Pūtaiao

MANAAKI WHENUA SCIENCE SUMMARY / ISSUE 17 / FEBRUARY 2024

Soil science – the hole story

All the dirt on our soil research

Pūtaiao

Science for our land and our future

Tēnā koe and welcome to Issue 17 of *Pūtaiao* (science), our quarterly publication showcasing the work of Manaaki Whenua scientists.

We are the Crown Research Institute for our land, biosecurity and biodiversity, action on climate change and people's relationship with the environment. We have a clear responsibility to Aotearoa New Zealand: this land, and everything that shares it with us, is our future.

Each issue of *Pūtaiao* describes the benefits and impact of our science in helping to ensure a sustainable, productive future for Aotearoa New Zealand. This issue contains stories on the progress we are making in science for our land and soils. We describe several different aspects of progress in online soil mapping tools, the benefits of embracing technology such as LiDAR and proximal sensing, and take a close look the impact of urban development.

If you wish to be included on the mailing list for *Pūtaiao*, or to find out more about any of the stories, contact Manaaki Whenua's Senior Communications Advisor, Kim Triegaardt: triegaardtk@landcareresearch.co.nz

Cover image: Pedologist Dr Kirstin Deuss (right) with Matt Oliver from Marlborough District Council soil sampling in the Blind River area, just south of Seddon. (Photo: Kim Triegaardt)

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Down to the ground

"I'm not sure this is my most flattering angle," mumbles pedologist Dr Kirstin Deuss as she is head down in a metre deep hole near the Wairau Valley river (see story on page 7).

For the team of pedologists who cross Aotearoa New Zealand (AoNZ) sampling the country's soil, unflattering camera angles are part of the job. Soil sampling is hot, dirty work and involves hours and hours of hard physical labour.

Over 2 weeks, Kirstin and her colleagues will dig between six and eight pits a day, sampling at different depths down the metre-deep holes.

The soil profile needs to be graded for a suite of characteristics, describing differences such as colour, structure, and stoniness, with a final muddying of the hands to confirm the texture.

Samples are then packaged up and sent to the lab where they get tested for chemical and physical attributes, depending on the questions being asked. A large

Matt Oliver from Marlborough District Council identifies soil colour during soil sampling in the Blind River area, south of Seddon.

That's important when AoNZ's high pedo-diversity is considered. Much of our regional identity, land use differences, and environmental challenges reflect how different soils have shaped our use of the land. Think of Northland's very old clay soils, contrasting with the free-draining volcanic soils across the central North Island, to the highly leached soils on the rainfall-soaked South Island West Coast, and the stony glacial outwash soils across the Canterbury plains.

Manaaki Whenua researchers are working across a wide range of issues facing AoNZ, and at the heart of all of them is the soil. In this issue of *Pūtaiao* we highlight a range of research across our diversity of soils.

focus of our current sampling effort is supporting the establishment of the national soil carbon monitoring network, and increasing coverage in our national soil survey programme, S-map.

S-map now boasts information on an incredible 10 million hectares of farmable land (see story on page 4). Manaaki Whenua science portfolio leader Dr Sam Carrick says 68% of AoNZ farmable land area, the land that has the potential for multiple types of use has now had its soils mapped.

S-map is more than a soil map: it's a soil information system, with a comprehensive database and modelling research platform delivering data and information across several platforms and tools.

Pedologist Dr Kirstin Deuss head down in a soil sampling pit with Matt Oliver from Marlborough District Council in the Blind River area, south of Seddon.

S-map expands further

Last year closed out with a significant achievement for S-map, Aotearoa New Zealand's comprehensive on-line resource delivering authoritative soil maps. Through a funding collaboration between MPI and 12 Regional Councils, Manaaki Whenua has completed an extra 500,000 hectares of new soil mapping coverage across some of AoNZ's best food-producing land. The partnership is on track to deliver a further million hectares of new mapping over the next two years.

Pedologist Emily McKay who conducted fieldwork in Northland with Senior Researcher Dr Scott Fraser reported back that the soils in the region were "highly interesting, incredibly variable, and can be really hard to dig!"

"We encountered the famous Kerikeri Oxidic soils, and Allophanic soils formed on young basalt flows, both really valuable for horticulture," says Emily. "The most interesting feature so far among many of the Ultic and Podzol soils is the presence of a silica-rich layer that makes your auger squeak and spin in circles, and are some of the most difficult soils for farmers to manage."

Meanwhile, other researchers collecting data for the most recent S-map update didn't let a little thing like a late spring snowfall stop their important work. Lincoln-based pedologist Balin Robertson soldiered on in the snow down in Mokoreta in Southland to collect his soil samples.

Developed and updated by Manaaki Whenua, S-map provides the best available soil survey data for AoNZ. Displaying basic soil property data like depth, stoniness, and clay content, as well as more complex data like water-holding capacity and nitrogen leaching risk, S-map provides comprehensive and accurate soil information to support sustainable management of our soil resource. There are also tools that help land managers and consultants find the S-map soil type that best matches on-farm field observations.

Soil scientist Dr Sam Carrick says richer soils data mean much better modelling assumptions, which in turn support better decision-making on the ground. "A major focus has been on provision of soil hydrology information, soil attributes that have significant effects on farmers' nutrient budget calculations," says Sam. "More accurate soil moisture information will lead to better knowledge of irrigation demand and nutrient losses."

The new mapping in the most recent release includes nearly 80,000 ha on Banks Peninsula in Canterbury, 143,000 ha in the Catlins region of Otago and nearly 60,000 ha from Waitara to Hāwera in the Taranaki.

Mapping has also been upgraded for the Awatere Valley in Marlborough, Eltham in Taranaki, and approximately 170,000 ha covering the Rotorua Lakes catchment and north to the coast between the Kaituna River and the Pikowai Stream in the Bay of Plenty (turn to page 6).

Balin Robertson collecting soil samples by auger in Mokoreta, Southland.

Filling in the banks

As part of ongoing efforts to extend the coverage of S-map, a team of pedologists from Manaaki Whenua recently targeted one of the very conspicuous blank spots – Banks Peninsula in Canterbury.

This significant achievement had its genesis two decades ago, when Manaaki Whenua partnered with Environment Canterbury (ECan) to upgrade Canterbury's soil information. In 2020, the Ministry for Primary Industries joined the partnership, as part of its S-map expansion programme working with regional councils across AoNZ.

After almost complete deforestation in the late 1800s, Banks Peninsula today is dominated by sheep and beef farms, with some exotic forestry and reserves for native vegetation. Soil parent material is either basalt or wind-blown loess.

Land-use intensity varies because of the variable topography, from flat river terraces to rolling hills and vertical cliffs.

