Pūtaiao

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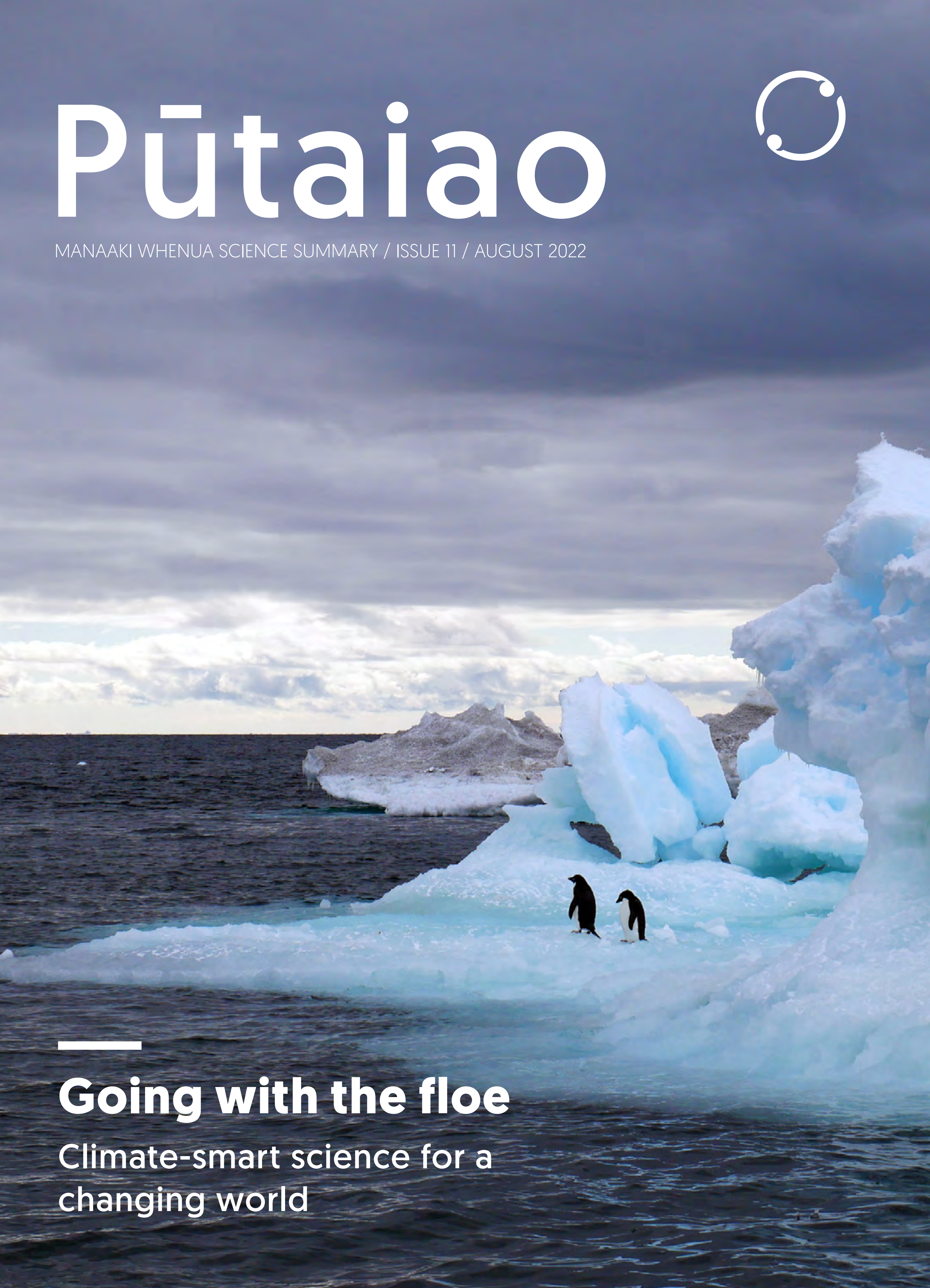

Going with the floe

Climate-smart science for a changing world

Pūtaiao

Science for our land and our future

Tēnā koe and welcome to Issue 11 of *Pūtaiao* ('science' in te reo Māori), our quarterly publication showcasing the work of our scientists at Manaaki Whenua.

We are the Crown Research Institute for our land environment, biosecurity and biodiversity, climate action, 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* shares the benefits and outcomes of our science in helping to ensure a sustainable, productive future for New Zealand. This issue shows the breadth of our research into the environmental consequences of climate change, from the international to the farm scale, and how we might mitigate those consequences to ensure a sustainable future for Aotearoa's land environment.

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Cover image: Adélie penguins on ice near Cape Bird, Antarctica.

