LINCOLN AGRITECH LTD

Annual Review 2023

60 Years of Innovation

LINCOLN AGRITECH LTD

MEASURE. MODEL. MANAGE.

Engineering and Science for Agriculture, Industry and the Environment

Contents

60 Years of Innovation

Delivering world-class research, science & engineering solutions for 60 years

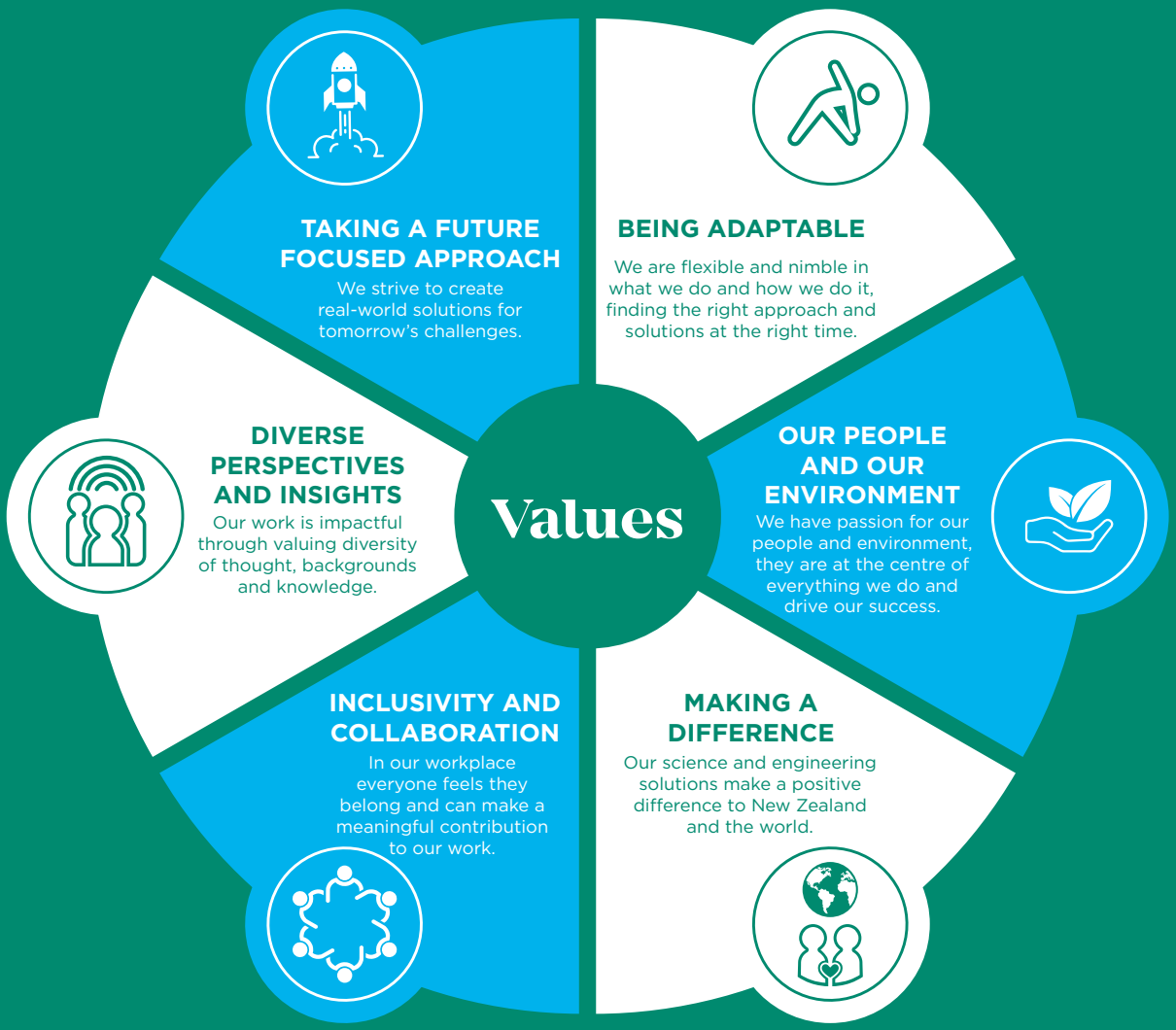
Who We Are

Our Ambition

We deliver innovative research and development of responsive, sustainable solutions that enable industries and communities to thrive globally in a healthy environment.

Our Guiding Principles

- Collaborate and connect
- Research is at our core
- Embody Te Ao Māori and Te Tiriti o Waitangi
- Design for people and the future
- Sustainability



Our Impacts

The big social and environmental goals of our work are:

- Sustainable production
- Protecting water resources
- Enhancing natural materials
- Action on climate change
- Sustainable economic growth

Our Expertise

Lincoln Agritech is a multidisciplinary research and development company and is a 100% subsidiary of Lincoln University. We have a long track record of delivering leading-edge science and engineering technologies for primary industries and the environmental sector.

Our areas of expertise are:

- **Digital & Precision Agriculture:** We apply and support the development of sensing technologies, including remote sensing, to assess and understand the spatial and temporal variability of soils, crops, and animals. We aim for such data to improve decision-making.
- **Water & Land:** We provide water-related research, focused on understanding and measuring groundwater systems. We also supply tools to regional and central government, and water users, to manage groundwater quality, nitrogen impacts, and water allocation, enabling a sustainable future for water resources.
- **New Materials:** We develop new high-value materials from biological sources, including coarse wool and plant-derived cellulose. We partner with industry, including the Wool Research Organisation of New Zealand, and focus on commercial applications of new materials.
- **GreenTech:** We develop engineering-based methane mitigation and CO_2 removal techniques to combat climate change and help to reduce global greenhouse gas emissions.
- **Sensing:** We provide agricultural and industrial clients with smart sensing technologies that reduce costs, realise new revenue streams and improve decision-making – this includes expertise in machine vision and electromagnetics.
- **Biotechnology:** We provide microbiome analyses and microbial biotechnologies for biocontrol to manage disease and to enhance plant growth systems.

Our commercial initiatives and partnerships include:

- **IRRICAD™ and Information Technology:** IRRICAD™, is a world-leading computer software system for designing pressurised irrigation systems, which we sell in more than 90 countries, and is available in eight languages. It is used by the world's largest irrigation company, Netafim, Nelson Irrigation in the USA, and other irrigation design companies.
- **Wool Source:** a company formed by the Wool Research Organisation of New Zealand to commercialise transformative wool fibre research developed in partnership with Lincoln Agritech.
- **HydroMetrics:** a business providing ground- and surface-water assessment of nitrate and other pollutants, selling in nine countries.
- **Autonomous Pivot:** an overseas company licensing our technology for sensing soil properties from irrigation pivots and providing real-time control.
- **TDRI:** a New Zealand company licensing our technology for sensing soil water for measuring infiltration under road surfaces and providing valuable maintenance data.

Chairman's Report

Lincoln Agritech Chairman, Bruce Gemmell.

Recognition and thanks

I am proud to present our 2023 Annual Review. This review celebrates Lincoln Agritech's 60th anniversary. It provides short summaries of our contributions, that have been many and have evolved since we were founded in 1964.

Our focus has shifted from designing heavy farm machinery to designing high-tech solutions for a range of industries related to food and fibre production.

This review also profiles our current work with our partners, and it celebrates our people, who are highly skilled and dedicated to Lincoln Agritech's ambition.

Lincoln University is proud to have Lincoln Agritech as a wholly owned subsidiary. Both organisations have recently refreshed their strategies and these are closely aligned. Both are focused primarily on the land and land-based sectors. Both are focused on making a difference through excellent research and on meaningful partnerships in New Zealand and overseas.