Considering this complexity, combined with the resource constraints of soil surveys and limited access to private land, pedologist Dr Andre Eger says researchers chose to use a hybrid mapping approach. "We first selected sites using a geostatistical algorithm that accounted for topography, climate, geology, and land cover. Then we added a more classic sampling approach using transects across sequences of different landforms (e.g. a succession of levees, river terraces and fans, from foot slopes to ridge crests)."

Soil survey is a collaborative initiative, and the new map reflects the collective contribution of Banks Peninsula farmers, ECan staff, Manaaki Whenua pedologists, and laboratory and informatics staff. At a scale of 1:50,000, it is a significant improvement over the 1:253,000-scale soil map of Banks Peninsula from 1968, which it replaces, and it will support better land-use decisions across the peninsula, including sediment and nutrient management.

Two soil extremes: on the left, a Pallic Soil from loess (with a distinct fragipan, a dense, drainage-impeding layer indicated by a coarse prismatic structure), which is a typical soil for the less-steep slopes at lower elevations; on the right, a Melanic Soil from basalt, a darker soil with a much finer, granular structure and varying amounts of rock fragments, more common at higher elevations and in steeper terrain.

(From page 4) Sam says advances to S-map data have led to its extensive adoption in farm environmental planning, monitoring, and reporting. In addition to the popular S-map Online website, data are supplied directly to an expanding list of Agri-service business tools including those used by fertiliser companies, dairy companies, most regional councils, and banks. S-map data are a critical input in the NZ Water Model (NIWA), the Agricultural Production Systems Simulator crop model (Plant & Food Research and AgResearch), IrriCalc (Aqualinc) and the OverseerFM nutrient budget tool.

“These tools provide critical information to public organisations, farmers and the agri-service sector across Aotearoa New Zealand,” he says.

Additionally, S-map data are used by scientists for erosion, crop production, nutrient management, irrigation, and other hydrological research. Regional councils rely on S-map in the development of regional plans focused on water quality and consenting for water takes.

“Through a collective multi-agency collaboration we have put a large effort into developing easily accessible land resource assessment capability for New Zealand,” says Sam. “S-map Online usage continues to grow, with more than 27,000 registered users downloading 51,000 soil factsheets every year.”

HTTP *smap.landcareresearch.co.nz*

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Advances to S-map data have led to its extensive adoption in farm environmental planning, monitoring, and reporting. In addition to the popular S-map Online website, data are supplied directly to an expanding list of Agri-service business tools including those used by fertiliser companies, dairy companies, most regional councils, and banks.

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Emily McKay mapping soil in the Coromandel.

Scouting out soil data

Marlborough District Council environmental science technician Zeke Hoskins (right) and Manaaki Whenua – Landcare Research technician Kishor Kumar (left) standing next to the mobile soil-sensing platform.

Although the stony soils of the upper Wairau Valley, Marlborough, have underpinned the success of winemakers, they have made soil mapping there a slow and arduous task.

Any digging below the surface often requires a crowbar, and quick observation methods using an auger are simply not possible. Using diggers within vineyard rows is also problematic, with limited access and health and safety concerns putting landowners off. Observation pit sites need to be chosen very carefully because they are costly and time-consuming.

In a project with Marlborough District Council in May 2023, Manaaki Whenua scientists Dr Pierre Roudier, Dr Kirstin Deuss, Kishor Kumar, and Dr John Triantafilis embraced innovation as part of a regular S-map survey. They developed and tested a new proximal soil-sensing platform that used gamma and electromagnetic data that combined with the soil survey data, as well as aerial imagery and LiDAR.

In this way the technology acted as a 'scout' for pedologists, revealing almost in real time what was under their feet.

"Usually pedologists and soil-sensing people don't tend to work in such an integrated way," says Pierre. "Our novel approach in the Wairau Valley used a mixture of pedological knowledge and sensing to identify important changes in the soil, and which enabled targeted and rapid selection of where to spend time digging a soil pit."

For Matt Oliver, an environmental scientist at Marlborough District Council, this work is a crucial part of the council's efforts to optimise land and water management in the valley.

"The soils of the Wairau Valley were last mapped in 1939. It has been great to work alongside Manaaki Whenua's team, using the latest technology to accurately and quickly remap these areas to meet our increased demand for high-quality soils information," he says. "It very much feels like we have brought soil mapping in Marlborough into the 21st century."

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Smarter research hits its target

The Smarter Targeting of Erosion Control (STEC) MBIE programme has wrapped up five years of research aimed at answering some of the key questions around where erosion occurs and how much and what type of sediment is produced by which processes.

Project co-leads Dr Chris Phillips and Dr Hugh Smith say the research has significantly improved the understanding of the complex array of erosion processes, including the economic impact of erosion and sediment mitigation. "As severe storms and significant weather events continue to increase in New Zealand, so does the amount of erosion. Recent extreme weather has re-focused attention on landslide-triggering events and approaches for better targeting erosion control to reduce damage to land and water environments from excess sediment," says Chris.

Manaaki Whenua erosion researchers partnered with regional councils, iwi, and international and New Zealand agencies and universities during the programme. Many of the studies have put Manaaki Whenua at the forefront of global research to understand how to best target erosion control.

A key area of research focus was on rainfall-induced shallow landslides. This included work to automate the mapping of landslides using high-resolution satellite imagery with the landslide data used to model landslide susceptibility with LiDAR-derived digital elevation models (DEMs). The resulting high-resolution landslide susceptibility maps are informing land-use planning and allowing improved targeting of tree planting for erosion control. This research is also helping our understanding and future management of the 'window of vulnerability' following harvesting in steepland plantation forests.

Exposed fence posts left behind after a hill slumps away.

Similar data-driven approaches to modelling the likelihood of shallow landslides delivering sediment to streams have also been developed. These models represent the spatial probability of 'landslide-to-stream' connectivity and provide new, high-resolution insight into those specific areas most likely to produce landslides and deliver sediment to streams. Hawke's Bay Regional Council is already using high-resolution shallow landslide susceptibility layers produced by STEC research following Cyclone Gabrielle. Equivalent landslide susceptibility layers were also produced for Tairāwhiti and shared with Gisborne District Council, MPI and forestry companies following the cyclone.

The work on sediment source fingerprinting spanned multiple applications of the technique to support improved targeting of erosion control to reduce downstream sedimentation (see story on page 9). There was also a four-year study of the movement rates for a large earthflow located in the Haunui research catchment, a headwater tributary of the Manawatū River (see *Pūtaiao* 15). This work aims to help us better understand the hydroclimatic conditions that drive variations in the rates of sediment delivery to streams from these large, slow-moving landslides.

Chris says the programme has delivered several firsts, including data-driven modelling that represents the influence of individual trees on landslide susceptibility and a new New Zealand landslide susceptibility model that incorporates ground-based weather radar data on rainfall intensities.

