Pūtaiao

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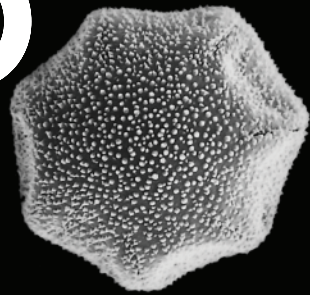

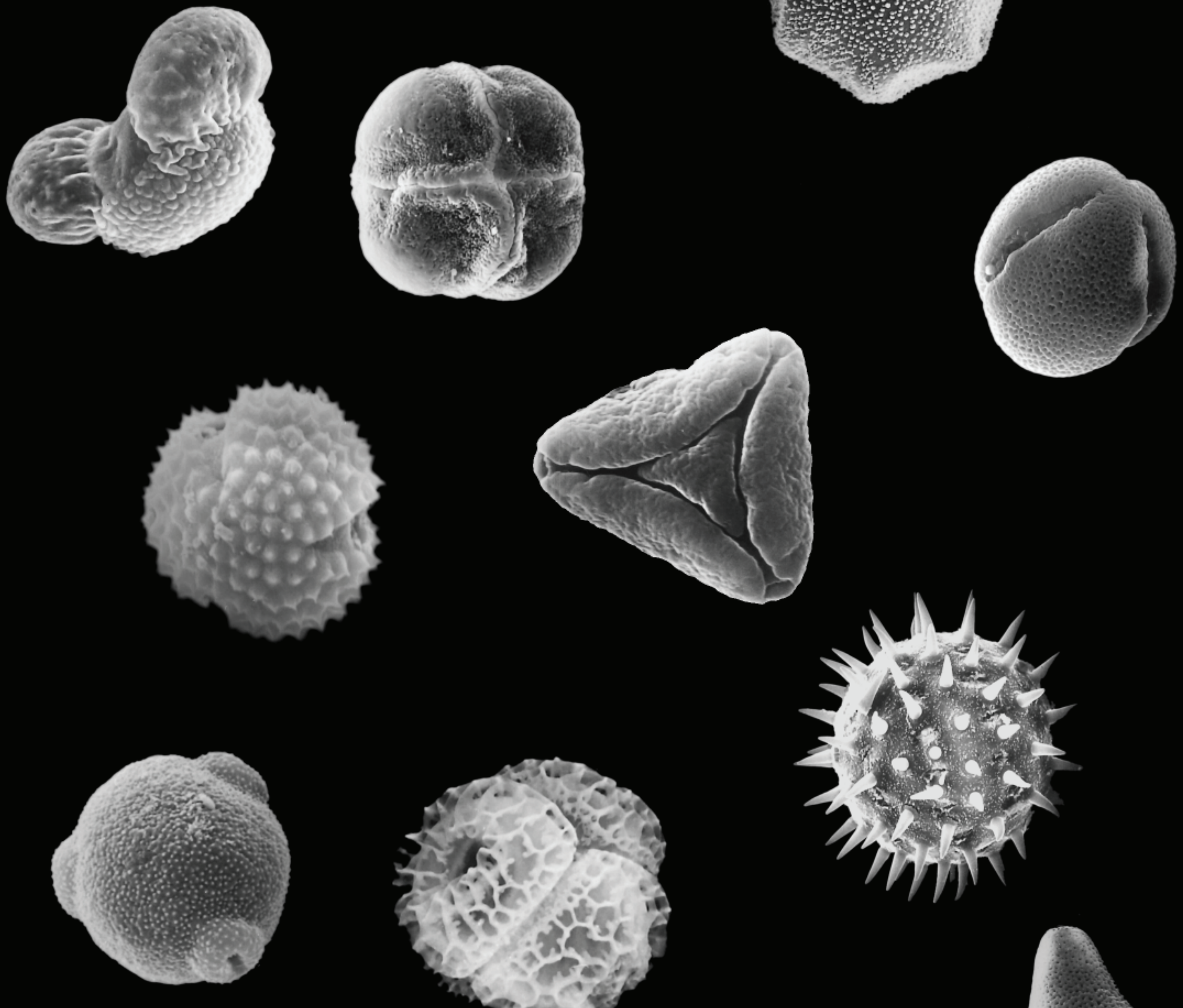

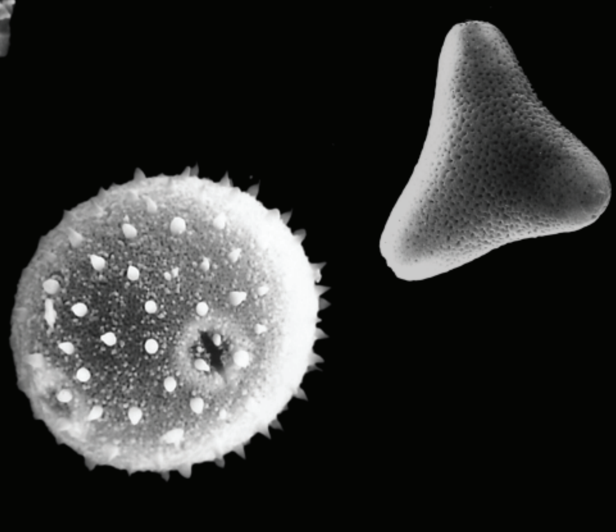

Grains of truth

Climate-smart science
for Aotearoa New Zealand

Pūtaiao

Science for our land and our future

Tēnā koe and welcome to issue 7 of *Pūtaiao* ('Science' in te reo Māori), our quarterly publication showcasing the work of our scientists at Manaaki Whenua.