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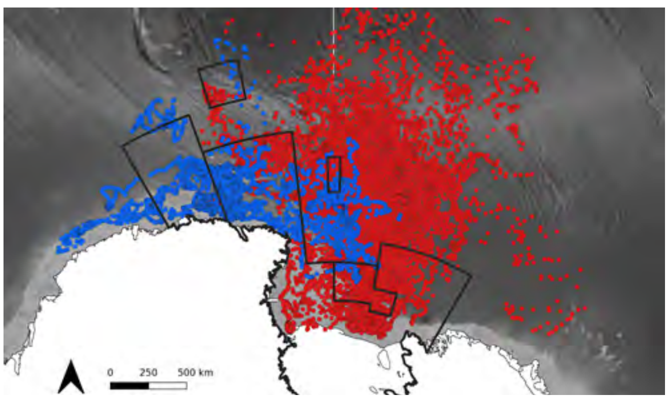
Adélie penguins, climate change and fisheries management

As a harbinger of change, Antarctica's Adélie penguins make the perfect subjects. They are an ice obligate species and are highly sensitive to the abundance and distribution of their primary prey – krill and fish.

Manaaki Whenua researcher Dr Dean Anderson says Adélie are a sentinel species because changes in their behaviour or population dynamics are indicative of changes in climate (which can be seen in the ice) or fishery management. Much of the Ross Sea was designated as a Marine Protected Area (MPA) in 2017, and Adélies use the entirety of the Ross Sea and the MPA through movement and migration. "If we want to be able to disentangle the effects of climate change or fisheries on their population or behaviours, we need to understand those relationships."

Adélie penguins are the most widespread birds in the Antarctic. They breed on outcrops of Antarctic rock. At Cape Bird, where Dean and his team do their research, about 80,000 birds return every year to nest and breed, from around the start of summer in late October.

During the Antarctic summer Dean and the team attach GPS telemetry units to the backs of breeding adult penguins. The data



Over-winter migration location points of 53 penguins from Cape Bird, Ross Island (red) and 14 from Cape Adare, northwest Ross Sea (blue). Data were collected with light-measuring geolocators.

Adélie penguins on sea ice, Cape Bird, Antarctica.

show how far and where the birds are travelling to feed relative to ice and prey abundance. The birds then return to the colony to feed their chicks. Abundant ice and prey lead to efficient foraging and fast-growing chicks.

Following the breeding season, adult penguins and newly fledged chicks migrate north over a period of about 8 months. They can't stay at the colony over winter because it is dark 24 hours a day and the sea is frozen solid. During this period, the penguins need to fatten up and gain strength to prepare for the following breeding season. To do this they need to find 'primo Adélie luxury spots', where they have access to water, high prey abundance, ice, and daylight (they need to see to forage). This can require a round trip of 14,000 km.

To learn where the penguins migrate, Dean and the team deploy small light-reading devices on the ankles of breeding adults. The information gained provides an understanding on how climate change and fisheries may impact survival and behaviour during this critical time.

The work is about establishing a relationship between the migration patterns, ice conditions, prey abundance, and sea currents, so that when change does happen it makes it possible to attribute the change to something in particular, for instance either climate change or changes in fishery practices.

The next steps in the project are to start using remote sensing to start monitoring the size of penguin breeding colonies across the Ross Sea.

"If we can use satellite images to count every year then we can really monitor the annual fluctuations and relate that to changes in the larger Ross Sea," says Dean. While the satellites can't yet distinguish individual penguins, they do show up differences in the pink-coloured guano on top of grey-black rock. "We can establish a relationship between how much area is covered in guano and the number of penguins," says Dean.

Those data feed into a model that can show whether population changes are natural fluctuations or due to deviations in sea ice or prey abundance, which would be indicative of the effects of climate change or fisheries management.

Dean says 3 years of data so far have given a good baseline of relationships between ice conditions and fisheries practices. "The Ross Sea is in a marine protected environment, but it's only set in place for 35 years. We really need a scientific basis for making decisions on what happens to it after that."

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

Real-time avian malaria warning system aids hoiho conservation efforts

Hoiho/yellow-eyed penguin with mosquitoes feeding.

A new web-based tool has the potential to make a significant impact on conservation efforts to protect the vulnerable yellow-eyed penguin, or hoiho, as warming temperatures impact their environment.

Manaaki Whenua researchers Dr Chris Niebuhr and Dr Simon Howard, with support from the Yellow-eyed Penguin Trust and the Department of Conservation, began developing their real-time avian malaria early-warning system in response to an increase in avian malaria mortalities observed in wild hoiho populations in 2018. The rarest penguin in the world, populations of the hoiho are declining rapidly from shrinking food stocks, and now increasingly from disease, notably avian malaria.