He says it's been satisfying to complete the programme seeing increased awareness and confidence among collaborating regional councils to target their erosion control investments towards meeting catchment targets for sediment. "We've seen a more holistic understanding of New Zealand's erosion-sediment and water quality problem particularly among regional and central government agencies."

"With better data, and better models that allow us to actually link erosion on the land to instream related water quality impacts it enables us to better inform managers when it comes to deciding where to target their investment in erosion control to maximise the benefits downstream," says Hugh.

"Iwi partners are using new knowledge of landslide susceptibility in the Whanganui catchment while several regional councils are routinely using improved sediment modelling tools to implement National Objectives Framework sediment targets and assess outcomes under future erosion mitigation and climate change scenarios."

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Fingerprints point to the sediment source

Hugh Smith doing sample collection and recording of site characteristics for sediment fingerprinting in the Ōreti catchment, Southland.

Manaaki Whenua researchers are recognised internationally for their knowledge of sediment fingerprinting (also referred to as sediment tracing), an approach that directly connects the place where erosion happens in a catchment to the sediment that ends up in downstream rivers or lakes.

A research team led by Drs Simon Vale and Hugh Smith has conducted sediment fingerprinting studies in several catchments, including the Manawatū, Oroua, Ōreti, Tiraumea, Aroaro, and upper Mōtū, as well as work for Horizons Regional Council and Gisborne District Council.

These studies aim to understand how much sediment comes from different sources, depending on erosion processes and the type of soil or rock.

The team collected samples from different erosion sources in the field, picking specific properties (called tracers) that help identify each source. These tracers can include various physical and chemical properties of soils and sediments, such as their geochemical composition, radioactive elements, or isotopic signatures.

Simon says the implications of understanding the origin of sediment in rivers or lakes is crucial to enabling targeted erosion control and land management strategies.

"As climate change affects precipitation patterns and intensifies extreme weather events, sediment fingerprinting becomes an increasingly important tool for assessing how sources of erosion and downstream sediment delivery are changing in response," he says. "This information is valuable for adapting land management practices to mitigate the impact of climate change on erosion and sediment transport."

Hugh adds that the study provides a framework for evaluating catchment erosion sources based on their sediment-related water quality attributes, which can be used to guide catchment management strategies and ensure effective targeting of erosion control.

"Overall, the research has important implications for managing and improving water quality in streams and rivers, particularly in terms of visual clarity and sedimentation issues," he says. "This knowledge helps prioritise efforts to control erosion in specific areas of a catchment, making sure that interventions target the sources contributing the most sediment."

A forest clearance in Tairua on the east coast of the Coromandel Peninsula.

Closing the ‘window of vulnerability’

Most commercial forests in Aotearoa New Zealand are clear-fell harvested. Trees of harvest age are cut down in areas called coupes or compartments. In many forests, these compartments often include steep hillsides, which go from being forested for decades to being bare and visible almost overnight. The years following harvesting are when forests are more susceptible to erosion; and this has been termed the ‘window of vulnerability’ (WoV).

Dr Chris Phillips, a senior researcher in Erosion Processes at Manaaki Whenua, says better information on the WoV can help forest managers develop appropriate risk management strategies. “This is a period of several years, where the landscape is particularly susceptible to rainfall-triggered shallow landslides between crop rotations. It is also often when the impacts of large storms such as Cyclone Gabrielle are at their greatest.”

Chris recently led a project that looked at the WoV in steepland plantation forests in three regions that had been affected by large rainfall events.

“Using forest company information, LiDAR and satellite imagery we manually discriminated rainfall-triggered landslides for each of our three study areas. Landslides were ‘tagged’ to vegetation cover, time since harvesting, whether associated with forest infrastructure such as roads and landings, and if they connected to the stream network or not.”

Maximum landslide density occurred on land clear-felled 2–4 years before the rainfall event that triggered them. Landslides also occurred in older forest age classes and on areas with different vegetation covers (mature indigenous forests, pasture, scrub, etc). “There were fewer landslides associated with forest infrastructure than those deemed to be ‘natural’ slope failures, and half the triggered landslides reached the stream network,” he says.

Chris says better information on the period of susceptibility to rainfall-triggered landslides following forest removal will help forest managers know what can and can’t be done to mitigate the effects of rain events that result in landslides and in some cases often disastrous off-forest impacts.

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Keeping urban soils spongy

Manaaki Whenua researchers are assessing the impact of urban development on soils, quantifying if urbanisation is making soils less spongy. Urbanisation is associated with increased stormwater run-off, largely due to an increase in impervious surfaces. When coupled with less spongy greenspaces and extreme weather events, vulnerability to flooding is increased.

The team is collaborating with engineering colleagues at AECOM, who will undertake modelling to better define the risk of flooding in various storm events, and with Koru Environmental to investigate policy responses. The research, co-funded by Auckland Council, is the only urban project in a Ministry for Environment portfolio investigating nature-based solutions. It is hoped learnings can be shared with other regions.

Lead researcher Dr Robyn Simcock says soil is often compacted during urban development, slowing the rate at which water moves into and through soil. "Sometimes less rain can enter the soil, but compaction can also mean soils lose much of their 'sponginess' especially when topsoil depths are reduced," she says. Two sub-catchments in Auckland, Mangere and Te Auaunga (Oakley Creek), have been chosen for the study.

"The sub-catchments meet most or all our technical criteria. They have natural soils in public open spaces that range from well-drained to poorly drained and have extensive development sites. Having recent development sites is important so that we can quantify the impacts of modern construction practices," says Robyn.

The research team will be hand-excavating pits to measure how fast water moves into and through the soil and to identify soil horizons with limited water and root movement. Intact soil cores will be taken back to the Hamilton soil physics laboratory to test soil density and moisture storage capacity.

The project includes modelling potential solutions such as soil loosening to increase the rate water enters soil, increasing topsoil depth and increase profile water storage (for example, by building with piles to retain soil depth). Options will be explored through engaging with industry and iwi/hapū, led by Koru Environmental and Auckland Council respectively. Robyn says the project also aims to identify hot-spots within the chosen sub-catchments where maintaining or improving permeability is likely to have the greatest benefit.

"By early 2025 the project team plans to have a draft technical guidance document for regional councils, the construction industry, and individual property owners providing potential methods to improve soil sponginess and thus improve our resilience to a changing climate," says Robyn.

Terracing and land contouring creates flat, geotechnically stable land for establishing roads and concrete foundations.

Maximising use of ‘surplus’ soils and sediments

Manaaki Whenua researchers have developed the first ever Aotearoa New Zealand guide to help improve the management of surplus soils. These are the soils left behind after excavations and widespread soil disturbance associated with building and infrastructure developments, or natural processes such as landslips. Typically the soil left behind is surplus to requirements, or unsuitable, for on-site use. This soil is currently largely disposed to various classes of landfills ranging from cleanfills to Class 1 landfills for highly contaminated materials.