This issue of *Pūtaiao* highlights some of our most recent work in environmental management and climate science, including our underpinning research that fills knowledge gaps for national environmental reporting and monitoring, advances in mapping land cover at very high resolution, progress in the management of soil erosion, and estimates of the likely financial effects of future drought.

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 Communications Manager Dan Park: parkdj@landcareresearch.co.nz

Cover image: Scanning electron microscope photographs of fossil pollen grains from native New Zealand plant species. For more on how we use pollen to trace patterns of climate change, see pages 6–7.

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Conservation and climate change

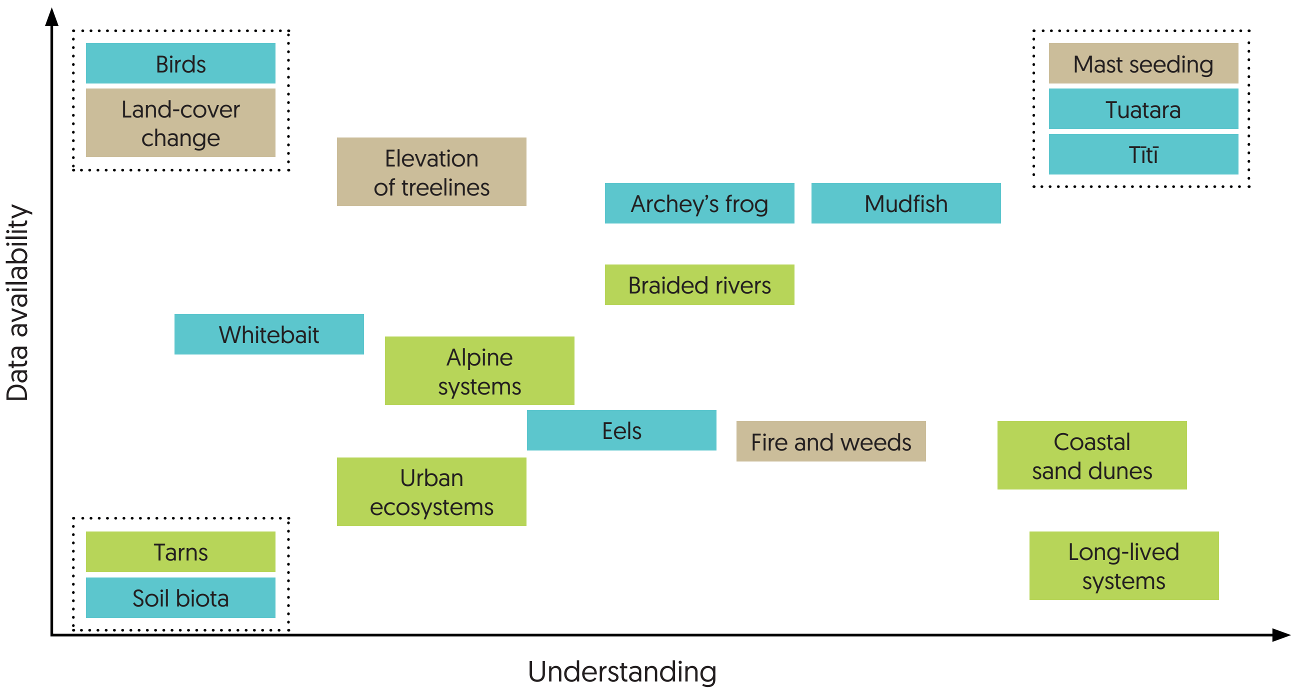
Island systems, such as New Zealand, are hotspots of endemic species found nowhere else – some 80% of vascular plants, 86% of molluscs, 81% of arthropods, 60% of vertebrates, 36% of mosses and liverworts, and 30% of lichens are endemic, and these are particularly vulnerable to extinction. Competition for habitat and predation by exotic invasive species make conservation efforts critical.

Rapid advances in eradicating invasive species from islands – for example, via species-specific toxins and smart trapping methods – are improving conservation outcomes in these biodiversity hotspots. However, recent conservation gains could be reversed not only by future invasions from non-native species but also by future extinctions of native species, both of which may be driven by global environmental changes.

The problem, according to Manaaki Whenua's Dr Sarah Richardson, Dr Duane Peltzer and colleagues, writing in the journal *Frontiers in Ecology*, is that we don't know what we don't know about these system-level environmental changes.

Climate-change impacts are complex to study. They are often indirect (operating through an intermediate factor, such as fire caused by drought), interactive (where climate-change effects depend on the effects of another factor, such as warming caused by changes in land-use affecting surface temperatures), or synergistic (producing a combined effect greater than the sum of separate effects). In all three cases, changing climate also magnifies other stressors, such as habitat fragmentation caused by human activity or the expansion of invasive species into areas currently free of them.

Another problem is that reliable data and deep, contextual understanding are rare. Our knowledge of forests is generally good, partly because our



A data availability–understanding matrix showing species and populations (blue), habitats and ecosystems (green), and ecological processes (brown) that are vulnerable to climate change in New Zealand. Understanding includes knowledge, insights and wisdom. See text for a fuller explanation of this matrix.

conservation estate is concentrated in mountain landscapes, but we know less about lowland lakes and wetlands, as the matrix diagram shows. The matrix emerged from a group discussion at a workshop, led by the University of Auckland's Cate McInnis-Ng and funded by the Biological Heritage National Science Challenge, which drew on a wide spectrum of expertise in ecology, conservation, and mātauranga Māori (indigenous knowledge in New Zealand). Items in the same boxes have similar data availability and understanding. Data availability is self-explanatory, whereas understanding requires not just data, but knowledge, insights, and wisdom drawn from those data. The farther to the right in the space, the better the understanding, and the higher up, the more extensive the available datasets are – but more data about what species are where don't necessarily correlate with better understanding of how those species are being affected by processes such as climate change.