Avian malaria, transmitted to birds by mosquitoes (but harmless to humans), can infect a variety of New Zealand bird species, including kiwi, songbirds, and penguins. At least two mosquito species found in New Zealand probably transmit avian malaria, including the endemic and widespread *Culex pervigilans.*

Previously, temperature thresholds in the cool south of the country, the home of the hoiho, have been a limiting factor for mosquitoes. They were present for short periods in relatively smaller numbers compared with warmer areas in the north. However, warming temperatures may lead to an increase in mosquito numbers, expansion of mosquito zones (both in latitude and elevation), and a lengthening of the period they are active. Early model projections show that warmer temperatures could influence the timing of mosquito emergence and peaks in abundance, which could in turn lead to more avian malaria transmission during the time hoiho adults are moulting and chicks are fledging.

“These are the most vulnerable times for the penguins in terms of mosquitoes, so understanding the transmission dynamics of avian malaria during these sensitive penguin times is crucial to conservation efforts,” says Chris. The online tool uses existing epidemiological models that incorporate minimum threshold temperatures for both mosquito vector and avian malaria pathogen development. “It will also automatically retrieve the latest temperature data from local weather stations near penguin nesting sites.”

The data will be used to predict trends, including periods where high abundances of mosquitoes are anticipated, which will make it possible to target management efforts, such as potential mosquito control. The work also has the potential to translate to other mosquito species and diseases, some of which may not yet be present in New Zealand, such as Ross River virus, West Nile virus, and dengue fever.

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An update on national soil carbon benchmarking and monitoring

Every year, under the United Nations Framework Convention on Climate Change and the Paris Agreement, Aotearoa New Zealand is obliged to report its national human-produced (anthropogenic) greenhouse gas (GHG) emissions and removals, including changes in soil organic carbon (SOC) stocks. With average soil carbon stocks in New Zealand's agricultural soils estimated at about 100 tonnes per hectare in the top 30 cm, any change in soil carbon could make a significant contribution to carbon footprints at national, industry and farm scales.

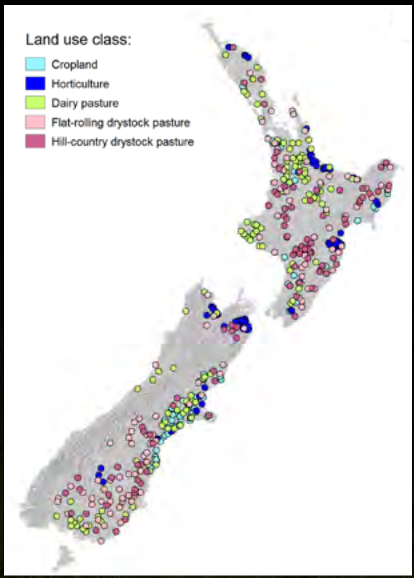
National-scale changes of SOC stocks in mineral soils are currently predicted based on transitions of land use (e.g. forest to pasture) using a statistical model calibrated with historical data. The model assumes that SOC doesn't change if there isn't a change in land use (e.g. if an area remains in long-term pasture).

The new national SOC benchmarking and monitoring system, reported in *Putaiao* issue 3, July 2020 and funded through the New Zealand Agricultural Greenhouse Gas Research Centre, is making good progress on benchmarking soil carbon stocks at 500 sites across agricultural land in New Zealand. Samples are collected in 10 cm increments to 60 cm depth using soil cores, or quantitative pits for stony soils. About 100 sites will be sampled in each of five broad land use classes (see map) to monitor change in SOC stocks through time within each land use class.

As of June 2022, 275 of the 500 sites have been sampled, with sampling of remaining sites ongoing. Initial estimates of the SOC stocks within each land use class have been made – on average, the highest SOC stocks are in soils under dairy pasture and the lowest under cropping land. However, these results must be treated with caution. More, or less, SOC cannot be interpreted as a land-use effect because the location of different land uses is often related to soil type and climate in the first place. For example, there are proportionally more dairy sites on Allophanic soils, which have naturally high SOC stocks, due to the soil's specific mineralogy.

When benchmark sampling of all 500 sites has been completed in 2023, further inferences about the effect of some key land use/soil order interactions on SOC stocks should be possible, particularly within grassland classes. However, the key longer-term focus of this study is to determine whether SOC stocks are changing through time within different land use classes, and the answer to this question will be obtained after resampling the sites. The plan is to begin resampling sites in 2023 (benchmark sampling started in 2018).

Our results will provide greater certainty about SOC stocks and stock changes



in New Zealand and will be used to improve national greenhouse gas inventory reporting. Robust data for different land uses will also help enable the primary industry to make credible statements about SOC to international markets amid increasing emphasis on good environmental stewardship. Information from direct measurement of changes in SOC stocks under different land uses (in New Zealand conditions) will assist farmers as they consider options for reducing their net GHG emissions at the farm scale.

Acknowledgements
We are very grateful to the hundreds of farmers who have provided access for sampling and information on land use and management.

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Is my paddock carbon-neutral? How our scientists contribute to understanding global climate change

Measuring fluxes, the uptake or release of gases from a surface, is a crucial part of climate science. A method known as eddy covariance, first developed in the early 1950s, is today used by scientists worldwide to measure the carbon, water and energy flows between ecosystems and the atmosphere.