Peter Barrowclough, CEO for 15 years, stepped down from the role at the end of 2023. Lincoln Agritech almost trebled in size during Pete's time and both diversified and modernised its skills and partnerships. Pete was well respected by his people and his extensive network in the sector. I want to thank Pete on behalf of the Board for his very substantial contribution.

Similarly, I wish to recognise the huge contribution that Dr Ian Woodhead has made to Lincoln Agritech and the agriculture sector over 47 years. In 2024, Ian steps down from his role as Chief Scientist and becomes our first Lincoln Agritech Emeritus Fellow.

I wish to thank my Board and the leadership group for their diligence and hard work. The research sector in New Zealand is again undergoing change and continues to experience very high levels of competition. I believe the Board and leadership group have positioned Lincoln Agritech well in this challenging environment.

My thanks also go to you, our people, partners, and funders who enable Lincoln Agritech to contribute to a better world.

LINCOLN UNIVERSITY
TE WHARE WĀNAKA O AORAKI

Lincoln Agritech is a wholly owned subsidiary of Lincoln University.

CEO's Report

Lincoln Agritech Interim CEO, Richard Gordon

The structure of this review

It has been a privilege and pleasure to be the interim Chief Executive of Lincoln Agritech.

I found a group of very competent and responsive people here and will pass them on to my permanent successor in good heart, focused on delivering outcomes and impacts from their work.

Highlights in 2023 included progress in many of our projects as profiled in this review. We have formed new partnerships and have been included in a new Horizons EU programme involving our digital agriculture and AI skills. We recruited a number of very talented people to lead areas of our work.

It was a very challenging year for Lincoln Agritech and the wider research community because of funding constraints, uncertainty, and the impacts of inflation. The organisation refocused; the structure of this review reflects that work. We have refreshed our ambition and set clear impacts and outcomes to which our work contributes.

The research sections of this review cover first our impact areas, looking back over the evolution of our work since the 1960s. Impacts are the big social, environmental, and economic goals of society to which we contribute along with other parties. Our impact areas are:

- Sustainable production
- Protecting water resources
- Enhancing natural materials
- Action on climate change
- Sustainable economic growth.

Second, we provide case studies from our work under the outcome themes. Outcomes are defined by the actions our work enables our partners to achieve. Outcomes of Lincoln Agritech's work are:

- Growers can increase productivity sustainably
- Businesses can extract higher value from natural materials
- Growers and industries have tools for managing greenhouse gas emissions
- Climate change impacts are predicted and mitigated
- Government and industries can develop strategies for managing clean, accessible, and efficiently used water
- Industries have access to novel sensing for animal and plant health, biodiversity, crop and stock management.

Not all our outcomes have case studies here as some projects are commercially sensitive and others are at an early stage.

Our strategic priorities are:

- Seeking impact through partnership with the users of our work and with other research and development providers.
- Enabling our people to thrive, developing their careers in a stimulating culture.
- Ensuring our systems and processes help us achieve our ambition.

These priorities will guide us though the coming year and beyond. In addition, we aim to be a partner of choice through being responsive, adaptive and professional. We are at an early stage in our journey to embrace te ao Māori and Te Tiriti o Waitangi, but we are on that journey in earnest.

We celebrate our relationship with our owner, Lincoln University, and are developing new links among staff and students for mutual benefit, especially in the areas of digital and precision agriculture and water research.

I wish to thank the Board, leadership group, and people of Lincoln Agritech for their ongoing determination to do their best for the organisation, for New Zealand and the wider world. The challenges the world faces demand nothing less.

60 years of Innovation

Sustainable productivity – from heavy machinery to algorithms

Over the past 60 years, the world has experienced rapid technological change. And we have been part of that change.

When established as the New Zealand Agricultural Engineering Institute in 1964 our focus was on agricultural engineering, specifically tractor safety frame testing. In 1966 our safety frame testing even aired on local television in Christchurch.

Now, our multi-disciplinary research and development focuses on sustainable solutions for primary industries and the environment, and our videos feature microwave sensing, microbes that support sustainable agriculture, and research into destroying methane electrochemically.

That heavy engineering we started with was frequently commercially successful. A de-awning machine for brome grass seed was designed and installed at a Canterbury seed-cleaning plant, earning the Institute, and later Lincoln Ventures Ltd, more than $500,000 by the time the royalty contract ended in 2008.

In 1971 we designed and trialled a blackcurrant harvester, building additional machines in 1973 and negotiating a licensing agreement with Peco Ltd. In 1978 we began research and development into a Rotodrill rotary cultivator, engineered to sow seed and fertiliser into a series of parallel slots in a single pass. Two commercial units were in use by 1981, with manufacturer Henry Engineering receiving an award at the National Fieldays in 1981.

In the 1980s the Institute designed and manufactured a rotary orchard sprayer, a New Zealand first, which was commercialised and sold by Modern Farm Aids Limited.

But the shift away from heavy machinery was happening. On the back of our success in designing and overseeing the Glenmark Irrigation scheme in Waipara, we developed a computer model to investigate how irrigation affected water resources. This led to irrigation feasibility studies in the Hakataramea Valley and the Rangitata, among others.

In the mid-1980s we also began work on the computer-aided design software for irrigation systems that became IRRICAD, now the world's leading irrigation design software, sold in more than 90 countries.

In the 1990s we changed our name to Lincoln Ventures Ltd and established a biosensor programme for rapidly measuring pollutants in water. This led to a very sensitive lactose sensor to help minimise the amount of dairy factory effluent discharged into waterways. It has been commercialised through Certus Bio, with installations in New Zealand and the United States.

In the 2000s research into managing soil moisture led to Smarter Irrigation, using radar and algorithms for measuring soil moisture from a centre pivot or farm vehicle. Autonomous Pivot has commercialised the technology as continuous, non-invasive soil-moisture sensing that takes 300 soil water content readings per rotation. It has several hundred installations in the United States.

Our current research ranges from developing a body fat scanner, to developing an app that counts fruitlets on trees to aid fruit thinning. Our field research happens as far away as Antarctica, and in inaccessible places such as under riverbeds. Far from focusing on farm machinery, we are now an organisation whose multidisciplinary research and technology makes a difference all around the world.

Our IRRICAD design software for irrigation systems is now sold in more than 90 countries.

Protecting water – a vital resource

Lincoln Agritech's water research history goes back to our beginning as the New Zealand Agricultural Engineering Institute in the mid-1960s – but our focus has shifted.

In the 1960s we focused on irrigation and drainage. The 70s saw work on irrigation and irrigator design, but also expanded into farm waste management and groundwater contamination.

Water management became a hot topic in the 1980s, when the removal of farming subsidies focused rural minds on efficiency. We conducted a major irrigation feasibility study in Hakataramea Valley in South Canterbury, a water resource study in the Rangitata area, and developed a computer model showing the effects of irrigation on Canterbury's water resources.

Increasing irrigation raised issues of inconsistent ground penetration, which led to investigations into how water moves through soil – the basis of much of our research today. It was also in the 1980s that our world-leading irrigation design software IRRICAD was born – now used in more than 90 countries.

In the 1990s the then-named Lincoln Ventures Ltd patented Aquaflex soil moisture sensors, which allow precise irrigation, minimising water use. Aquaflex units were exported to the UK, Australia, and the US, and we later sold the brand.

Groundwater was now a major research thread, and in 1997 Lincoln Ventures and ESR built two large artificial aquifers, allowing scientists to investigate under controlled conditions how spatial variations in aquifer properties affect contaminant transport. These were destroyed in the Canterbury earthquakes.