The authors recommend that defining knowledge gaps, and improving our knowledge of long-term system dynamics, the consequences of rare climatic events, and of how indirect processes and drivers affect New Zealand's biota, will help refine and improve long-term conservation management. Climate-change research should be incorporated in all conservation research and management plans.

Data deficiencies can be addressed, at least in part, by uncovering databases or information lost or stored in unusual places, or through support and integration of geographically distributed datasets. Knowledge gaps and important insights into complex processes can also be addressed through greater inclusion of Māori into co-development of knowledge and conservation practice, for example by use of data contained within centuries-old, location-specific Māori planting calendars known as maramataka. Co-development of projects can use the best of all knowledge systems to achieve effective conservation outcomes. Respectful partnerships and inclusion of mātauranga Māori has additional benefits for conserving or renewing culture and people's connection to the environment in Aotearoa New Zealand.

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HTTPS *https://doi.org/10.1002/fee.2285*

Our contribution to environmental reporting for Aotearoa New Zealand – the story so far

Since 2015, research organisations across New Zealand have contributed to a growing national cache of environmental reporting data under the 2015 Environmental Reporting Act, which brought into existence the requirement for cyclic national environmental 'domain' reports. This means the Ministry for the Environment and Statistics NZ need to report on the state of one aspect of our environment every 6 months, and on our environment as a whole every 3 years. There are five domains: air, atmosphere & climate, fresh water, land, and marine.

Scientists at Manaaki Whenua have acted as science leads for much of this work, offering expertise and strategic direction on the comprehensive Environment Aotearoa 2015 and 2019 reports, as well as individual domain reports including *Our Land 2018*, *Our Freshwater 2020*, and *Our Atmosphere and Climate 2020*.

During this time, the government's Treasury has also been shaping a new and ambitious commitment – to prioritise public spending by accounting for its contribution to people's well-being. Treasury's Living Standards Framework aims to define well-being with reference to four future well-being capitals: financial, human, social, and natural – explicitly recognising that maintaining the natural environment is a key part of well-being.

In a 2019 commentary, *Focusing Aotearoa New Zealand's environmental reporting system*, Simon Upton, the Parliamentary Commissioner for the Environment (PCE), assessed the success of the environmental reporting requirements under the 2015 Act. Supportive of the government commitment to well-being, nonetheless the PCE maintained that New Zealand cannot make economically efficient or socially fair environmental rules if we cannot measure authoritatively what's happening to our physical resources, on which our well-being ultimately depends.

Work now being done across Manaaki Whenua covers the breadth and depth of environmental research required by the ambitions of the government. Released on 15 April this year, the latest interim report, *Our Land 2021*, drew heavily on Manaaki Whenua's expertise and information, including that of Dr Nina Koele who was seconded to MfE to 'hold the pen' for the project, Dr Anne-Gaelle Ausseil and Garth Harmsworth of the senior science and mātauranga team, and Drs Bryan Stevenson and John Drewry who peer-reviewed the report.

The report is the first in the series to respond to the PCE's recommendation to take a theme-based approach to state-of-the-environment reporting, and it also aligns with the 'DPSIR' model used for public policy overseas: **Drivers** of change, **Pressures** on the environment, **State** of the environment, **Impacts** of that state, and society's **Responses.**

As a result, *Our Land 2021* focuses on dynamic land-use issues rather than static land indicators. It explores the pressures on land, the Māori perspective, the interaction with climate, links to public well-being, and wider aspects of the environment.

The report's environmental indicators are at a formative stage in this new approach, but each is given a full

explanation and trend analysis on the Statistics NZ website. As part of this work, Dr Sam Carrick and others at Manaaki Whenua updated and created new data for environmental indicators in soil quality and land fragmentation.

> *The absence of comprehensive and authoritative environmental data stands in the way of making good links between the state of the environment and well-being* – Simon Upton, Parliamentary Commissioner for the Environment, 2019.

Land fragmentation is an increasing concern in New Zealand, driven by urban expansion onto rural land on the fringes of urban areas. The most highly productive land in the country is vulnerable to fragmentation for commercial, industrial, residential, and lifestyle block land uses, limiting in particular high-value horticultural use of the land. This indicator uses data from Manaaki Whenua's New Zealand Land Cover and Land Use Capability databases, combined with LINZ topographic, land ownership and protected area data. Between 2002 and 2019, the area of highly productive land that had an urban or residential land use, hence unavailable or restricted from use as farmland, increased by 54 percent nationally, from 69,920 to 107,444 hectares.

For *Our Land 2021*, Manaaki Whenua scientists led by Dr Bryan Stevenson also collated site soil quality data covering the period 1996 to 2018 from Northland, Waikato, Bay of Plenty, Hawke's Bay, Horizons, Taranaki and Greater Wellington Regional Councils, Environment Canterbury, and Environment Southland; Marlborough and Tasman District Councils; Nelson City Council (2018 data only); and Auckland Regional Council. The data enabled nationwide reporting on seven soil properties across nine land uses: pH, Olsen phosphorus (measures of fertility), total carbon, total nitrogen, anaerobically mineralisable nitrogen (measures of organic status), and macroporosity and bulk density (measures of physical status).