This science is becoming more and more sophisticated. As gas gets exchanged at plant or soil surfaces, it is transported vertically by turbulent eddies. Instruments placed on towers above the surface can measure these eddies, which then allows the fluxes of carbon dioxide, water vapour and other gases to be calculated.

Improvements in technology and data processing power have allowed these flows to be measured and modelled in ever-increasing detail and has led to the development of a global network of about 1000 flux towers known as FluxNet.

Fluxes of nitrous oxide and methane can also be measured, which is important to help New Zealand's agricultural sector to assess the effect of different management options on total greenhouse gas emissions.

OzFlux, which counts Manaaki Whenua as a partner organisation, is part of FluxNet. The OzFlux network was set up in 2001 to provide Australian, New Zealand and global researchers with consistent flux data for Australia's and New Zealand's unique ecosystems. Since then, it has matured into a network that provides relevant and robust data and information on ecosystems for researchers, resource managers and policy makers, with an important emphasis on data sharing and integration.

Ecosystems measured by OzFlux span a huge range of bioclimatic conditions, from alpine to tropical, from coastal to continental, and from deserts to rainforests. This wealth of data is also being used to develop sophisticated ecosystem models that are being tested and verified with the OzFlux data. These models allow researchers to make powerful predictions about the future and the responses of ecosystems to our changing world: for example, will ecosystems switch from being carbon dioxide sinks to carbon dioxide sources? Will agricultural productivity increase or decrease? Are some systems particularly vulnerable? Will the emissions of other greenhouse gases increase or decrease? And most importantly, what can we do minimise any harm, while making the most of any new opportunities?

A recent study by OzFlux scientists, including Drs Miko Kirschbaum and Johannes Laubach of Manaaki Whenua, has outlined the important contributions made by the OzFlux network over the past 20 years to global understanding of how climate affects carbon fluxes.

OzFlux has allowed researchers to:

- develop the science and models needed for accurate ecological forecasts and longer-term projections of responses to climate extremes.
- document ecosystem recovery from disturbances such as storms and fire.
- study the fluxes associated with agricultural ecosystems to understand what combinations of farming practices and environmental factors lead to carbon gains and losses.
- diagnose year-by-year variability in the carbon cycle and net greenhouse gas emissions.
- verify carbon market products and greenhouse-gas mitigation approaches.
- benchmark and improve models

Example of a flux tower on a dairy farm in mid-Canterbury. Photo: John Hunt.

of terrestrial ecosystems and understand their important feedbacks to climate change.

- evaluate and improve simulations of the feedbacks between the land and the atmosphere during short-term events such as heatwaves and droughts.

This underpinning science is vital to enable climate-smart future land management. It demands continuity of data collection over many decades. Some OzFlux sites, particularly in New Zealand, have been dedicated to investigating the net carbon gains or losses (including carbon dioxide as well as imports and exports) of pastoral agriculture and from conversion of pasture to forest. Two teams participating in OzFlux, at Manaaki Whenua in Lincoln (including Johannes) and at the University of Waikato, operate sites to determine net greenhouse gas balances of grazing systems and to test mitigation approaches. Manaaki Whenua scientists in Palmerston North (including Miko) use these data to model the underlying processes.

Manaaki Whenua's scientists will continue to contribute to the important global resource provided by OzFlux.

Future development of the network will include further integration of the tower stations with remote sensing technologies; more research about how soil processes contribute to the fluxes, including how soil moisture affects plant transpiration; and exploration of how changes in land use or management impact net greenhouse gas emissions.

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HTTPS *doi.org/10.1111/gcb.16141*

How will pathogen communities change as climate warms?

Manaaki Whenua researchers, in collaboration with Dr Ian Dickie at the University of Canterbury, are using next-generation sequencing to try and understand what drives kānuka health.

Dr Kate Orwin, a senior researcher with Manaaki Whenua's Land Use and Ecosystems team, says how a plant interacts with its neighbours, the soil underneath it, and the landscape that it is in can all influence plant health and how a plant resists pathogens.

The work is funded by the Bioprotection Aotearoa Centre of Research Excellence and has developed from an earlier project using molecular-based methods to quantify biodiversity across different land uses. As part of that project, researchers examined how land use influences which plant pathogen communities are found where.

“We are able to use the methods developed by former Bioprotection student Andreas Makiola in his PhD research on drivers of plant pathogen composition and richness, and take a similar approach to a different question,” says Kate.

Andreas’s research showed that in the face of future climate and land use changes, changes in plant pathogen community composition and richness at a plot-scale are likely to be driven primarily through changes in plant communities, rather than the direct effects of climate or soils.

“What we are really trying to understand in this new project, is what drives health at an individual plant level, using kānuka as a model species,” says Kate. “In a broader sense, as the climate changes we potentially face more and different diseases, so understanding how to make systems more robust would be helpful.”