Anecdotally, the scale of the problem is large, although there is a lack of data on the amount of material seen as ‘surplus’ soil and lack of agreement on what should be measured.

Manaaki Whenua Land Use & Ecosystems Senior Researcher Dr Jo Cavanagh says there has been growing awareness of the lack of sustainability of current practices in managing these soils including disposal costs, carbon emissions associated with transporting surplus soils, unnecessarily filling up landfills – as well as the simple wastage of this valuable resource.

Jo and fellow Manaaki Whenua researchers Dr Robyn Simcock, Dr Hadee Thompson-Morrison, and Garth Harmsworth worked with multiple sectors in AoNZ to disentangle the factors leading to the generation, and barriers to the beneficial use, of surplus soils, Some factors leading to the generation of surplus soils include geotechnical (un)suitability or contamination concerns, while barriers to reuse include regulatory challenges associated with the use of materials containing trace elements above background concentrations, and logistic challenges in matching the generation and use of materials.

A key finding was the absence of a wider understanding of soil properties, beyond geotechnical and contaminant considerations.

“Addressing the challenge associated with surplus soils needs different thinking that focuses on valuing soils and understanding the beneficial attributes that can provide different beneficial uses” says Jo.

She adds that development projects should be designed with surplus soil management in mind from the start to minimise the generation of surplus soils and to maximise the on-site re-use.

The work involved te ao Māori and mātauranga Māori from inception to completion with the whakapapa of soil (including its connection to an area, location, tribe, and ecosystem) underpinning decision-making. Māori have no definition for surplus soil or what it would look like but rather all soils are considered a resource and treasure, or taonga tuku iho, regardless of condition.

A parallel project with Auckland Council undertaken by Jo, Robyn and Hadee assessed beneficial use of sediments excavated from stormwater ponds during routine maintenance operations. This work highlighted similarities in the concerns around sustainability, regulatory and logistical challenges and potential solutions, but also demonstrated use of excavated sediments to successfully grow native plants. High water content and/or anaerobic status of excavated sediments are additional complicating factors for their beneficial use.

Through the projects there was strong engagement with different industry sectors, including contaminated land management and waste disposal to land, as well as central and local government and government agencies, including regional and unitary councils, city and district councils, the Ministry for the Environment, Land Information Aotearoa New Zealand, Kainga Ora – Homes and Communities, and Māori.

'Offsetting the demand for virgin materials through reused/reprocessed


Housing developments create huge disturbances of soil, often leaving quantities of unwanted or surplus soil.

surplus soils is one opportunity to use surplus soils and sediment," says Jo.

Key recommendations from the report included filling information gaps on the amounts of surplus soils and sediment generated and from where and establishing principles for developing a surplus soil sustainable management framework that enable the right systems and processes to be put in place. These include minimising the generation of surplus soils and maximising on-site use by considering these factors at the design stage, and ensuring use of soils and sediments on- and off-site have clearly defined beneficial use.

The surplus soils project was undertaken with funding from an Envirolink Tools Grant for the Regional Council Contaminated Land and Waste Special Interest Group and the Land Monitoring Forum, while the beneficial reuse of sediment from stormwater ponds project was undertaken for Auckland Council.

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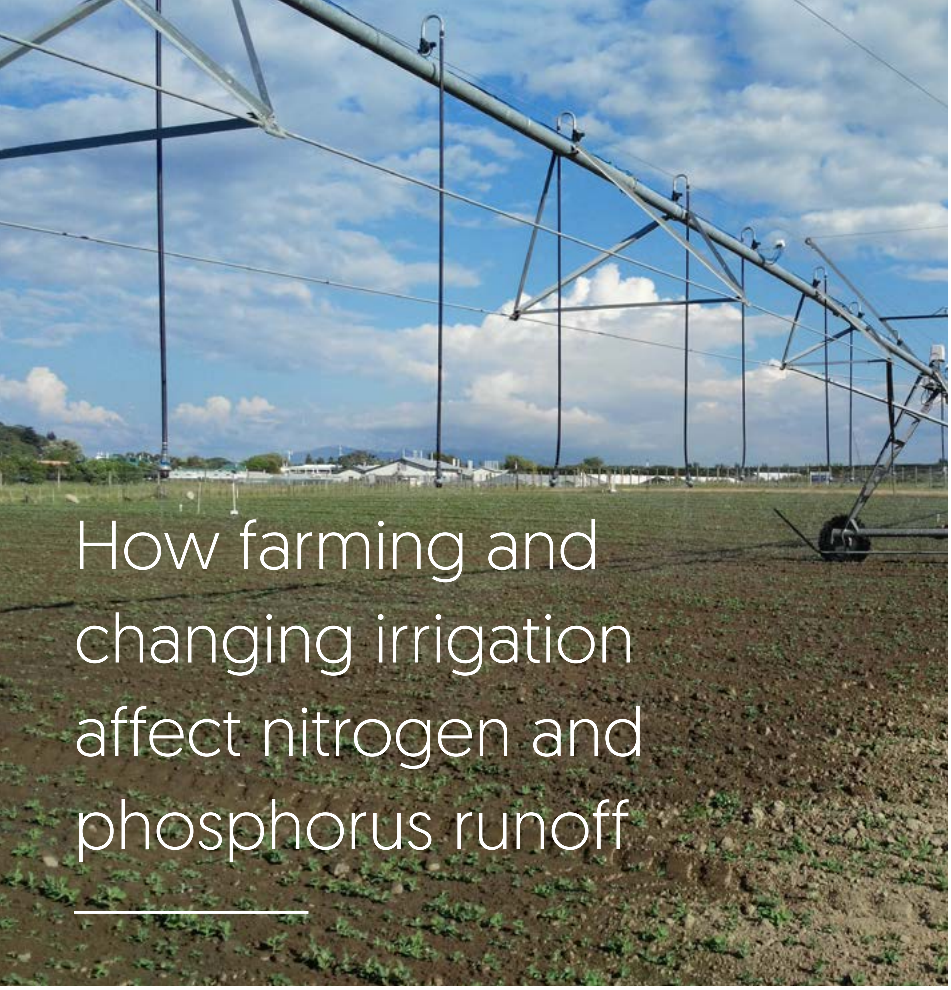
HTTPS *envirolink.govt.nz/assets/Envirolink/R18-1-Guidance-on-the-sustainable-management-of-surplus-soil-and-subsoil-consultation-draft.pdf*

HTTPS *knowledgeauckland.org.nz/publications/considerations-for-the-beneficial-use-of-sediments-from-stormwater-ponds-across-auckland/*



How farming and changing irrigation affect nitrogen and phosphorus runoff

Irrigation use at the trial site at Massey University.