We had become a significant player in Aotearoa New Zealand's water resource sector. In 2002 staff prepared a major report, "Canterbury Strategic Water Study", which quantified Canterbury's water resources and likely future demand. This report was one of several that formed the technical basis for Environment Canterbury's Canterbury Water Management Strategy, which is still used to manage the region's water.

At the same time, dairy farming was increasing in the Lake Taupo catchment, raising concerns about the effects on the lake. To help understand what was happening, in 2005 we developed an innovative vadose zone monitoring and experimental facility, called the Spydia. More than 2 m in diameter and 7 m deep it contained 15 automated equilibrium tension lysimeters. Over six years it provided data for numerous scientific papers and influenced Waikato Regional Council policy development.

Later research in Canterbury, Marlborough and Waikato showed we can link the effects of land use and management to freshwater only if we understand the hydrological and biogeochemical processes along the transfer pathways. This included revealing that groundwater denitrification is significant in some environments, but not others. Our work helped to underpin predictions of nationwide groundwater redox state, a crucial indicator of denitrification potential.

Tools developed and tested in our five-year Critical Pathways programme enabled us to provide local authorities with better insights into water and contaminant flows through catchments.

Our research into understanding and protecting water broadened in scope and understanding. We have shown how braided river systems interact with aquifers, and the effects of gravel extraction, based on field research in Canterbury, Marlborough and Hawkes Bay.

We have come a long way from the 1960s when we thought of water mostly in terms of irrigation and drainage to appreciating the importance of protecting this vital resource.

High-value natural materials

Ten years ago, entrepreneur, wool industry innovator and fibre physicist Garth Carnaby CNZM approached Lincoln Agritech with a proposal. He was seeking space and facilities to develop novel ideas in wool fibre science developed by a visiting Iranian textile chemist Shaahin Saleh.

The work extended well outside Lincoln Agritech's existing business at the time, but New Zealand's strong wool sector had been in the doldrums for many years and was keen to find new markets for its product. Lincoln Agritech was happy to respond to an industry need.

The ideas developed quickly. Once partnership funding support from the Wool Research Organisation of New Zealand (WRONZ) and the Ministry of Business, Innovation and Employment was secured, Lincoln Agritech rapidly grew by bringing in commercially minded applied scientists and engineers, including current group leader Rob Kelly.

The New Materials group's philosophy has always been to understand market need and meet it by applying new technologies to the natural materials that New Zealand has a competitive advantage at producing, such as wool and cellulose. We work closely with those who commercialise the technologies we develop, to ensure maximum chance of impact.

Through technical expertise in several market segments, including powders, pigments, dyes, coatings, print and personal care, and a unique in New Zealand capability for wet spinning textile fibres, we are generating impact for multiple industry partners.

The primary impact is for New Zealand's wool industry. By developing patented technology, scaling up processes from lab, through bench and into pilot-scale manufacture, and working in market alongside the commercialising entity Wool Source, we are enabling New Zealand crossbred wool to enter new international high-value and high-volume markets. Recent market launches from lipstick brand Karen Murrell and clothing brand Mons Royale were both based on Wool Source pigments developed and produced by the New Materials group.

While crossbred wool is still our core business, our work has extended into cellulose, collagen and a range of other primary industry products that have potential as high-value solutions to international needs.

The group's work in regenerated textile fibres from New Zealand plant sources could create significant impact for plant producers and textile processors. We have developed a novel textile fibre spinning technology that has potential to add substantial value to plant-derived cellulose. With the global textile and fashion industries well recognised as highly polluting, this technology provides substantial environmental benefits over existing processes. It is attracting interest from international brands as well domestic plant producers and textile companies.

The New Materials team's experience in providing bio-based technologies to international brands based on traceable, ethically produced, New Zealand-sourced biologicals can be applied to many animal- and plant-based primary products. Our future lies in helping New Zealand primary producers maximise the natural materials they produce by transforming them into high-value, high-volume solutions for the global chemicals, fibres, personal care, and nutrition markets.

Action on climate change

Climate change is an issue of increasing importance not just to our researchers, but to the world.

In the past eight years, we have expanded our climate change research, taking it from Antarctica to the laboratory, on farm, and most recently to New Zealand's longest river. Scientists specialising in electromagnetics and radar, electrochemistry, electronic engineering, geochemistry and more have applied their minds to understanding, measuring, and mitigating this existential issue.

Sea ice

Our input began in Antarctica in 2016. We were part of a team led by the University of Canterbury, aiming to better understand weather systems and the processes underlying climate change.

Sea ice drives weather by creating the major ocean currents as it forms and melts. It also reflects solar heat back into space. Less sea ice means disrupted currents and weather, and a warmer world, but it's difficult to measure as it's covered by snow.

In 2017 our scientists and engineers designed and built radar to help measure snow depth over sea ice in Antarctica – the first step in knowing how much sea ice was below.

The project was successful – mounted on a drone, the snow radar could estimate the depth of snow with an accuracy of ±9.1 cm or better.

This led, in 2021, to a new study testing a three-part radar device to measure not just the depth of the snow, but also the distances to the top of the snow and to the top of the water – all while suspended under a helicopter. From this the sea ice depth could be calculated.

Again, this project was successful and led to a $929,000 Marsden Fund award to conduct an aerial survey of up to 5000 km of Antarctica's coastline. This data will be used to develop a satellite-derived measure of coastal sea ice thickness and data that can be used to develop computer simulations showing the impact of continuing sea ice loss. All these projects have been led by the University of Canterbury.

GreenTech team

In 2021 Lincoln Agritech launched a GreenTech team to investigate climate change issues. Scientists have developed a potential pathway to reduce farm methane emissions, in a way that doesn't affect cow biology. This research, funded by the New Zealand Agricultural Greenhouse Gas Research Centre, is now investigating the most likely method of application.

The team has also done exploratory research on extracting carbon from seawater – which will then take up carbon from the air, so reducing atmospheric CO_2. It is currently seeking funding to further develop this.

Water quality effects

Finally, in late 2023, Lincoln Agritech was awarded $10 million by the Ministry of Business, Innovation and Employment for a five-year study into how increasing CO_2 is changing water quality in the Waikato River, and by extension, freshwater systems across New Zealand.

The team will start intensive monitoring of the river soon, to help scientists understand the relationship between CO_2 and harmful algal blooms. They also aim to develop models that predict such blooms under different climate scenarios, thereby building water supply resilience.

Key Research

In this section we show the outcomes our work will help our partners achieve.

OUTCOME:

Growers can increase productivity sustainably

CASE STUDY 1

Project: Manipulation of fungi-associated bacterial communities to combat plant fungal disease

Working with: Scion, Utrecht University, Foundation for Arable Research

Funded by a $1 m contract from the Ministry of Business, Innovation & Employment in 2023, we are developing a new way to protect plants against fungal disease, by exposing plants to the inactivated variants of the disease-causing fungi.

Fungal diseases can cause huge damage to crops, for example, in 2022 80% of New Zealand's passionfruit crop was lost. The most common method of protecting crops is to use synthetic chemical sprays. However, legislation and consumers are increasingly demanding reductions in chemical residues and fungi are becoming resistant to synthetic fungicides, driving a search for more sustainable solutions.

We aim to vaccinate plants by infecting them with inactivated fungus. We have discovered that the degree of disease a fungus will cause is related to the bacteria living with it. If you change the bacteria, it seems that you change whether a fungus can make a plant sick.

We will test this concept by removing and changing the bacteria in a fungus that infects brassica plants, for example, broccoli and cabbage. We will coat seeds with the altered fungus, then try to infect the seedlings with the original fungus to see whether our new products have protected the plant from infection.