The first step is to study the characteristics of individual kānuka plants that have pathogens on their leaves or roots but no signs of disease. Using Banks Peninsula as an initial research area, postdoctoral researcher Dr John Ramana will be collecting samples from kānuka trees and stands across 30 sites with different rainfall, temperature, and soil properties.

Researchers will then test whether a core microbiome is shared among healthy plants, or if that microbiome is determined by environmental conditions. “It’s about taking a holistic approach and looking at a community of pathogens, rather than just a specific pathogen or the disease it causes,” says Kate.

“We are hoping to understand what makes a plant healthy – what is on its leaves, what is in the soil, what makes it able to resist disease? We want to test the hypothesis that healthy plants are not defined by the absence of pathogens, but rather by the absence of disease.”

Kānuka is ideal for this research as it is ecologically and culturally important, and grows in a range of habitats that should result in individual plants interacting with different microbes, soils, and neighbouring communities.

The ultimate aim of the research will be to provide managers with guidance on how to manage their landscapes, for instance how to increase the health of kānuka plants to make them more resistant to disease in the face of climate change.

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HTTPS *doi.org/10.1111/nph.17797*

Towards local-parallel scenarios for climate change adaptation

We live in an already complex world, to which climate change is rapidly adding an extra layer of complexity. Communities and societies are increasingly having to adapt to climate change, but the unpredictability of change makes it very difficult to plan for future responses at any scale. To address this problem, scenario planning is commonly used to explore potential impacts, assess vulnerability of populations, and identify their adaptation options. The 'global-parallel' method, as used by the Intergovernmental Panel on Climate Change (IPCC), is one example. It creates projections of the effects of climate change for specific regions, using consistent global datasets of, for example, greenhouse gas emissions and population growth, set within a variety of policy options.

In developing such scenarios, however, there is a challenge in moving from the global scale to the national and local scales in a way that connects and explains complex systems in meaningful ways for stakeholders such as farmers and other rural business people. Another risk is that the experts who develop such scenarios are seen as privileged out-of-towners or 'suits', leading to problems of trust and even undermining the perceived legitimacy of climate change as an issue.

In response, Dr Nick Cradock-Henry and Dr Gradon Diprose of Manaaki Whenua have worked with former Manaaki Whenua colleague Dr Bob Frame to extend global data-driven scenarios to national and local contexts in ways that are time and resource efficient, are relevant to local decision-makers, and combine the complex synergies between climate change and other stressors – financial, social, and environmental – experienced by people in rural areas and on-farm.

Using the West Coast as a testbed, they have developed a novel 'local-parallel' method that might be applied across other regions, to gain insight into local and regional farm management dynamics, and to better understand climate change adaptation locally in terms of complex adaptive systems.

At the heart of the approach was the co-creation of contemporary, locally specific yet globally connected knowledge about the likely effects of climate change on farm management on the West Coast. This was achieved by interviewing a wide range of local business people and thought leaders – from doctors and clergy to writers and artists – both formally and informally, to discover their lived experiences, and researching easily relatable documents and visual cues such as local photographs, maps, and opinion pieces from local newspapers.

At a pair of workshops attended by West Coast farmers, the team then

presented global and national trends in climate adaptation for two scenarios, a low emissions scenario and a high emissions scenario, alongside the local stakeholder knowledge.

The researchers showed that the local-parallel approach, with its additional components of locally specific knowledge, helped make the climate change scenarios appear as accessible and credible representations of plausible local futures.

"Futures scenarios are an exciting way to address long-term challenges

Climate Change 2022: Impacts, Adaptation and Vulnerability (ipcc.ch)

characterised by uncertainty and complexity. Involving stakeholders and end-users in scenario development and using the diversity of data can deliver rich insight into plausible and possible changes. Developing this futures literacy in turn, enhances resilience through improved foresight to deliver better outcomes in the face of climate change and other stressors," says Dr Cradock-Henry.

In other recent work, Dr Cradock-Henry was an invited contributing author on the Australasia chapter of the IPCC's *Sixth Assessment Report,* which was finalised in February 2022. The chapter covered climate change impacts and risks, vulnerability, barriers, and options for adaptation and climate resilient development here and in Australia, including for primary industries, tourism, and the water/food/energy nexus. With Dr Frame he also gave an invited webinar in April 2022 to the Business School, Worcester Polytechnic Institute, Massachusetts, USA, focusing on the impacts and implications of climate change in Aotearoa, and the risks and opportunities for business. Case studies in the dairy and wine industry, financial services and retail were used to illustrate the ways businesses are adapting to change.

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HTTPS *doi.org/10.1177/20530196211059199*

HTTPS *ipcc.ch/report/sixth-assessment-report-working-group-ii/*

HTTPS *youtube.com/watch?v=sI4VpvL2reg*

A data centre for environmental research

A new website powered by high-performance computing and increased data storage and analytics capability now provides easy access to important national environmental data for science, government, local bodies, industry, business, iwi/Māori, and the public.