Irrigation to increase pasture and crop yields is often associated with an increase in nutrient inputs through fertiliser and changing management practices. Use of these practices has raised concerns about nutrient losses and their potential environmental impacts, especially for water quality.

While the losses are known to be happening, the exact extent of them is still uncertain. Manaaki Whenua researchers have been able to draw on more than 5 years of research to start to close the knowledge gap relating to variable-rate irrigation.

In a recent study in *Soil Research*, researchers were able to show that water and nutrient losses from farms can be reduced through precision agriculture practices, such as the use of management zones for improving the management of irrigation on spatially variable soils or crops – called variable rate irrigation (VRI).

The study, conducted on a mixed cropping site at Massey University's No.1 Farm, near Palmerston North, measured nitrogen and phosphorus leaching losses under two contrasting management zones, Zone 1, a Manawatū fine sandy loam, a deep, free-draining soil, and Zone 2 ,a poorly drained Manawatū silt loam.

The site had a centre-pivot irrigator with variable rate control, and drainage flux meters were constructed and installed for each of the zones.

Senior researcher Dr John Drewry says the study sought to contribute to sustainable agricultural practices and water quality management. "The practical significance of our results is that, where spatially variable soils (or crops) exist under irrigators, irrigation can be managed in specific zones to reduce irrigation-induced drainage and nutrient leaching."

"With some exceptions, and allowing for an unexpected rain event, there was generally more nitrate and nitrite leaching from the free draining Zone 1 soil," says John. However, the nitrogen concentrations and loads generally had greater uncertainty in Zone 2. "We found the drainage flux meters worked well for the free-draining soil, but were less reliable in the poorly drained soil."

John adds these findings highlight the importance of understanding nutrient leaching losses under zone-specific irrigation, as well as the need for improved monitoring and modelling techniques to accurately assess nutrient losses in different soil types and management zones. "It also highlights the need to map soil types and understand their water-holding characteristics under the irrigator footprints at a scale that land managers can make practical use of."

Funding was provided by the Ministry of Business, Innovation and Employment (MBIE) Strategic Science Investment Fund. Funding was also provided in part by the Manaaki Whenua and Plant & Food Research-led Endeavour research programme, Maximising the value of irrigation.

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SedNetNZ supports land and water planning

Researchers from Manaaki Whenua have been working closely with regional councils in Aotearoa New Zealand to apply the SedNetNZ model to support land and water planning.

SedNetNZ is an erosion model developed by Manaaki Whenua that predicts the generation and transport of sediment through river networks, based on representation of hillslope and channel processes at the sub-catchment scale. It was first applied in the Manawatū catchment in 2013 as part of the Clean Water Productive Land research programme.

Researcher Dr Hugh Smith says that since then SedNetNZ has undergone several updates, including improvements to better represent processes such as bank erosion and development of model functions to estimate the potential effects of climate change on erosion rates and sediment loads.

SedNetNZ improves on available erosion models in AoNZ by providing estimates of sediment load generated by different erosion processes (landslides, gullies, earthflows, surface, and bank erosion) and sediment deposition on floodplains.

Researcher Dr Andrew Neverman says this allows improved targeting of erosion mitigations to the key sediment-contributing processes when modelling land management scenarios, and analysis of the linkages between upstream sediment generation and downstream sediment loading. "SedNetNZ is highly suited for scenario analysis of changes in land management and the implementation of erosion mitigation practices," he says.

Recently, Horizons Regional Council asked Manaaki Whenua to apply the latest version of SedNetNZ in the Manawatū-Whanganui region and to update the assessment of the impact of soil conservation work to date. The council also wanted to model sediment loads under future climate change conditions for two different policy scenarios, which involved assessing both the impact of the current Sustainable Land Use Initiative (SLUI) farm plans and works on sediment loads and water clarity, and the impact once full implementation of the Freshwater Farm plans is complete.

With climate change predicted to nearly double sediment yields, the council is interested in understanding the potential impact of climate change on sediment loads. Researcher Dr Simon Vale says the model shows continued investment in SLUI and lowland erosion mitigation will be required to reduce potentially significant impacts of climate change on suspended sediment loads by late century.

"Model scenarios representing the implementation of future erosion mitigation policy show significant reductions in region-wide suspended sediment loads by late century, with the first policy scenario achieving a 48% reduction and the second achieving a 60% reduction on average, without the effects of climate change," he says.

As well as the Horizons Regional Council work, the Manaaki Whenua researchers have recently completed SedNetNZ-based analysis of erosion and suspended sediment loads for Southland, Taranaki, Bay of Plenty, and Hawke's Bay, while SedNetNZ modelling is currently underway for the Waikato region.

The researchers also helped Otago Regional Council to model suspended sediment loads and the reductions in load required to meet freshwater limits, which contributed to setting freshwater objectives in Otago's Land & Water Regional Plan.

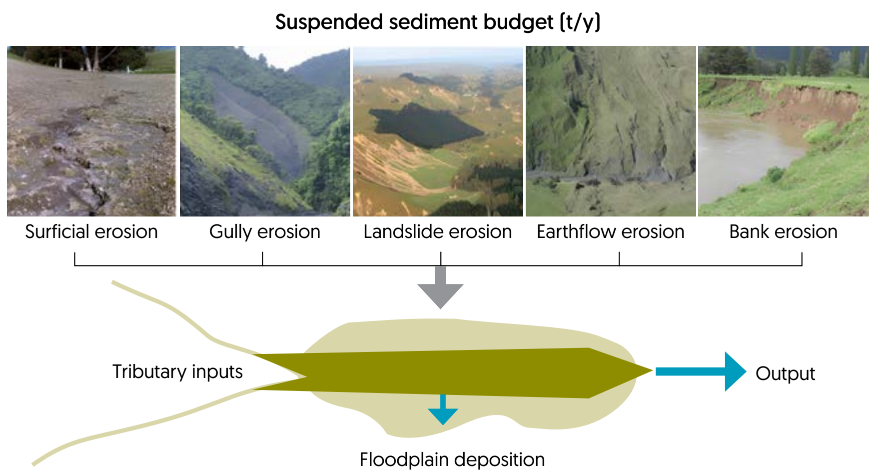

Illustration of the erosion process-based structure of the SedNetNZ model.

Linking soil quality indicators to land use pressure and water quality

For the first time in Aotearoa New Zealand researchers have been able to link soil and water quality to land-use pressures by including the use of land valuation data.

Manaaki Whenua senior scientist Dr John Drewry and geostatistics senior researcher Dr Stephen McNeill worked with Prof Rich McDowell, Chief Scientist, Our Land and Water National Science Challenge, to improve the understanding of the relationship between land use, land pressure, catchment characteristics, and soil and water quality indicators.