Project team members are experts in plant pathology, microbiology, next-generation sequencing, microscopy, mātauranga Māori and commercialisation of new horticultural products. We will trial our products in the field with horticulturalists and work with the agricultural products industry to commercialise our new approach.

Impact: Resulting fungal bioprotectants will help protect New Zealand growers and provide export revenue from an ongoing stream of new products that protect plants against disease-causing fungi.

Cauliflower infected with *Alternaria brassicae.*

CASE STUDY 2

Project: Reduced fertiliser use through irrigation nitrogen recycling on a Canterbury farm

Working with: Hekeao / Hinds Water Enhancement Trust

The Hekeao/Hinds catchment is a farming area in Mid Canterbury representing one of the most productive irrigated agricultural regions in New Zealand. Despite ongoing advancements in nutrient and irrigation management, it still faces significant environmental pressures due to high nitrate concentrations in groundwater.

Hekeao / Hinds Water Enhancement Trust engaged HydroMetrics to design and install real-time monitoring of irrigation water at a Canterbury dairy farm to quantify the potential fertiliser savings and implications of irrigating with groundwater containing high nitrate levels.

Previous reports highlight the potentially significant contribution of nitrogen coming from high nitrate-N groundwater sources utilised for irrigation. Accurate measurement and application data are required to precisely measure the full potential of fertiliser substitution.

Impact: High nitrate concentrations in groundwater are a concern for human health and for the environment. New Zealand drinking-water standards set a maximum acceptable value (MAV) for nitrate nitrogen at 11.3 mg/L. Potential fertiliser savings are possible, with associated economic, environmental, and health benefits.

CASE STUDY 3

Project: Time & motion study of labour for on-orchard tasks

Working with: Zespri International

With increasing orchard automation, a critical understanding of the time needed for individual on-orchard activities is essential.

Zespri International commissioned Lincoln Agritech to assess the labour requirement of selected kiwifruit orchard tasks to provide a baseline for future work. The objectives were to measure the time it takes to achieve each task and evaluate the movements it takes to achieve individual activities. Efficiencies could then be recommended based on the results.

We videoed on-orchard activities in three orchards and analysed the video for all relevant activities. This allowed us to identify challenges to managing staff and to determine technological gaps that may improve productivity.

On average, 39.8% of annual on-orchard labour hours were spent on winter pruning; 14.3% on summer canopy management; and 21.5% on thinning. There was a large difference between the total hours spent per hectare between the orchards.

Impact: Some kiwifruit growers are changing their growing systems to minimise the most labour-intensive activities, such as growing replacement canes up strings. This will help seasonal management practices to be carried out more quickly and efficiently, and ultimately result in better crop outcomes.

OUTCOME:
Climate change pressures are predicted & mitigated

CASE STUDY 1

Project: Emerging climatic pressures on freshwater

Working with: Cawthron Institute; Griffith, La Trobe, and Lincoln universities; Universities of Otago and Waikato; Victoria University of Wellington

How we think about freshwater quality hasn't meaningfully changed in 30 years. We associate good, clean water with fast-flowing, well-oxygenated streams in forested catchments and poor water quality with nutrient- and sediment-laden lowland rivers and lakes. So when we consider the state and trend in freshwater quality, it's easy to look to only one source of change.

But what if other drivers and factors could be increasingly relevant in the 21st century? Lincoln Agritech is leading a Ministry of Business Innovation and Employment Endeavour Research Programme that examines an alternative perspective: that CO_2 exchange across the air–water interface is affecting water quality now and may increasingly do so in the future.

Our five-year study examines the ecological and biogeochemical effects of rising CO_2 pressures on the Waikato River, and Aotearoa-New Zealand freshwaters more generally. For carbon, river corridors are the largest interface between the continents, oceans, and atmosphere. Carbon transformation and exchange between land, water, and atmosphere also contribute to changing acidity and nutrient availability, inorganic carbon forms (or speciation), and carbonate solubility (the material comprising mollusc shells).

This programme asks fundamental questions about the relationship between CO_2 exchange and water quality, and how future atmospheric CO_2 levels could influence ecosystem cycles and the habitability of freshwater for molluscs. These scientific questions about water quality matter to communities (e.g. safety for contact recreation), industry (e.g., drinking water source contamination), and Māori (e.g., mahinga kai).

Impact: The Waikato River has huge cultural significance for tangata whenua, as well as socioeconomic and recreational importance for all New Zealanders. It is a strategic waterway that provides drinking water to around one third of Aotearoa New Zealand's population and around 12.5% of our sustainable power generation capacity. The project is therefore aligned with several stakeholders with a direct interest in the Waikato River, including Waikato River Iwi (Waikato-Tainui, Ngāti Maniapoto, Ngāti Tahu-Ngāti Whaoa), the Waikato River Authority, Waikato Regional Council, Hamilton City Council, WaterCare and Mercury Energy Ltd. Representatives from all these organisations form our advisory panel to guide our research programme.

CASE STUDY 2

Project: Characterising sea ice using novel radar technology

Working with: University of Canterbury, University of Otago, Australian Antarctic Division, Alfred Wegener Institute for Polar and Marine Research

Sea ice drives the world's weather by influencing major ocean currents as it forms and melts. Less ice means disrupted ocean currents and weather, and a warmer world, but existing measuring tools are not accurate.

Satellites can measure the area of sea ice, but not its thickness, while manual methods measure the thickness only in a small number of locations.

Lincoln Agritech Research Scientist Adrian Tan is part of a team led by Professor Wolfgang Rack of the University of Canterbury working to develop a snow radar. The radar is one of three components of a device designed to measure sea ice thickness beneath the polar snowpack. This is an international collaboration, and the most recent research has been funded by a Marsden grant.

In 2023, we developed and field-tested a miniaturised snow radar being towed by a fixed-wing Twin Otter aircraft. We had previously tested a larger radar that was flown by a helicopter.

The measurement platform is a towed "mini bird" developed by Christian Haas of the Alfred Wegener Institute. The main challenge was to replace existing instrumentation with the snow radar in the mini bird's confined space, and field test it when towed by a fixed-wing aircraft.

Besides the snow radar, the team also deployed other sensors, such as a laser altimeter and an aerial camera. This survey allowed them to better understand the process of how sea ice is formed by the Ross Sea polynya (an area of open water surrounded by sea ice). Flying at 60 m/s and 50 m height, with the mini bird towed at a height of 15 m, they surveyed fast ice (sea ice attached to shore), pack ice (consolidated, drifting sea ice), and vast ice floes (relatively flat sea ice 1-5 km across) at the Ross Sea.

The team also conducted ground-truth measurements along a validation line on both multi-year and first-year sea ice at McMurdo Sound. Ground validation was led by Associate Professor Inga Smith of the University of Otago with participation of the Australian Antarctic programme.

Impact: The aim of this project is to devise new ways to measure sea ice, including a tailored satellite-derived measurement system for Antarctica's coastline.

In late 2024 we plan to survey up to 5000 km of Antarctica's coastline – the most comprehensive study of sea ice in the Antarctic ever carried out. The resulting data will be internationally significant in predicting sea ice trends and understanding its role in a warming climate. As well as being used to develop a tailored satellite-derived ice thickness product, the data will also provide observational datasets for computer simulations that will allow better forecasting.

OUTCOME:

Government & industries can develop strategies for managing clean, accessible & efficiently used water

CASE STUDY 1

Project: Relationships between hydrological pathways, travel times and nutrient transfers

Working with: Waikato Regional Council

Numerous reports in recent years have made it clear that many of our waterways are degraded. But it is less clear which hydrologic pathways are critical for transporting contaminants in individual catchments.