The contribution of soil quality to wider environmental health was recognised, but further work is needed on the breadth of indicators, particularly measurements of soil biodiversity, as part of long-term soil quality monitoring.

Looking ahead, Manaaki Whenua's scientists are aiming to contribute to the MfE's *Environment Aotearoa 2022*, and are looking into the feasibility of new indicators that will be needed to assess impacts and meaningful linkages between the environment and human well-being. Fit-for-purpose indicators, which need to be transparent, reproducible, and traceable, all require robust supporting data.

Dr Ausseil is now leading work on identifying these indicators in conjunction with MfE, using a framework based on ecosystem services (ES) and Nature's Contribution to People (NCP), an approach favoured by the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). Initial work has proposed that indicators are split into 'supply' indicators, which represent an ecosystem's capacity to supply the service, and 'benefit' indicators, which refer to the service's contribution to well-being. Next steps include wider discussion of this framework and building indicators with the participation of a larger group of stakeholders.

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Urban development encroaching on productive land in Pōkeno, Waikato.

Reconstructing long-term climate change

Long-term palaeoecological and climate reconstructions provide baseline information to show how species and ecosystems have responded to climate change and human activities in the past. These palaeo-archives are increasingly being used to help inform conservation management plans and policies, increasing our understanding of the long-term impact of humans and the degree to which ecological changes today differ from natural disturbance and climate changes in the past.

Photo: Nelson Parker www.nelsonskaihukauri.co.nz

Photo: Dr Jonathan Parker, UNSW

Upper photo: Preserved 42,000-year-old kauri log (note truck for scale and saw cut for tree ring data). Lower photo: Tree rings from the saw cut.

Dr Janet Wilmshurst from Manaaki Whenua's Long-Term Ecology Lab has recently been involved in a number of international collaborations on long term palaeoecological records, resulting in three *Science* publications this year.

The first paper, ***Using paleo-archives to safeguard biodiversity under climate change***, led by Associate Professor Damien Fordham at the University of Adelaide, provided a review of how palaeoecological records can offer new prospects for benchmarking and maintaining future biodiversity.

The team found approximately 40 percent of terrestrial ecosystems are projected to have experienced shifts in temperature during the past 21,000 years that are similar in pace and magnitude to regional-scale future forecasts. The records reveal that terrestrial biodiversity will experience significant changes in response to future global warming, including wide-scale species declines that will threaten the goods and services ecosystems provide to humanity.

Identifying what causes some species to be more sensitive to climate-driven change in the past than others can lead to improving early-warning systems signalling population collapse, extinction or ecosystem shifts as a result of climate change, helping to safeguard biodiversity into the future.

In the second study, ***A global environmental crisis 42,000 years ago***, Dr Wilmshurst and Research Associate Dr Matt McGlone formed part of a major international collaboration between 31 scientists from seven different research fields (geochronology, climate modelling, atmospheric chemistry, solar physics, anthropology, palaeontology and genetics) that examined the impact of the last reversal of the Earth's magnetic poles.

The researchers analysed radiocarbon (carbon-14) in the tree rings of New Zealand kauri (*Agathis australis*) logs found preserved in Northland peat bogs for more than 40,000 years. The age of the trees happened to cover a key period of Earth's history when one of the most dramatic reversals of the magnetic poles occurred 42,000-41,000 years ago, known as the Laschamps Excursion after the French village where it was discovered.

Although the Laschamps Excursion has been recognised in palaeo-archives from around the world, until now it had not been clear whether such magnetic changes had any impacts on climate and life on the planet. Analysis of the ancient kauri tree rings revealed a prolonged spike in atmospheric radiocarbon levels, caused by a surge of cosmic radiation as the Earth's magnetic field weakened and the poles switched, providing a way of precisely linking widely separated records of environmental change from around the world.

The team found that the changes in magnetic and incoming radiation patterns caused substantial changes in atmospheric ozone concentration and circulation, electrical storms in the tropics, tropical Pacific rain belts and Southern Ocean westerly winds to change abruptly, arctic air to chill North America, and ice sheets and glaciers to advance. These synchronous global climate shifts occurred at the same time as major environmental changes, extinction events, and transformations in the archaeological record.

With some indication that the Earth's magnetic field could be relatively close to another, similar flip, having weakened about 9 percent in the past 170 years, this research illuminates some of the possible environmental consequences of such an event.

The third collaboration Dr Wilmshurst was involved with, ***The human dimension of biodiversity changes on islands***, led by Dr Sandra Nogue from the University of Southampton, sheds new light on the impact of humans on Earth's island biodiversity.

The team studied long-term pollen records dating back 5000 years, extracted from sediments on 27 islands around the world, including from New Zealand. By analysing all these fossil pollen data, they were able to build up an understanding of the composition of each island's vegetation and how it changed over time.

Globally, islands provide the ideal environment to measure human impact using fossil pollen analysis, as most were settled in the past 3000 years when climates were similar to the present day. Knowing when people arrived on an island means that scientists can study how the composition of its ecosystem changed in the years before and after.