The National Environmental Data Centre (NEDC, https://nedc.nz/) is a collaborative Crown Research Institute (CRI) initiative, integrating CRI data in a networked national environmental research data infrastructure.

The datasets – Global Eradication and Response Database (Gerda), hosted by Plant & Food Research, Our Future Climate New Zealand, hosted by NIWA, National Tsunami Hazard Model, hosted by GNS Science, and Biota of New Zealand, hosted by Manaaki Whenua – include a huge range of information, giving new insights in areas such as sustainable use of natural resources, land use decision making, environmental management and reporting, resilience to natural hazards, and conservation.

Nick Spencer, Informatics Team Leader at Manaaki Whenua, says: “This important collaboration paves the way for the CRIs to provide even greater value from the information we care for on behalf of New Zealand. Making data easier to find and access will support data-led decision-making and enable new research insights to help New Zealand adapt to environmental change.”

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New look for Biota of New Zealand

Manaaki Whenua’s taxonomic information has a new collaborative home. Until now NZFlora, NZFungi, NZFungi2 and NZInverts, which between them provide taxonomic and nomenclature data for terrestrial invertebrates, fungi and bacteria, and plants, have existed as four separate websites.

Systematics & Biodiversity Informatics researcher Aaron Wilton says the sites have grown over this time to be among the more popular pages published by Manaaki Whenua. “They have racked up significant visitor numbers over the years. NZFungi2 had more than 450,000 average page views a year, and eFlora more than 107,000 page views annually. This really shows the significance of these collections of data.”

Sadly, while the old sites were well-loved and well-used, the software underpinning the sites recently reached its end-of-life, presenting an opportunity to build a single, contemporary resource that would deliver what key users needed.

The result is the Biota of New Zealand website: https://biotanz.landcareresearch.co.nz/

Developers were able to build an innovative framework that enables real-time or near-real time updates as data are uploaded. Other features are an enhanced search function, photo galleries, and graphics to make it more intuitive to navigate. It’s also been made easier to download a record, share it or cite it. Each page presents a record of the available information for a scientific name, reference or vernacular (common) name.

In time the other sites, such as NZ Flora (nzflora.info), Systematics Collection Data (SCD), and Floraseries, will be migrated to this new framework.

BIOTA of NEW ZEALAND
Names and classification of bacteria, fungi, land invertebrates and plants

Developing land-use decision-making frameworks in partnership with Māori essential

A recent study involving Manaaki Whenua Kaihautū Māori Dr Nikki Harcourt and Senior Researcher Dr Melissa Robson-Williams, has found it is essential to co-develop land-use decision-making frameworks in genuine partnership with Māori if they are to be of any use.

Choices about how to use land are critical to managing water quality in Aotearoa-New Zealand. Both Māori and non-Māori communities are needing decision-making frameworks that enable their values and priorities to inform these choices. However, researchers say few of the available frameworks meet the needs of Māori communities, and constructing decision-making frameworks that are truly useful for both Māori and non-Māori land stewards is challenging because of the differences in their relationships with te whenua (land), te wai (the water), and te taiao (the environment).

In the study, researchers utilised a modified version of Cash et al.'s Credibility, Salience, and Legitimacy framework to evaluate a range of land-use decision-making frameworks. This was to help non-indigenous researchers understand the required development processes and design features if a framework aimed at a broad audience is to have genuine relevance and utility for indigenous users. Following the assessment, researchers found it is critically important that any decision support tools are designed to embrace Māori values if they are to be truly useful to Māori and elicit the information required to achieve their aspirations for managing their whenua.

Researchers conclude it is essential to co-develop frameworks in genuine partnership with Māori and believe taking a true co-development approach and operating at the research interface where indigenous and non-indigenous research partners share knowledge and perspectives will produce more relevant and useful outputs that are transformational for land-use decisions.