In recent years there has been increasing confidence that predicting and managing freshwater quality happens through a better understanding of soil and land use.

"We wanted to find out what relationship exists between land valuation, soil quality, and other pressure indicators such as stock numbers and land use," says John. "We also wanted to find out through our analysis if there are early indicators associated with catchment water quality."

The team analysed existing and publicly available data from sources such as Land, Air, Water Aotearoa (LAWA), StatsNZ, regional councils' soil quality monitoring, and nationally available district land valuations for 192 catchment areas around AoNZ.

The research is the first attempt at this scale to directly link soil quality, land use pressure and water quality response. It's also the first time this information has linked land values to soil and water quality. "Land value is often publicly accessible, well defined and routinely estimated," says John. "Land valuations in New Zealand generally occur on a 3-year cycle. The idea was that land valuation could act as an indicator of land use intensity, which may drive water quality response," says Rich.

Researchers were able to link soil quality indicators, such as pH, bulk density, anaerobically mineralised nitrogen, Olsen phosphorus, and soil organic carbon, to indicators of land-use pressure, such as stock numbers and agricultural land valuation data, to determine the relationship between land valuation and soil quality and other pressure indicators.

"All these indicators are essential for assessing soil health and can provide valuable insights into the impact of land-use pressure on soil quality," says John.

The team then applied statistical methods to explore potential linkages within and across catchments and land-

use pressures to evaluate water quality indicator trends within the catchments.

The overall modelling approach showed some water quality indicators were more closely associated with some soil quality, land-pressure and catchment indicators than others. It also explained a moderate to high proportion of variation of several nutrient water quality indicators, but *E. coli*, a bacterial indicator of faecal contamination, and water clarity were only moderately explained by this approach. Soil quality variables had an effect and could potentially act as an early indicator of water quality response at a farm level. However, because soils are sampled infrequently and only in a few places, catchment characteristics and land use had a greater effect on water quality.

The broad results of the study and selected catchment information are available on a public website (available from late February 2024) with easy-to-understand maps that show the land-use proportions, and water quality trends over time, per catchment. Land-use proportions per catchment are represented in a waffle chart that makes it easy to visualise the different land use.

While using valuation data proved a novel way of associating with soil and water quality, it didn't come without its challenges. The valuation data required significant cleaning before it could be used, taking considerable time," says Stephen. "Given the size of these national-scale data sets, and the complexity of combining large spatial datasets, the run-times for the statistical modelling analysis were very high and necessitated developing a method to reduce them."

The researchers also point out that while this research has established the trends across a variety of key water quality indicators per catchment, the study did not interpret the results from a water quality perspective, or why they occur. "While our research can show that the value of a key water quality indicator has changed," says John. "We can't say why it has, because that was beyond the scope of our work."

This study was funded by the Our Land and Water National Science Challenge, and co-funded by the Manaaki Whenua-led research programme, 'Soil health and resilience: oneone ora, tangata ora', funded by MBIE. The monitoring programmes were funded by the regional authorities.

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Antarctic soils in from the cold

Dr Iain Campbell packing samples at Edisto Inlet during a 1964 expedition to Antarctica.

Manaaki Whenua researchers have made a significant contribution to future research on the properties of Antarctic soils.

Dr Ursula Jewell led a team that spent 2 years curating, digitising and cataloguing the world's most extensive collection of Antarctic soil samples dating back as far as 1957. The data are now publicly available through the Antarctic Soils Explorer website.

"Soil data from polar latitudes are rare," says Dr Thomas Caspari, the principal pedologist on the project. "Our collection of Antarctic soil samples is truly unique. We now have the best record of Antarctic soils in their most pristine condition, with the earliest collected samples essentially representing pre-human visitation. These samples also predate the arrival of micro-plastics."

During the project, researchers transferred 8,837 soil samples, topping the scales at more than 1.5 tonnes, to a robust storage container where each sample was weighed, photographed and labelled with a unique identifier. The samples are now fully curated, stored and preserved at the Quarantine Facility of the National Soils Archive at Manaaki Whenua in Palmerston North.

"These are invaluable 'time capsules' for assessing temporal changes in soil properties, and their data will form the baseline for all further scientific analysis on Antarctic soils," says Thomas. The data pertaining to those samples are available for download within the

Antarctic Soils Explorer, and include location details and soil physical, chemical and mineralogical properties where available.

The first sample dates to 1957 when AoNZ scientists who were part of the initial Commonwealth Trans-Antarctic Expedition (TAE) filled a biscuit tin with soil from where new Scott Base huts were under construction. The sample formed part of AoNZ's contribution to the International Geophysical Year (IGY) in which scientists from around the world took part in coordinated earth science studies.

The bulk of the early samples was collected by pioneering Antarctic soil scientists Drs John McCraw (1925–2014), Graeme Claridge (1932–2021), and Iain Campbell (b. 1935). The locations from which these samples have been gathered can be explored via an interactive map of the Antarctic continent that features original materials and recollections from these early Antarctic excursions.

The Frozen Assets project was made possible through funding support from Te Tahua Taiao Ngā Taonga (Lottery Environment and Heritage) and Manaaki Whenua to ensure AoNZ's Antarctic soils heritage is professionally protected, managed, and made accessible for future generations.