The findings suggested that the rate of change in an ecosystem's plant-life increases significantly during the years following human settlement, with the most dramatic changes occurring in locations settled in the past 1500 years. The most rapid changes occurred in islands that were settled more recently - such as the Galápagos, first inhabited in the 16th Century. Islands where humans arrived more than 1500 years ago, such as Fiji and New Caledonia, saw a slower rate of change, probably because land-use practices, technology and introduced species brought in by earlier settlers were less transformative and far reaching than those of later settlers.

In New Zealand, and on many other islands, the legacy of human impact almost always surpasses the natural impact of earthquakes, volcanic eruptions, and extreme weather events, and the resulting vegetation changes are often irreversible.

The results of these three *Science* papers illustrate how reference periods in Earth's history serve as important natural laboratories for understanding biodiversity responses to climate and anthropogenic change.

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HTTPS *science.sciencemag.org/content/369/6507/eabc5654*

HTTPS *science.sciencemag.org/content/371/6531/811*

HTTPS *science.sciencemag.org/content/372/6541/488*

Future drought could drain primary sector profit

New research by the Deep South Challenge and Manaaki Whenua, with support of Motu Economic and Public Policy Research, has found that more intense future drought is likely to lead to drops in farm profit.

Comparing trends in 70,000 farm tax returns with temperature and soil moisture data, scientists were able to understand the historical relationship between local weather and farm profits in both the dairy and sheep+beef industries, and apply it to future scenarios.

Manaaki Whenua research co-lead Dr Kendon Bell says that uncontrolled climate change is likely to bring somewhat more severe and far more frequent drought.

"Year-on-year drought is still uncommon in New Zealand, giving farmers opportunities to recover – financially, mentally and environmentally, but in the year 2100, our 10-year-old children will be 90 years old. Their children – our grandchildren – will be managing farms in a far more tricky climate than we have to negotiate today."

Under a high climate change scenario – the pathway representing little climate action and high economic growth – sheep+beef farmers, vulnerable to high temperatures and soil moisture loss, could see a profit loss of up to 54% by the end of the century, subject to a high degree of uncertainty. Analysing potential changes in soil moisture, both dairy and sheep+beef show a decrease in profit by 2100 (an average of 20% for dairy and 7% for sheep+beef). A more moderate climate change scenario suggests – unsurprisingly – more moderate losses given soil moisture changes alone, but losses nonetheless.

Dr Bell notes one use of these results is to better understand how climate change might encourage farmers and growers to implement adaptation measures, or even to change what they farm and where. Due to large capital investments, it's difficult for farmers to change the way they use their land, and the slow pace of climate change will be unlikely to force land-use change in the near future. Yet this research suggests that land-use change should at least be on the cards in some places.

54% PROFIT LOSS

For sheep+beef farmers by 2100 in high climate change scenario

Dry hill-country grassland near Matamata, Waikato.

“Given that animal agriculture is a major contributor to both climate change and water pollution, understanding the extent to which climate change might affect this baseline over time is important for policy considerations over the coming decades, including the setting of future budgets for adaptation support.

“However,” Dr Bell continues, “what’s important is the relative attractiveness of animal versus other land uses. To gain a full understanding of how climate change might affect land-use pressures, we require profit-weather functions for all relevant land uses, in addition to those provided here for dairy and sheep+beef, but the underlying quantitative studies have not yet been done across all sectors.

“In New Zealand, very little research has been done about the implications of climate change for society using approaches that measure the historical relationship between weather conditions and economic and social outcomes – this research is among the first to do so. Rural communities may bear a large share of the burden of reducing emissions, and we have tried to understand, using real financial data, the size of the additional burden that climate change might impose.”

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HTTPS *deepsouth challenge.co.nz/audience/farms-whenua-awa/*

New way to map pasture productivity

Researchers at Manaaki Whenua have used remote sensing techniques to produce a national scale map of pasture productivity for New Zealand.

Difficulty in measuring the mass of pasture dry matter yield per unit area per year drove this research, which used 4 years of Sentinel-2 satellite imagery and collected pasture yield measurements to develop a model of pasture productivity.

The model uses a Normalised Difference Vegetation Index (NDVI), with spatio-temporal segmentation and averaging, to estimate mean annual pasture productivity across all of New Zealand’s grasslands to within around 2.2 tonnes per hectare.

Researchers applied the model to field-level segments, enabling regional and local trends to be explored. Due to its ability to highlight areas of land use intensification suitability, the national map of pasture productivity is of value to landowners, land users, and environmental scientists.

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Getting to the root causes of soil erosion using high-res remote sensing

Soil erosion processes are notably active in New Zealand: our steep slopes, generally weak sedimentary rocks, and high annual rainfall totals including frequent large rainfall events, underscored by a history of vegetation clearance for agriculture, mean that around 192 million tonnes of soil on agricultural land are lost to erosion every year.

Large rainfall events in New Zealand commonly trigger hundreds to thousands of shallow landslides, especially in more marginal pastoral hill country, causing significant damage to land and infrastructure as well as contributing large quantities of sediment to aquatic environments. These landslide inventories are used to determine which land is most susceptible to shallow landsliding to support targeting of erosion control measures.

