opportunity to use S-map Online and probe the minds of Landcare Research S-map experts.

More than 60 participants from regional and district councils, industry groups (e.g. Fonterra, Heinz Watties, Balance Agri-Nutrients, Irricon Resource Solutions, McCain Foods, HB Wine Growers, AgFirst, Abron) and local iwi (Ngāti Kahungunu) participated. Post-workshop feedback was overwhelmingly positive and many participants indicated their desire for other training (such as in SedNet NZ, Land Use Capability Classification, and understanding soils in the field). The workshops provided a great opportunity to build capacity in using S-map and gain feedback on how it could be improved, which will ultimately ensure S-map is used to create impact. Other regional councils have subsequently indicated their interest in hosting similar workshops, and Landcare Research is investigating the option of providing accredited training.

If you are interested in hosting or attending a workshop, have a request for other science-based training or want to incorporate training within your organisation's accreditation schemes, please contact Alison Collins or Daina Grant for more information.

ALISON COLLINS AND DAINA GRANT – LANDCARE RESEARCH

Dr Malcolm McLeod presenting to a packed room.

Sharn Hainsworth explaining aspects of S-map online in a hands-on session.