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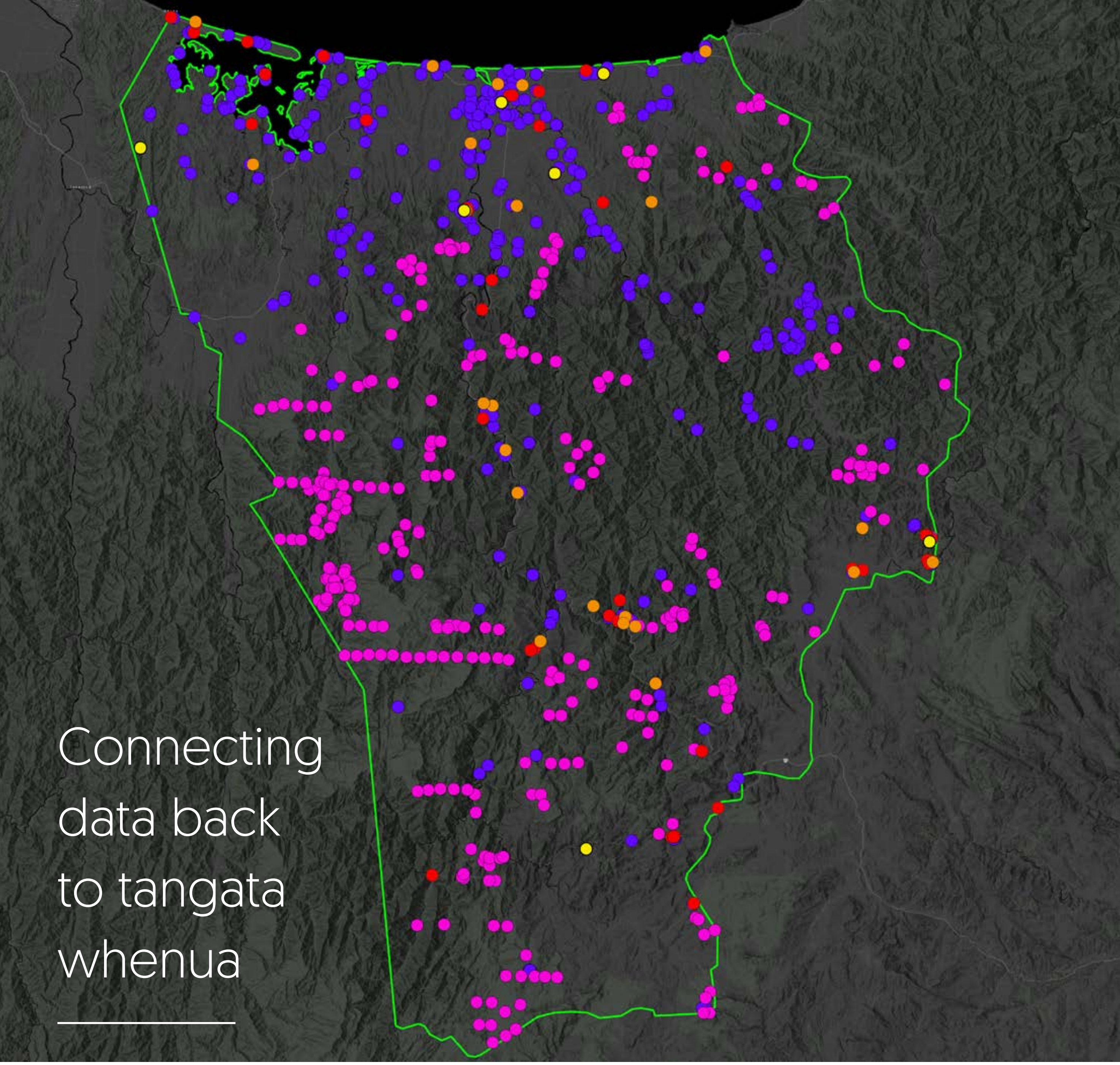
Dr Graeme Claridge packing accumulated soil samples during an expedition in 1969.

Curated samples of Antarctic soils at the National Soils Archive.

Connecting data back to tangata whenua



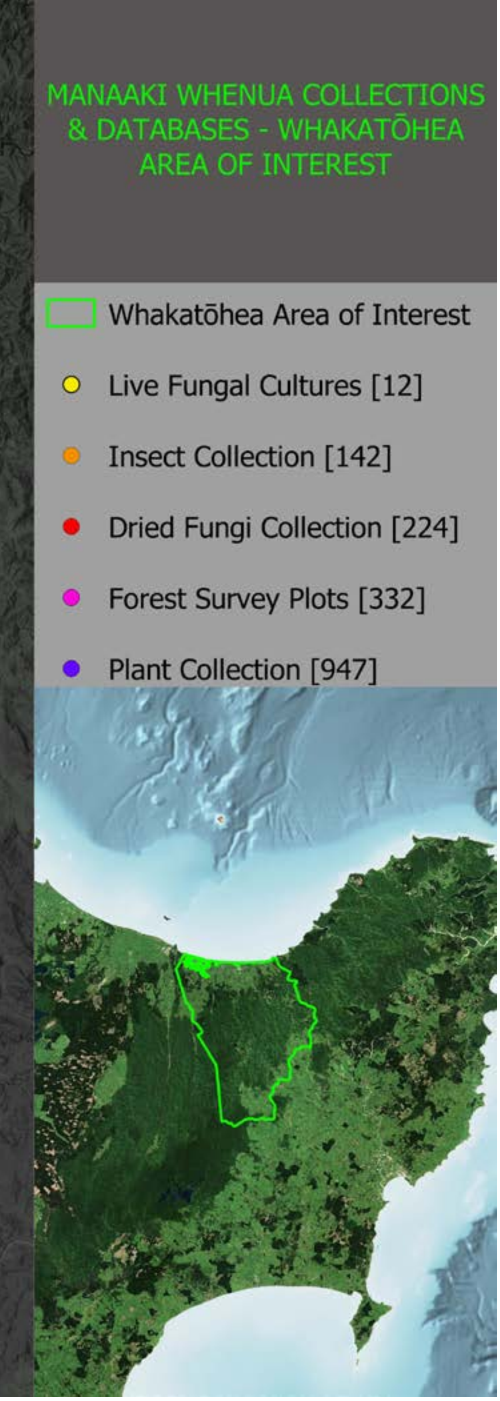
Onscreen map of the Whakatōhea rohe showing where specimens have been collected.

Connecting data back to the whenua is at the heart of a new Manaaki Whenua project. Across our collections, Manaaki Whenua holds and cares for a rich array of more than 820,000 specimen samples from invertebrates, to fungi, to flora and fauna and taonga plant species.

A new documentary produced by Local Contexts E Kore Au E Ngaro, explores Manaaki Whenua's work with Whakatōhea, an iwi in the eastern Bay of Plenty, to apply biocultural labels to some of these specimen samples through our Systematics Collections Data website. Local Contexts is a global initiative that supports indigenous communities with tools such as Biocultural Labels and Notices to reassert cultural authority in heritage collections and data.

For Whakatōhea Māori Trust Board Council Member Local Contexts Council Member and Strategic Advisor Māui Hudson (Whakatōhea, Te Korowai Ngāruahine, and Te Māhurehure), this work is about how his community can reassert cultural authority.

"There's some plants that are unique to our rohe (territory), critically endangered like the scrub daphne –



> *There's some plants that are unique to our rohe, critically endangered like the scrub daphne – and that's something that we've found out is part of the collection at Manaaki Whenua.*

and that's something that we've found out is part of the collection at Manaaki Whenua," says Maui.

"Because indigenous knowledge has developed over a long period of time, it's not subject to the kinds of intellectual property (IP) protections that are in place. Within research domains you end up with this situation where the copyright is claimed by the researcher or the institution and so our traditional knowledge then becomes subject to someone else's IP rights."

Maui explains that the Biocultural Labels now applied across thousands of Manaaki Whenua samples are digital tags that reflect indigenous interests in scientific data.

"Now there are several things that we're trying to express through the biocultural labels. First and foremost is provenance: that the connection back to the community should be maintained and retained across records. The other things that are being reflected are what kind of protocols are being put in place, and whether consent is being associated with the material as well."