Within the MBIE research programme Smarter Targeting of Erosion Control (STEC), scientists at Manaaki Whenua have been using new remote sensing techniques to fill these data gaps, mapping over 100,000 landside scars from high-resolution satellite or aerial imagery across the North Island. The latest mapping uses very high resolution (0.5 m) satellite imagery from storm events in the Horizons (2018 storm), Waikato (2017), Auckland (2017), Hawke's Bay (2011), and Greater Wellington (2005–2010) regions, complementing previous landslide mapping in the Horizons and Northland regions over many decades. These landslide inventories form the basis for machine learning models that predict where landslides may occur in future based on landscape factors such as topography, land cover and rock type. Regional-scale modelling of shallow landslide susceptibility for Hawke's Bay and Horizons is now complete.

detected by LiDAR in Wairarapa

As part of his PhD work within the STEC programme, Manaaki Whenua's Raphael Spiekermann used semi-automated mapping with high-resolution aerial imagery and slope information from Light Detection and Ranging (LiDAR) data to record some 40,000 shallow landslides in the Wairarapa. Use of LiDAR-based data significantly improved the ability to correctly identify landslide versus non-landslide locations. The current acquisition of LiDAR elevation data across much of New Zealand will enable improved targeted erosion control with higher-resolution landslide susceptibility modelling.

In linked work published recently in the *Journal of Environmental Management*, Manaaki Whenua's Mr Spiekermann, Dr Hugh Smith, and colleagues at Massey University have used LiDAR to delineate individual tree crowns and classify these into one of four dominant tree classes – poplar/willow, eucalypts, kānuka and conifers – on two pastoral hill country farms near Masterton. This is the first classification of individual trees at landscape scale in New Zealand using freely accessible data, which achieved an overall accuracy of 92.6%.

Tree roots bind soil and help mitigate soil erosion, but some species are better at it than others. Poplars and willows are commonly used in pastoral hill country to mitigate landslide erosion on hillslopes. By identifying the locations and types of trees present in the landscape, the researchers can estimate the reduction in future landslide erosion achieved. Additionally, the models can be used to predict what effect future planting would have on erosion rates.

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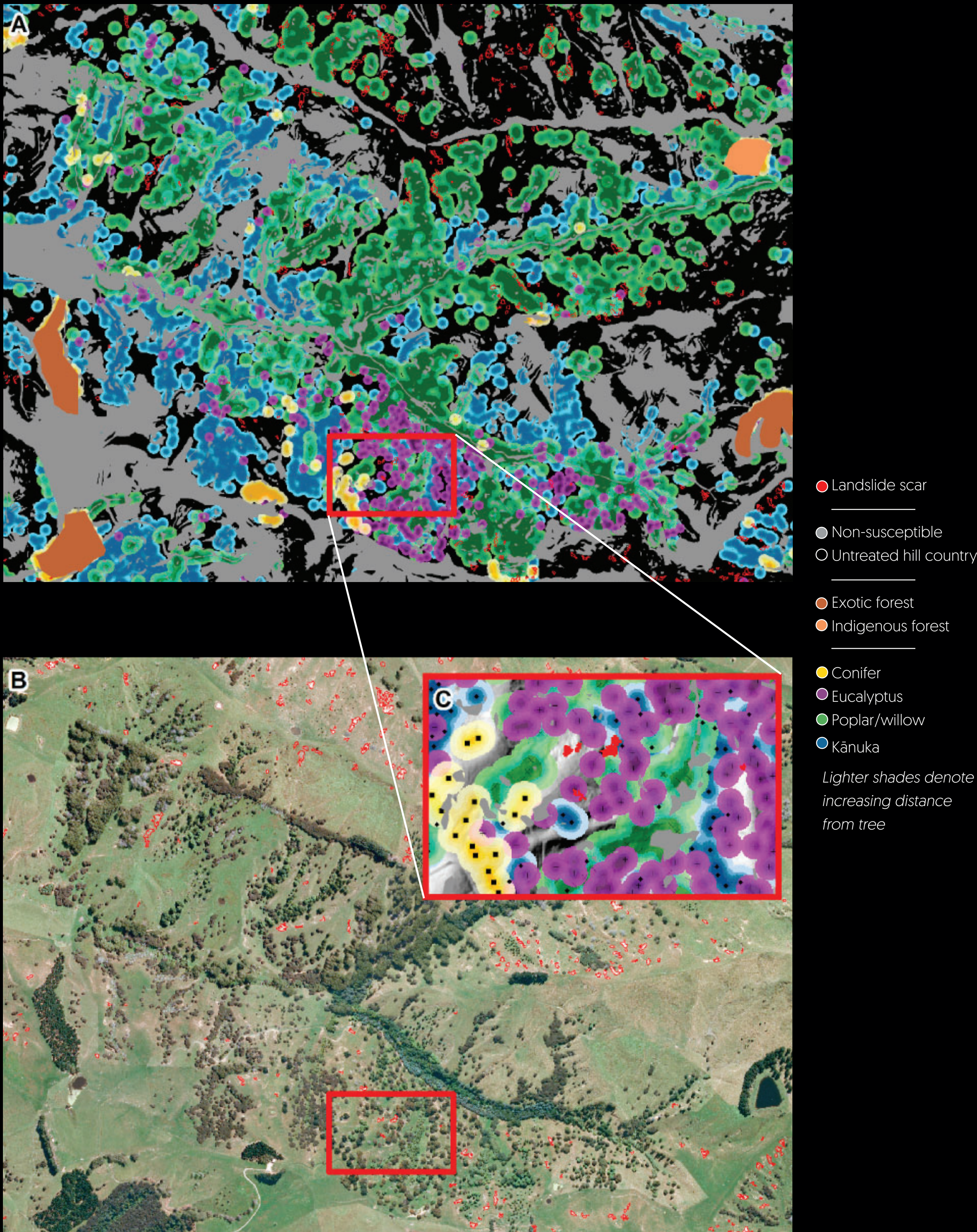
HTTPS *doi.org/10.1016/j.geomorph.2021.107660*

HTTPS *doi.org/10.1016/j.jenvman.2021.112194*



LiDAR imagery of tree crowns delineates species and crown height, enabling landslide risk to be calculated. A = false colour map, B = satellite view, C = detail of individual tree crowns.