Understanding these pathways is important to ensure mitigation measures and policy are designed for the appropriate pathways and their associated lag times. Near-surface water reaches waterways within minutes to days, shallow groundwater takes from a couple of months to around three years, while deep groundwater can take decades to reach waterways.

We combined the BACH modelling approach (Bayesian chemistry-assisted hydrographic separation and load partitioning) with tritium-based age-dating of stream water to investigate the different pathway contributions in 29 varied Waikato catchments.

Both approaches suggested that shallow groundwater (with a mean age of no more than three years) was the greatest contributor to flows in most of these catchments. Deeper and older groundwater was the predominant contributor only for waterways with significant groundwater recharge areas on the Central Plateau.

In these catchments, we can expect long hydrologic lag times that could cause high nitrogen 'loads to come' from past land use. However, even there our analysis shows the hydrologic lags might be shorter

than previously thought, as the role of near-surface and shallow groundwater discharges appears to have been underestimated in the past.

Outside the project, we shared the results of our BACH modelling and field investigations, with Ngāti Tahu-Ngāti Whaoa iwi to compare scientific and cultural assessments of stream health. We found western science and mātauranga Māori assessments largely agreed in determining which waterways were in poor health.

Impact: Regionally, catchment management in Waikato might only need to differentiate between two hydrologic zones, namely catchments with Central Plateau recharge areas and others.

CASE STUDY 2

Project: SFFF plantain potency and practice

Working with: DairyNZ, MPI, Fonterra, PGG Wrightson Seeds, AgResearch, Agricom, Massey University, Lincoln University, Manaaki Whenua Landcare Research, Plant & Food Research

The plantain programme is a seven-year collaborative research and development project, that aims to use plantain to substantially reduce nitrogen lost to freshwater and in greenhouse gases from pastoral agriculture. The programme aims to deliver the knowledge, confidence and support required for farmers to adopt a low-cost, scalable forage solution to preserve the fundamental competitive advantage of our exports.

Lincoln Agritech is involved in the effectiveness project, measuring the productivity and nitrate leaching from plantain-based pastures and comparing this with ryegrass pastures over four years. We are responsible for installation, maintenance and sampling of the suction cups, which collect soil leachate, providing an understanding of the composition of nutrients being lost from each pasture system.

PHOTO: DairyNZ

Impact: After two years of drainage data, the plantain treatments have reduced cumulative nitrogen leaching losses by 18%, and the difference between treatments is statistically significant. These results indicate that introducing plantain into the farming system could provide another tool for reducing nitrogen leaching.

CASE STUDY 3

Project: Community engagement & education via data insights delivered using HydroMetrics GW50™ portable nitrate sensors

Working with: Mid Canterbury Catchment Collective (MCCC)

The Mid Canterbury Catchment Collective team has effectively combined with multiple smaller catchment groups to jointly deliver their mission: “Bringing ideas, action and science together to improve our environmental footprint, support catchment group initiatives and champion community wellbeing.”

Many factors contribute to improving the health of our waterways, and engaged communities are taking a holistic approach to identify and implement enduring solutions. Monitoring nitrogen levels with portable sensors is a powerful tool for pin-pointing cause and effect, something that was costly to achieve before the real-time technology.

High nitrate concentrations in groundwater are a concern for human health and for the environment. New Zealand drinking-water standards set a maximum acceptable value (MAV) for nitrate nitrogen at 11.3 mg/L.

The MCCC proactively accessed grant funding and purchased portable nitrate sensors from HydroMetrics, putting these devices in the hands of a wide range of members, to test the water in their regions.

Impact: The data the MCCC has collected has delivered significant insights into the health of their various catchments and built a science-based approach to tackling these important issues.

PHOTO: Mid-Canterbury Catchment Collective

OUTCOME:

Industries have access to novel sensing for animal and plant health, biodiversity, crop and stock management

CASE STUDY 1

Project: Detecting partially hidden or camouflaged pest insects on apples with thermal imagery

Working with: New Zealand Apples & Pears Incorporated (NZAPI)

Detecting insect-infested fruit is a major concern for the apple import/export industry. It becomes even more challenging when the insects are hidden in the calyx end or stem end, or when they are barely distinguishable from the colour of the apples.

We are investigating the potential for detecting insects on apples using active thermography, a technique that applies external energy to change an object's temperature and then analyse it with a thermal camera. Our experiment focused on one insect species, the apple leaf-curling midge (*Dasineura mali* Kieffer). We may consider looking at other problematic apple insects in later experiments.

This work is part of NZAPI's Smart & Sustainable project, a seven-year Sustainable Food and Fibre Future project, a partnership between NZAPI and the Ministry for Primary Industries.

Impact: We plan to collaborate with sorting equipment manufacturers to integrate our thermography-based insect detection method into apple sorting machines. This aims to make detecting insect pests on apples faster and more robust.

CASE STUDY 2

Project: Digital technologies for plant health, early detection, territory surveillance and phytosanitary measures (STELLA)

Working with: Agricultural University of Athens, and 12 other European universities and research institutions; seven sensing and risk assessment companies; New Zealand Apples & Pears (NZAPI)

STELLA aims to develop a holistic digital system (STELLA PSS) to help with early warning and detection of regulated pests, together with a response strategy by using modern sensing technology and artificial intelligence.

The STELLA PSS will be tested over three years at field, farm, and regional levels across six use-case pilots covering arable, orchard and vineyard crops as well as large, difficult-to-reach areas (forests). STELLA focuses on eight different diseases present across four European countries and New Zealand. Lincoln Agritech is running the New Zealand use-case pilot, focusing on *Neofabraea alba*, a fungus that causes bull's eye rot in apples.

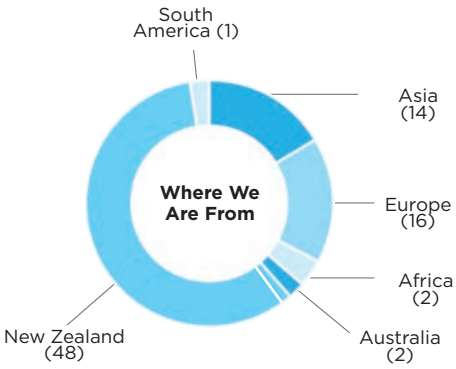
STELLA will perform capacity-building activities to equip farmers, agronomists, and stakeholders with the necessary skills to use the STELLA system and encourage them to adopt eco-friendly crop protection methods. In New Zealand, this will be done with NZAPI and the industry.

Impact: Policy recommendations generated through the STELLA PSS findings will be targeted to policy makers and decision makers aiming to support the European Commission's goals of reducing pesticide use, managing priority plant pest outbreaks, and promoting digitalisation of EU agriculture and forestry.