He continues, "And then the third component relates to the permissions and the sorts of activities that the community is comfortable with in terms of outreach activities, research use and giving an indication about what sort of relationship they're happy to engage with researchers going forward."

Manaaki Whenua General Manager Te Tiriti Strategy Holden Hohaia (Ngāti Maru) says this work is about recognising indigenous rights and interests in the specimens (and related data) that we hold in our collections.

"For much of Aotearoa's post-colonial history the scientific endeavour of collecting specimens and data has been carried out usually with little recognition of Māori rights or interests in what was collected. In effect we have tended to collect without first seeking permission from local iwi/hapū interests."

The labels seek to address this imbalance by putting the research community on notice that these specimens have a provenance, explains Holden. They also serve as a reminder that iwi/hapū may wish to have some say over, or involvement in, how that material and data are used in the future.

"They offer an ethical framework for us to recognise indigenous rights and interests in indigenous data without needing a comprehensive legal framework– which may be a long way off yet," he says.

Manaaki Whenua Herbarium database manager Aaron Wilton who has managed the project says about 60 to 70% of the collections data are georeferenced. "This means we can pin down, based on a coordinate, to a particular rohe such as Whakatōhea," says Aaron.

"There is significant work that happens under the hood to support how we deliver information out for use – the labels are critical as a tool as we start that journey – just to raise awareness among the scientists but also as a signal to iwi and hapū that we want to collaborate."

Next steps in enriching data

Dr Alexander Amies, a data scientist at Manaaki Whenua, has been supervising Jason Tang from Lincoln University's Masters of Applied Computing programme to develop an app to give collectors the information required to determine the value/ suitability of collecting a specimen.

It's important cultural considerations are recognised when collecting in the queried location, and where known, biocultural labels for existing records, says Alexander.

"These are key for researchers to apply proper tikanga when collecting and using specimen information, particularly when looking at specimen lists in aggregate. This is also a great opportunity to add a wider perspective to data stored in Manaaki Whenua's collections to enrich data in ways that haven't been previously explored."

To watch the full Local Contexts documentary

HTTPS *vimeo.com/888530710*

To access Manaaki Whenua Systematic Collections databases

HTTPS *scd.landcareresearch.co.nz/*

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Celebrating our achievements

At the annual Science New Zealand Awards in Wellington in December 2023, Dr **Chris Phillips** was awarded an Individual/Lifetime Achievement for his professional expertise in the fields of erosion research and integrated catchment management. Climate-smart landscape researcher Dr **Dan Richards** was recognised as an Early Career Researcher for his work towards understanding how terrestrial landscapes can support climate adaptation in Aotearoa whilst integrating objectives of climate mitigation, biodiversity conservation, and multiple benefits to people. Our **Land Use and Carbon Analysis System (LUCAS) Land Use Mapping (LUM) team** received an award for their significant update to LUM 2020 which utilised significant advances in automation, AI and machine learning.

Dr Susan Wiser was the 2023 winner of Te Tohu Taiao – Award for Ecological Excellence –conferred by the New Zealand Ecological Society at its annual conference. This award is presented annually to recognise individuals who have made an outstanding contribution to the study and application of ecological science. Susan has made an impressive contribution to the development of the National Vegetation Database.

Postdoctoral scholar Dr **Marion Donald** has been awarded a Rutherford Foundation Postdoctoral Fellowship for research titled 'A trait-based approach for predicting conservation status of Aotearoa New Zealand's pollinators' Using 'trait-based ecology'. Marion's project focuses on two key pollinator groups in Aotearoa New Zealand – flies and bees. This work will generate new information for data-deficient species and integrate prior data to build Aotearoa-specific models.

Chris Phillips

Dan Richards

Susan Wiser

Marion Donald

Members of the Land Use and Carbon Analysis System (LUCAS) Land Use Mapping (LUM) team with Manaaki Whenua Board Chair Colin Dawson (left) and CEO James Stevenson-Wallace (right)

Farming the ‘F1’ way

In Formula 1 racing, the difference between winning or not comes down to fractions of seconds. That’s why team engineers are always eyes down on the data collected from sensors on the vehicle. Using tens of thousands of data points, the team uses that information to optimise performance by adjusting the balance and aerodynamics of the car on the go to claim the chequered flag.

As farmers are challenged to meet increasing demands to transform their operations into climate-smart landscapes, decarbonise their operations and supply chains, and be financially sustainable, ‘Smart Farming’ allows farmers to adopt that F1 mindset.

Farmers need to optimise technology in the farm management cycle to be their most productive.

However, the cycle starts at the most basic level with the soil. A farmer needs to know the condition of the soil before the capacity or capability of it can be improved.

On the highly productive, but stony, Canterbury Plains, for example, dairy farmers need to improve intensive irrigation to mitigate nitrate leaching that degrades water amenities. To do this requires knowing the available water capacity, which means collecting data on the minimum (permanent wilting point) and maximum (field capacity) amount of water the soil can hold.

A farmer also needs to know how much fertiliser to add and the lime requirement to neutralise acidity. All this requires costly, and labour intensive, soil sampling. But what if you could make this analysis more cost effective by reducing the number of sample points and still be confident in the accuracy of the data?

At the Lincoln Dairy Farm, our scientists are demonstrating it is possible to acquire digital data from a smaller number of soil condition data points.

During a trial across the 160-hectare Lincoln University Dairy Farm we started with 160 sampling points to create accurate, digital soil maps showing water capacity.

Then we introduced data from remote (i.e., LiDAR) and proximal sensors (e.g., electromagnetic (EM) and gamma-ray) to make higher resolution digital soil maps. Researchers demonstrated they were able to significantly drop the number of soil samples required, while still producing accurate maps.

LiDAR was able to create models of ground elevation and show features such as small depressions that can indicate the location of stony soils. Similarly, EM and gamma-ray data identified the location of more conductive clay soil.

Preliminary results indicate that to make digital soil maps of biological (carbon and nitrogen), chemical (exchangeable calcium and magnesium), and water conditions, as few as 10 to 20 soil samples are needed. A huge cost saving for farmers who can then use the data to drive decision-making based on the soil’s capacity to increase carbon, build structural resilience and store water.

Moreover, it opens the potential to make it affordable to monitor a range of other digital information on soil water (using moisture probes), climate (installing weather stations), yield (satellites) and even from collars on cows. Being able to run simulations from all this data, such as tracking individual cows all the way home to work out where they have been and what they have been grazing, will allow farmers to make better decisions about how to irrigate and where to fertilise. Using digital data to map soils could potentially reduce sampling costs by 80%, which will definitely put farmers in pole position.

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Manaaki Whenua
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