A first for on-farm carbon certification

Lake Hawea Station has been named as the first farm in New Zealand to have a carbon footprint certified by environmental certifications provider Toitū Envirocare, a subsidiary of Manaaki Whenua.

Owned by Geoff and Justine Ross, Lake Hawea Station, a 6,500-hectare station on the eastern shores of Lake Hawea, runs close to 10,000 Merino sheep and 200 Angus cows. Selling its Merino wool offshore to carbon-focused brands such as All Birds and Sheep Inc., the farm is pursuing a farming strategy that is both beneficial to the planet and the farm's bottom line.

The process was relatively simple, says Mr Ross. "We started with some simple online calculators. We then had this process 'ground truthed' by two scientists and then Toitū came in to check our numbers and view our operation. Much of the information needed to calculate a carbon footprint is available as part of systems that farmers are already using, (Farm IQ and Overseer). So, it is more about gathering existing information and having Toitū run the calculations."

Close to 1,800 tonnes of CO_2-equivalent emissions from Lake Hawea Station, 71% of their total emissions, are due to methane from grass-eating sheep and beef. Other contributing areas include greenhouse gas from animal urine, fertiliser use, supplements, and farm vehicles. However, on the other side of the carbon ledger, the farm locked up well over 3,966 tonnes of carbon through extensive tree planting and areas of regenerating bush.

> *"Through extensive planting and regenerating bush, Lake Hawea Station has gone beyond carbon zero to sequester twice the amount of carbon they emit."*

Mr Ross has therefore been able to increase stock numbers while improving the farm's carbon position. "The popular myth is the only way to reduce your carbon profile is by reducing stock numbers. This hasn't been the case here. Instead, we have increased stock numbers and wool production while increasing our tree plantings and retiring of marginal land".

Becky Lloyd, Toitū Envirocare Chief Executive, says Toitū carbonzero farm certification is important as it demonstrates to farmers, their customers, and regulators that pastoral farms can be carbon-neutral and at the same time commercially viable.

Developed in partnership with Overseer and AsureQuality, Toitū's farm certification programme is New Zealand's first carbon certification designed specifically for farms. The programme uses Toitū carbon management software that integrates OverseerFM greenhouse gas emission analysis. AsureQuality's role is to independently verify the farm's carbon footprint.

The certification process Toitū has undertaken on Lake Hawea Station is planned to be the first of many for New Zealand farms, as the country moves to lower its overall carbon footprint and consumers worldwide demand carbon-positive food and fibre. To demonstrate this commitment, in 2020 the primary sector and the Government signed a joint action plan, He Waka Eke Noa, to require farmers to measure and reduce primary sector carbon emissions, and to put a price on farm carbon emissions by 2025.

Lake Hawea Station's Toitū carbonzero certification was supported by The New Zealand Merino Company as part of the exploratory science work behind their ZQ^{RX} regenerative platform. The Station sells its Merino wool through the ZQ^{RX} platform to offshore brands.

A moth to a flame: species survival against the odds

On 29 August 2020, a fire began near the Pūkaki Scientific Reserve in the South Island's Mackenzie district. Fuelled by wilding pines, the fire burned through more than 3,000 hectares of drought-dry land on the shore of Lake Pūkaki, and destroyed most of the reserve.

As well as containing rare montane scrub vegetation with an abundance of aquatic and terrestrial insects, the reserve was also the only known site for the endemic and critically endangered grey-white moth *Izatha psychra*, which depends on this increasingly rare old growth shrubland for its habitat. Found nowhere else on earth – and fewer than a dozen have ever been seen – the moth's chances of survival were vanishingly slim.

Therefore it was with some relief that, in late January 2021, a team of ecologists including Dr Robert Hoare of Manaaki Whenua and staff from DOC rediscovered *I. psychra* in a half-hectare gully of undamaged shrubland. An expert on New Zealand's moths, Dr Hoare's advice on light trapping was crucial to its rediscovery.

The moths were found in a small gully that still had undamaged leaf litter, deadwood, and lichens in it, thought to be where their caterpillars live. It was a narrow escape, but the future of the species is still uncertain, especially until the scrub recovers, which may take years. The fragment of land is now more vulnerable to risks such as weed invasion, primarily cotoneaster and wilding pines, browsing animals such as rabbits and pigs, and future fires exacerbated by drought. A fence is being reinstated to keep out the browsers, but the other problems persist and may well get worse if climate change leads to more prolonged dry periods.

For Dr Hoare, the tale of *I. psychra* raises an important question: does it matter if species such as these lapse into extinction?

"Already they and others like them are so rare that they are unlikely to be performing a major function in the ecosystem," he says. "They are not economically important; they may not even seem very beautiful, except to an entomologist.

"However, New Zealand's little-understood Lepidoptera (moth and butterfly) fauna is highly endemic, found nowhere else (there are roughly 1,800 endemic Lepidoptera out of 2,000 in total). Many other orders of invertebrates in New Zealand show similarly high levels of endemism. Thus, when we contemplate these species as the tiny and unique moving parts of a much greater and impossibly complex whole, full of as-yet unknown biological benefits and dependencies, the perspective changes.