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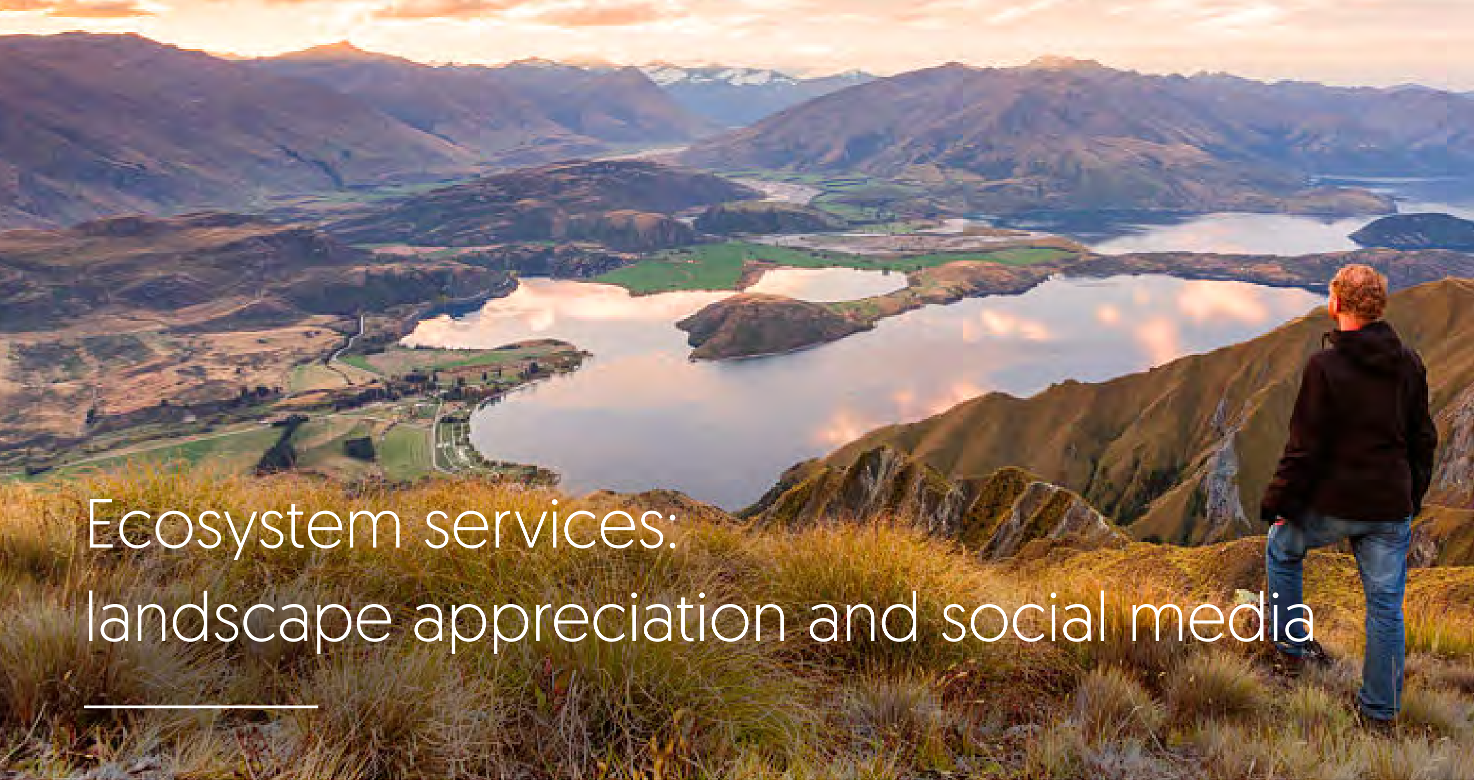

Ecosystem services: landscape appreciation and social media

Ecosystem services – defined as the benefits people obtain from natural environments and healthy ecosystems – are broadly categorised into four main groups: regulating services such as air purification and pollination; provisioning services such as food, energy, and medicinal resources; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational experiences and the aesthetic, educational, and therapeutic value of the natural environment.

Measurement of ecosystem services is an important part of policy-making in land management. Ecosystem services such as pollination, pollution treatment, and food production can be measured relatively easily, and their contributions quantified. However, it is harder to measure much more subjective cultural ecosystem services – how are aesthetics or well-being benefits to be judged, for example, if no two people experience a landscape in the same way? This issue leads to cultural ecosystem services being overlooked when modelling future scenarios in land management.

Social media data – principally geotagged photos – are increasingly being used to show where recreational, tourism, and cultural activities are being done, and can therefore be used as proxies to infer the value of some cultural services being provided by an ecosystem.

Manaaki Whenua's researchers Dr Dan Richards and Dr Sandra Lavorel extracted over 150,000 geotagged landscape photographs uploaded to the website Flickr in New Zealand to develop an indicator of landscape appreciation. Photographs specifically uploaded for public viewing were accessed using an official Flickr interface and the content of the photographs was analysed using the image recognition software Google Cloud Vision and a machine learning technique known as maximum entropy modelling that is also used to model species distributions.

"Many people go outside to appreciate landscapes, but it is difficult to measure why certain landscapes are more popular. There is huge untapped potential to use the public information in social media to help us better understand people's use and appreciation of nature," said Dr Richards.

This unusual combination of techniques allowed the researchers to delineate what types of landscape were photographed and where, giving a likely indication of the value of the landscape to the photographer. Around 40% of the photographs were defined in this way as landscape appreciation photographs, and over 70% had keywords associated with landscape appreciation.

The researchers then extended the reach of their study, to see whether machine learning could allow social media data on landscape appreciation to inform future planning decisions. How might appreciation of an agricultural landscape change if, for instance, native forest was restored in that landscape, and how might enhancing landscape appreciation have trade-offs with other ecosystem services objectives – such as storing carbon?