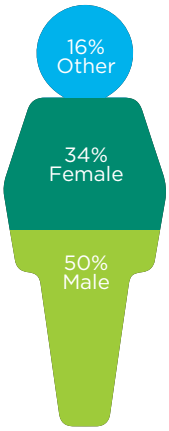
Our People

What We Look Like

LAL Staff Profile as at the 31st December 2023

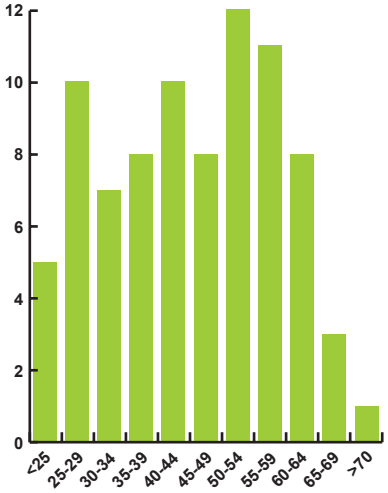


Staff Gender Ratio



Total Staff: 83

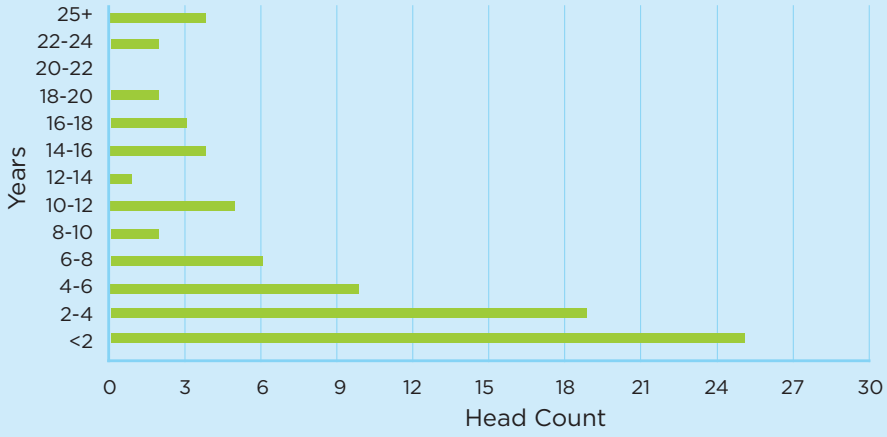
Age Profile



Staff Gender Ratio

Our Gender Equality Plan has been established to enable us to deliver on our commitment to create an environment where our people are treated equally, regardless of their gender identity. This plan includes leadership, career progression, awareness, sexual harassment, and organisational culture. We will report our gender pay equity in our 2024 annual review.

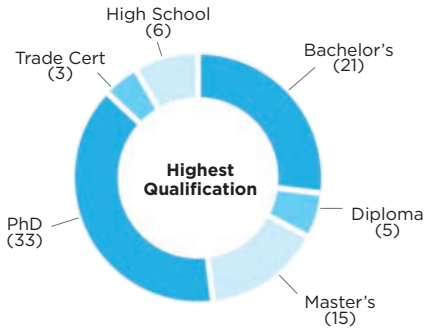
Length of Service

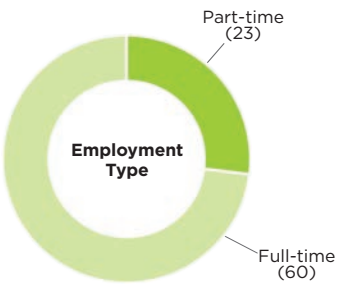


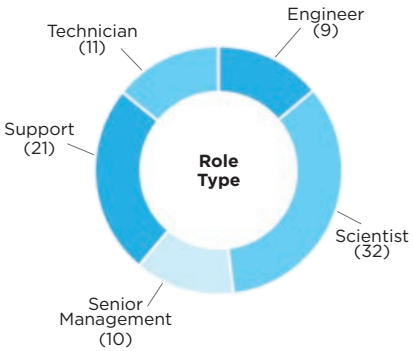
Turnover

Appointments 11
Departures (Voluntary) 14

Turnover for 2023 was 16.67%







NB: Short fixed-term, casuals, and students omitted.

Board

Bruce Gemmell
Chair

Bruce was appointed Chancellor of Lincoln University in January 2019 and joined the Lincoln Agritech Board in June 2019. He is a chartered accountant and former senior partner at international accounting firm EY.

Julia (Jules) Chambers

Jules has spent over 25 years working in the pharma-biotech space internationally, initially with corporates such as Eli Lilly (UK) and Genzyme (US). She has significant experience in evaluating commercial opportunities and executing corporate transactions.

Olivia Egerton

Olivia is an experienced manager with a track record for professionally delivering strategic projects, partnerships and events in primary industry, master-planned property development, and arts, heritage, and culture. She is the Director of Te Atamira, Tāhuna Queenstown's arts and cultural centre and Chair of Te Hono, a food and fibre sector movement.

Prof Grant Edwards

Professor Grant Edwards is Vice-Chancellor of Te Whare Wanaka o Aoraki Lincoln University. Grant has a research background in farm systems research directed towards improving the profitability and environmental performance of dairy farming.

Senior Leadership

Peter Barrowclough
Chief Executive

Peter joined Lincoln Agritech in 2009, after holding governance and management roles in organisations as diverse as the Canterbury Development Corporation Ltd, PGG Wrightson, Crop and Food Research, and NZ Food Innovation South Island Ltd. He stepped down at the end of 2023 and was replaced by Richard Gordon as interim chief executive. Richard was CEO at Manaaki Whenua Landcare Research from 2011 to 2022.

Andy Matheson
General Manager, HydroMetrics

Andy has 25 years' experience in technology business development and senior private equity and venture capital roles. He particularly enjoys taking new technology ventures to the global stage.

Anya Hornsey
Group Manager, Business Development & Marketing

Anya Hornsey has an academic background in intellectual property and business administration and a long history of working with researchers and innovators to secure funding and commercialise technology across a range of sectors.

Armin Werner
Group Manager, Precision Agriculture

Armin has a background in agronomy, crop modelling and sustainable development of land use. He specialises in novel agricultural production systems with a strong focus on digitisation and automation of agriculture and the impacts of new technologies for primary industries.

Senior Leadership

Ian Woodhead
Chief Scientist

Ian has more than 40 years' experience in sensor development. He is a member of the Institute of Electrical and Electronics Engineers (IEEE) and board member of Lincoln University's Centre for Soil and Environmental Quality. Ian was awarded the Royal Society Te Aparangi's Scott Medal in 2017. Ian steps down in 2024 and becomes our first Lincoln Agritech Emeritus Research Fellow.

Jane Carr
Financial Controller

Jane has a Bachelor of Management Studies (Hons) from the University of Waikato. She is a Chartered Accountant with membership of Chartered Accountants Australia & New Zealand and the Institute of Directors. She has worked in a variety of finance roles in both Auckland and Christchurch.

Joanne Hay
Group Manager, Sensing & Biotechnology

Jo received a PhD from the University of Canterbury, specialising in molecular biology, plant viruses and crop resistance. As well as leading the Sensing and Biotechnology group, she plays a pivotal role in Lincoln Agritech's responses to major Government investment rounds.

Kirsty Macdonald
Human Resources Manager

Kirsty has a Bachelor in Business Management, with a major in employment relations. She has extensive human resource management experience in New Zealand and the United Kingdom.

Phil Dewar
Group Manager, IT

Phil has over 30 years' experience in the design and development of specialised engineering software. Phil has worked at Lincoln Agritech since its inception. He has extensive irrigation industry knowledge and is an expert in theoretical and practical irrigation solutions.

Rob Kelly
Group Manager, New Materials

Rob studied chemistry at the University of Cambridge (UK), completed a PhD at the University of Otago and then a postdoctoral fellowship at Lincoln University. He has managed R&D teams in New Zealand science institutes, including the Wool Research Organisation of New Zealand.

Simon Pollock
Group Manager, Environmental Research

Simon has an MSc from the University of Otago and is a Certified Environmental Practitioner. Simon is focused on working with collaborators and partner organisations to advance scientific knowledge, particularly in the areas of water resources and environmental science.