"What parts of an interconnected tapestry can we afford to lose, when we cannot see the whole and don't know which thread is connected to which?" asks Dr Hoare.

"This is why researchers will continue to go out into the field after environmental disasters, to look for evidence of survival and to protect what remains, even against the odds."

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Celebrating our achievements

Manaaki Whenua has two new Royal Society Te Apārangi Fellows:

Zhi-Qiang Zhang has significantly advanced global taxonomy by founding and leading two of the largest international journals in biodiversity research: *Zootaxa* and *Phytotaxa*. Zhi-Qiang is a world-leading authority on the systematics and ecology of mites and has made outstanding global contributions to acarology. He has discovered and named over 150 new species of mites and wrote the first monograph on mites of greenhouses in the world. Due to the high frequency of mites existing in exported and imported produce, his work has greatly eased trade barriers and facilitated the import and export of fresh and stored produce.

Garth Harmsworth (Te Arawa, Ngāti Tūwharetoa, Ngāti Raukawa) is renowned for his work building Māori research capability nationally, and advancing mātauranga-based kaupapa Māori and collaborative research practice. His knowledge and understanding of catchment management from both science and te ao Māori has been ground-breaking in establishing sustainable development approaches. He has brought an indigenous perspective to a conventionally 'biophysical' science discipline, which now serves as a best practice guide for future land use within Aotearoa and across the globe.

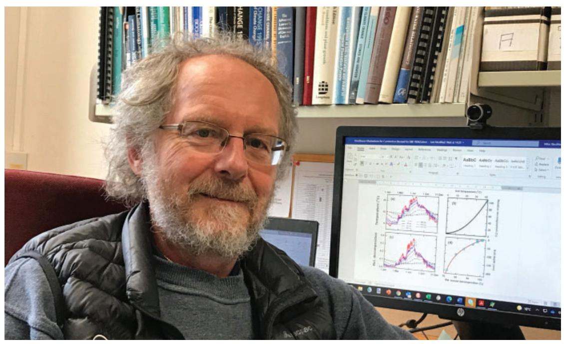
Manpreet Dhami has been appointed to the Royal Society of New Zealand Marsden Ecology, Evolution and Behaviour Panel. The panel assesses the applications to fund studies related to the interrelationships between organisms and their environment, evolution, and behaviour.

Miko Kirschbaum, who works in the development of computer models to investigate the growth responses of forests and grasslands to climate change, made it onto the Reuters 'hot list' of the top 1,000 climate scientists worldwide. The list is based on the numbers of papers published over a career, the number of citations of those papers, and a measure of public reach of the papers.

Zhi-Qiang Zhang

Garth Harmsworth

Manpreet Dhami



Miko Kirschbaum

Towards a national strategy for soil

Graham Sevicke-Jones, Sam Carrick and Garth Harmsworth

Why a soil strategy? After all, we have spent a few decades now in the absence of a strategic direction. As often plays out, urgency of fundamental information occurs during times of policy or management decisions being made. However, once the decision is made, the pressure goes off and the perceived need dies with that. This limits our ability to ensure we have sound underpinning information to protect and enable Aotearoa New Zealand to thrive in a changing world.

Soil is central to our success as a nation. This has been a constant through the history of Aotearoa New Zealand. Māori have had a long connection and understanding of soil reaching back centuries to Polynesian migration. Soil is recognised as a taonga (treasured resource), especially at the iwi/hapū, whānau and community level, providing cultural, spiritual, social, emotional, and economic sustenance to Māori with demonstrated links to land security, food production, healthy foods, and human well-being.

Across Aotearoa the soil underpins our economy, our biodiversity, environmental health, and well-being of our communities. Much of our regional identity reflects how soil has shaped our use of the land – think of the rolling grasslands of Waikato or Southland, the wine land in Marlborough, or the fruit lands of the Bay of Plenty. Soil sits at the nexus of many of the national challenges we face. Whether it's food and water security, biodiversity, healthy waterways, secure infrastructure, or adapting to climate change, the success of our response to these challenges will be strongly influenced by the management of our unique national soil resource.

The importance of soil to a nation's success is not unique to Aotearoa New Zealand. Soil security has become a global challenge. As part of the UN Sustainable Development Goals, Climate Change agreements, or freshwater and food security, the sustainable management of soil as a taonga is vital to global health. Recognising this, the UN has established the Global Soil Partnership, with the mission to 'position soils on the global agenda through collective action, by promoting sustainable soil management and improve soil governance to guarantee healthy and productive soils to support essential ecosystem services'. At the bloc and national level, the importance of soil security is being explicitly recognised. The European Union is currently consulting on an updated EU soil strategy, and the Australian Government has just released a national soil strategy as part of the national budget 2021.

In 2015, MPI commissioned a comprehensive multi-agency review of future requirements for soil management in Aotearoa New Zealand. One of the main outcomes identified was the need for a national soil strategy. Since then, the importance of soil to the nation's well-being has been increasingly recognised, while the pressure on this taonga has continued to increase. We propose it is timely to develop our national soil strategy; this will give us a pathway to provide for a healthy and thriving Aotearoa New Zealand. While we can learn a lot from other nations, we would also make a strong global contribution through embedding our soil strategy in the perspective of sustaining national well-being. To achieve this, it is logical that development of the national soil strategy follows a te Tiriti approach, recognising soil as a national taonga.

Kia tupu matomato a Tāne, a Rongo, a Haumia-Tiketike – Let it be that the land and all its fruits may flourish.