The results of their analysis showed that it was rarely possible to optimise both aspects of ecosystem service value – landscape appreciation and carbon storage – at the same time. Areas of high landscape appreciation – which tended to be coastal and closer to highly populated areas – did not necessarily gain further landscape appreciation value when increases in forest restoration were modelled. For distinctive agricultural landscapes such as the Canterbury Plains, scenarios involving native forest restoration could have a negative effect on landscape appreciation. At a national scale, the optimal method to increase carbon storage would be to focus native forest restoration in small areas, mainly in Canterbury. On the other hand, to bring the greatest benefit for landscape appreciation, it would be better to encourage native reforestation widely and at a lower density around the country.

The work showed that it is possible to quantify landscape appreciation as an indicator of cultural ecosystem services, and that this indicator can be meaningfully included in future landscape management scenarios alongside other, more familiar, ecosystem service indicators.

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Celebrating our achievements

In April 2022, **Dr Bev Clarkson** was awarded the Loder Cup by the Minister of Conservation, Minister Kiritapu Allan, at the Department of Conservation offices in Hamilton. The Loder Cup is a prestigious conservation award to encourage and honour New Zealanders who work to investigate, promote, retain and cherish our indigenous flora. Bev was specifically highlighted by Minister Allan for her work in wetlands both in international and national research, as well as for practical advice and science communication, and working with communities.

Dr Melissa Robson-Williams has been appointed to the Global Transdisciplinary Alliance Working Group on Toolkits and Methods. The Alliance strengthens and promotes the global capacity and the calibre of collaborative modes of boundary-crossing research and practice. The working group focuses on toolkits and methods to support these processes in research, practice or education. Melissa is responsible both for planning and organising several meetings for working group for the next year and for the communications with Global Transdisciplinary Alliance board.

Bev Clarkson [left] and Minister Allan.

Melissa Robson-Williams

Changing our SOCS:

Could increases in soil carbon offset farm-scale emissions in Aotearoa?

He Waka Eke Noa is the primary food and fibre sector's climate action partnership, working with farmers and with iwi/Māori to implement a framework by 2025 to reduce agricultural greenhouse gas (GHG) emissions and build the agriculture sector's resilience to climate change.

The partnership's recommendation for a farm-level emissions pricing system, as part of its guidance on how to measure, manage and reduce carbon emissions, is likely to lead farmers to explore innovative ways to reduce and offset their emissions. One of the workstreams of He Waka covers the practicalities of on-farm sequestration of carbon in Aotearoa.

Carbon storage in vegetation, notably pine trees, is the most well-known sequestration approach, but there is increasing interest in the potential for sequestration in soils. Whilst this is a potential opportunity, there are a number of key challenges to address before farm-scale emissions in Aotearoa could be credibly offset from soil carbon sequestration.

First, what changes in land use or management could be implemented to increase soil organic carbon stocks (SOCS) in Aotearoa's soils? At a coarse scale, we know that some changes in land use, such as conversion of forest or cropland to pasture can lead to increases in soil carbon, and conversion the other way to losses of soil carbon. However, our understanding of the effect on soil carbon of changes in management practices or systems (e.g. grazing management) within a given land use is very limited. In most cases, farmers will require more certainty that a specific change in land use or management practice will increase soil carbon before changes are implemented in the quest to offset emissions via this mechanism. Further, the net effect on total GHG emissions also needs to be considered (e.g. a change in land use or management aimed at increasing soil carbon could potentially increase methane and nitrous oxide emissions).

Second, how would changes in soil carbon on-farm be determined? There are two main ways to attempt to answer this question: direct soil measurements on farm, or models (or a combination). Well-documented sampling methods and monitoring systems are available to enable direct measurement of changes in soil carbon. However, these methods are currently laborious, expensive and multiple years (3+) would be required to determine whether any changes were indeed occurring. Modelling would be easier and cheaper, but currently there isn't enough data to parameterise models to confidently predict how soil carbon will change in response to changes in land use or management for specific, individual farms across Aotearoa (due to the diversity of climate, soil type and management regimes).

And third, what policy or regulatory frameworks would have to be put in place to enable soil carbon to be accounted for in a robust way? At present soil carbon is not explicitly included in Aotearoa's Emissions Trading Scheme and is not included in the He Waka Eke Noa proposal. Should Aotearoa choose to include soil carbon in such systems, the simplest approach might be to adapt the system already legislated in Australia. The Australian system not only considers measurement of changes in soil carbon, but also covers the issues of additionality, permanence, and the implications of changes in land use or management on other greenhouse gas emissions. It also stipulates how farm-scale results must be reported to enable aggregation to contribute to national scale reporting obligations.

Manaaki Whenua's soil and social scientists are working on all three challenges simultaneously (see for example page 5) and we are involved in both direct measurements and modelling work for soil carbon accounting systems at various scales.

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