New Arrivals

Alisa Roddick-Lanzilotta

Alisa joined Lincoln Agritech as Research Manager for the New Materials group. She obtained her PhD in chemistry from the University of Canterbury, before post-doctoral research at Utah State and Otago Universities. She has since had roles in the Wool Research Organisation of New Zealand, Canesis Network, AgResearch and was most recently Chief Scientific Officer at Keraplast Manufacturing.

Joanna Costello

Joanna joined Lincoln Agritech as a Business Development Manager. She recently completed an MSc in agroecology from the Norwegian University of Life Sciences and has a BSc in biochemistry and a Graduate Diploma of Commerce. Joanna is interested in growing international collaborations and is supporting Lincoln Agritech in its international activity.

Jeff Lang

Jeff joined Lincoln Agritech as a Postdoctoral Researcher in the Environmental group, based in Hamilton. He is working on an MBIE-funded programme investigating climate change effects on the Waikato River, and other group projects. Jeff has a BSc in geology and geophysics, an MSc in earth sciences and a PhD in geology, all from the University of Auckland.

Linda Robb

Linda Robb has joined us as a Field Research Scientist with our Environmental Group. Linda has a Masters of Water Resource Management from the University of Canterbury, where she worked on the Ministry of Business, Innovation and Employment (MBIE) funded science programme, "Subsurface processes in braided rivers – hyporheic exchange and leakage to groundwater." She focused on the groundwater/surface water interaction, using radon as a tracer.

Amol Jadhav

Amol joined Lincoln Agritech as a Research Scientist in the GreenTech team. Amol has an MSc in organic chemistry and a PhD in materials science. His research is on fundamental and applied aspects of novel nanomaterials and their application in energy conversion and storage.

Samantha Thomas

Sam works as a Chemical Technician for Lincoln Agritech's New Materials group. Sam has a Bachelor of Science from the University of Canterbury, majoring in biochemistry.

Tim Jones

Tim joined Lincoln Agritech as IT Manager in April. Tim has a Bachelor of Science in environmental science from the University of Worcester, in the UK. He has spent the last 20 years supporting, managing and leading IT change, mainly in the education sector.

Chaz Doherty

Having previously worked with the New Materials team on contract, Chaz (Ngāi Tūhoe/Ngāpuhi) joined as our Kaiārahi Māori, providing mātauranga Māori direction, guidance and leadership across Lincoln Agritech.

Jane Carr

Jane joined Lincoln Agritech in early 2023 as Financial Controller. Jane is a Chartered Accountant with membership of Chartered Accountants Australia & New Zealand and the Institute of Directors. She has worked in a variety of finance roles in both Auckland and Christchurch.

Simon Pollock

Simon has an MSc from the University of Otago and is a Certified Environmental Practitioner. His professional experience crosses a wide range of environmental fields from hydrogeology, irrigation modelling, and water quality to landfill investigations and contaminated land.

Sharing Knowledge

Non-Financial Highlights

50

Popular Press & Trade Journals

(excluding social media)

3

Videos

39

Conference Contributions

33

Client Reports

16

Journal Publications

LINCOLN AGRITECH LTD

X (Twitter)

2023: 1223 followers

3% increase

LinkedIn

2023: 3317 followers

27.6% increase

Facebook

2023: 165 followers

60.2% increase

Newsletter Circulation

2023: 959 subscribers, 38% open rate

38% decrease

IRRICAD™ IRRIGATION DESIGN SOFTWARE

LinkedIn

2023: 4479 followers

22.1% increase

HydroMetrics

LinkedIn

2023: 565 followers

12.3% increase

Facebook

2023: 169 followers

3.6% increase

Publications & Presentations 2023

Journal & technical papers

Anton, E.-M., Trewick, E., Holmes-Hewett, W. F., Chan, J. R., McNulty, J. F., Butler, T., Ruck, B. J. Natali, F. Growth of epitaxial (100)-oriented rare-earth nitrides on (100)LaAlO3 *Applied Physics Letters* 123, 262401 (2023) DOI: 10.1063/5.0186522

Ejaz, F., Guthke, A., Wöhling, T., Nowak, W. Comprehensive uncertainty analysis for surface water and groundwater forecasts under climate change based on a lumped geo-hydrological model *Journal of Hydrology,* 626, 130323 (2023) https://doi.org/10.1016/j.jhydrol.2023.130323

Di Ciacca, A., Wilson, S., Kang, J., Wöhling, T. Deriving transmission losses in ephemeral rivers using satellite imagery and machine learning, *Hydrology and Earth System Sciences*, 27, 3, 703–722 (2023) https://doi.org/10.5194/hess-27-703-2023

Hartland A. et al. Recurring summer and winter droughts from 4.2-3.97 thousand years ago in North India. *Communications Earth & Environment*, 4, 103 (2023). https://doi.org/10.1038/s43247-023-00763-z

Holmes, A. We don't know what we don't measure. *The Orchardist*, September 2023, pp53-55

Kelly. S. et al. A glycan receptor kinase facilitates intracellular accommodation of arbuscular mycorrhiza and symbiotic rhizobia in the legume Lotus japonicus. *PLOS Biology* 21 (5): e3002127 (2023). https://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.3002127

Pacheco-Gil, R., Velasco-Cruz, C., Pérez-Rodríguez, P. et al. Bayesian modelling of phosphorus content in wheat grain using hyperspectral reflectance data. *Plant Methods*, 19, 6 (2023) https://doi.org/10.1186/s13007-023-00980-9

Pot, C., Holmes-Hewett, W. F., Anton, E.-M., Miller, J. D., Ruck, B. J., Trodahl, H. J. A nonvolatile memory element for integration with superconducting electronics *Applied Physics Letters* 123, 202401 (2023) DOI: 10.1063/5.0175432

Rivas, A., Barkle, G., Sarrisc, T., Park, J., Kenny, A., Maxwell, B., Stenger, R., Moorhead, B., Schipper, L., Clague, J. Improving accuracy of quantifying nitrate removal performance and enhancing understanding of processes in woodchip bioreactors using high-frequency data. *Science of the Total Environment*, 880, 163289 (203) http://dx.doi.org/10.1016/j.scitotenv.2023.163289

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Samarasinghe, S. Tran, N. M.-T. A Comprehensive Conceptual and Computational Dynamics Framework for Autonomous Regeneration of Form and Function in Biological Organisms *PNAS Nexus*, 2, 2, 308 (2023) https://doi.org/10.1093/pnasnexus/pgac308

Schulthess, U., Rodrigues, F., Taymans, M., Bellemans, N., Bontemps, S., Ortiz-Monasterio, I., Gérard, B., Defourny, P. Optimal Sample Size and Composition for Crop Classification with Sen2-Agri's Random Forest Classifier *Remote Sensing*, 15(3), 608 (2023) https://doi.org/10.3390/rs15030608

Vogel, H.-J., Gerke, H. H., Mietrach, R., Zahl, R., Wöhling, T. Soil hydraulic conductivity in the state of nonequilibrium. *Vadose Zone Journal*, 22, e20238 (2023) DOI: 10.1002/vzj2.20238

Werner, A., Fourie, J. et al Modelling wine grapevines for autonomous robotic cane pruning. *Biosystems Engineering* 235, 31-49 (2023). https://doi.org/10.1016/j.biosystemseng.2023.09.006

Werner, A., Jafari, A. Virtual Reality, Augmented Reality, and Extended Reality - Beyond What You Can Perceive with Your Naked Senses. *Encyclopedia of Smart Agriculture Technologies*. Springer, Cham. https://doi.org/10.1007/978-3-030-89123-7_41-1

Conference papers/presentations

Bateman, C. J., Tan, A. E.-C., Nelson, J., Richardson, S., Zhou, Y., Anton, E., Nielsen, P., Eccleston, K. W., Platt, I. G. Orthogonal Bases for Biomedical Inverse Scattering. 2022 IEEE Conference of Antenna Measurements and Applications, January 2023 online. https://ieeexplore.ieee.org/Xplore/home.jsp

Clague, J., Phillips, M. Incorporating mātauranga Māori into our understanding of catchment health. 2023 AGC NZHS Conference, November 2023

Di Ciacca, A., Brand, M. Groundwater recharge from the upper Selwyn/Waikirikiri over the last four decades derived using satellite images. 2023 AGC NZHS Conference, November 2023

Di Ciacca, A., Wilson, S., Wöhling, T. Model simplification to simulate groundwater recharge from perched gravel-bed braided rivers. EGU General Assembly 2023, April 2023. https://meetingorganizer.copernicus.org/EGU23/EGU23-9868.html

Di Ciacca, A., Wilson, S., Wöhling, T. Model simplification to simulate groundwater recharge from braided rivers. 2023 AGC NZHS Conference, November 2023

Eccleston, K. W., Zhou, Y. Platt, I. G., Tan, A. E.-C., Anton, E.-M., Woodhead I. M. Multipixel Metamaterial Lens Imaging System. 2022 IEEE Conference of Antenna Measurements and Applications, January 2023 online. https://ieeexplore.ieee.org/Xplore/home.jsp

Eccleston, K. W., Zhou, Y., Platt, I. G., Tan, A. E.-C., Woodhead, I. M. Demonstration of a Negative-Refractive-Index Lens Imaging System. 2022 Asia-Pacific Microwave Conference, January 2023 online. https://ieeexplore.ieee.org/Xplore/home.jsp

Ejaz F., Guthke A., Wöhling T., Nowak W. Estimating catchment-wide total groundwater storage via space-time kriging provides calibration data for catchment-scale groundwater balance models. AGU, December 2023

Hartland, A., Farant, M., Torres-Rojas, D., Höpker, S.N., Saeed, H., La Croix, A., Grainger, M., O'Neill, T. Mines to Moana: Hydrochemical legacies in a historically mined watershed. 2023 AGC NZHS Conference, November 2023

Holmes, A. Baird, D. Modelling the spatial distribution of fertiliser spreading. Biometrics in the Bay of Islands 2023, December 2023

Holmes, A., Ekanayake, D., Werner, A. Profit and loss maps for precision agriculture in NZ, Society of Precision Agriculture Australia conference, September 2023.

Kraft, M., Wilson, S., Wöhling, T. The impact of braided river morphology on river – groundwater exchange – a model-based analysis. 2023 AGC NZHS Conference, November 2023

Moghaddam, R., Barkle, G., Rivas, A., Torres-Rojas, D., Schipper, L. Methanol Dosing Increases Nitrate Removal in Woodchip Bioreactors with No Substantial Adverse Effects: laboratory and field evidence. 35th Annual FLRC Workshop: Diverse Solutions for Efficient Land, Water and Nutrient Use. Published Abstract, February 2023. https://www.massey.ac.nz/~flrc/workshops/23/paperlist23.html

Moghaddam, R., Barkle, G., Rivas, A., Torres-Rojas, D., Schipper, L. Enhanced Nitrate Removal with Methanol Dosing in Woodchip Bioreactors: Laboratory and Field evidence. 36th Annual FLRC Workshop: Diverse Solutions for Efficient Land, Water and Nutrient Use.Occasional Report No. 35, May 2023. Moghaddam 2023 full paper FLRC 2023.pdf

Park, J., Stenger, R., Clague, J., Rivas, R. Assessment of a catchment's flow characteristics using readily available GIS data across NZ images, 2023 AGC NZHS Conference, November 2023

Perrera, G., Torres-Rojas, D., Rivas, A., Barkle, G., Moorhead, B., Schipper, L., Craggs, R., Hartland, A. Biogeochemical pathways for phosphorus removal in woodchip bioreactors. 35th Annual FLRC Workshop: Diverse Solutions for Efficient Land, Water and Nutrient Use. Published Abstract, February 2023. https://www.massey.ac.nz/~flrc/workshops/23/paperlist23.html

Platt, I. G., Eccleston, K. W., Anton, E., Nelson, J. Experimental Imaging of Meat and Bone Samples Using a Negative-Refractive-Index Lens. Conference on Antenna Measurement and Applications (CAMA), November 2023 DOI: 10.1109/CAMA57522.2023.10352873

Rivas, A., Stenger, R., Park, J., Clague, J., Barkle, G., Moorhead, B. Unravelling nitrate and flow dynamics in agricultural streams using high-frequency monitoring. 2023 AGC NZHS Conference, November 2023

Stenger, R., Park, J., Clague, J. Unravelling the pathways responsible for land-to-water nitrogen transfers in different types of catchments. 2023 AGC NZHS Conference, November 2023

Tan, A. Snow Radar Measurements as a Basis to Sea Ice Thickness Estimation. NZ Sea Ice Symposium, February 2023.

Tan, A., Platt, I., Hayward, A., Nelson, J., Eccleston, K., Anton, E. High gain microstrip patch antenna as illuminating source for near field imaging. IEEE International Symposium on Antenna and Propagation and UNSC-URSI Radio Science Meeting, July 2023. https://2023.apsursi.org/

Tan, A., Rack, W., Eccleston, K., Platt, I., Anton, E., Woodhead, I. Microwave field measurement of New Zealand alpine snow wetness. IGARSS Conference, July 2023. https://2023.ieeeigarss.org/

Torres-Rojas, D., Rivas, A., Barkle, G., Hartland, A. Simultaneous phosphorus removal and redox buffering of denitrifying bioreactors using organo-mineral composites. 35th Annual FLRC Workshop: Diverse Solutions for Efficient Land, Water and Nutrient Use. Published Abstract, February 2023. https://www.massey.ac.nz/~flrc/workshops/23/paperlist23.html

Tran, T. A robust rice identification tool. STIC: Science, Technology and Innovation Cooperation Programme, September 2023

Wilson, S., Measures, R., Hoyle, J., Di Ciacca, A., Durney, P., Wöhling, T. Groundwater recharge response from braided rivers. 2023 AGC NZHS Conference, November 2023

Wöhling, T., Kraft, M., Wilson, S., Nguyen, H., Davidson, P. Modelling Wairau Plains groundwater resources – a detailed analysis of the Wairau Aquifer water balance. 2023 AGC NZHS Conference, November 2023

Wu, T. Electrochemical CO2 Extraction from Seawater. 10th International Conference on Advanced Materials & Nanotechnology, February 2023.

Wu. T. Electrochemical CO2 Extraction from Seawater. 14th HOPE meeting, March 2023.

Wu, T., Rankin, D., Fraser, M. New low energy approaches for mitigating methane from agricultural sources. NZAGRC Climate Change Conference, March 2023.

Zhou, Y., Riding, P., Eccleston, K., Tan, A., Anton, E., Platt, I., Bateman, C.J., Nelson, J., Diegel, O. Additive Manufacturing of Human Torso Phantom for Microwave Imaging. 2022 IEEE Conference of Antenna Measurements and Applications, January 2023 online. https://ieeexplore.ieee.org/Xplore/home.jsp

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Throughout this publication the use of geometrical patterns represents the borders or edges of domains. The patterns indicate movement where spaces cross over and go back and forth – a space held to meet and greet, a space to navigate and negotiate. For us this pattern is symbolic of the fusion of cultures that seeks to develop and evolve, to grow its critical thinking, its shared learning systems. It supports a culture of science/mātauranga unique to this part of the world.