New Ground

INNOVATIVE IDEAS TESTED ON-FARM BY RURAL PROFESSIONALS FUND PROJECTS 2021–22

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OUR LAND AND WATER

Toitū te Whenua, Toiora te Wai

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Fertile ground for innovations

Jenny Webster-Brown

One of the main aims of the Our Land and Water National Science Challenge is to develop practical resources to help farmers add diversity, increase resilience and tackle environmental challenges for their farm, catchment and community. Although much of our funding is allocated to scientists and other researchers, we also appreciate that the ability of Kiwi farmers to solve their own problems has moved way beyond innovative ways with Number 8 fencing wire.

To support on-farm innovations, two years ago we launched our Rural Professionals Fund with strong encouragement from NZIPIM. This fund is for the rapid testing of innovative ideas that could enable Kiwi farmers to identify new ways to take care of their land and protect their sustainable farming legacy. The fund connects innovative farmers and entrepreneurs with the researchers who can help assess and develop their ideas, and with rural professionals who can share the ideas with other farmers.

In the first funding round (2020) the Rural Professionals Fund received 31 applications, of which 15 were selected for funding. The timeframe of six months and funding limit of $50,000 were challenging, and we commend the project teams for all they achieved in the inaugural round.

In 2021, round 2 of the Rural Professionals Fund saw 12 projects funded from 47 applications. The investment was bumped up to $75,000 per project, and a longer period of nine months was allowed. As in the previous year, some projects received co-funding from other organisations, and all were boosted by the time freely donated by participants.

Funded projects all have one thing in common: that proof of concept could create wider benefits for New Zealand farming communities, our land, or our water. Communicating the results of both successful and unsuccessful projects to the wider rural profession and farming community is therefore a crucial part of our process. In the pages that follow, you'll read about projects with promising results, as well as those that didn't quite work out as anticipated.

We are now underway with our third funding round, which closed in August 2022. The projects began in October and tackle questions such as:

- Can weed spray strips be replaced by growing perennial ground cover plants under fruit trees?
- What are the economic and environmental implications of differing wintering options?
- Can pines be used as an effective nurse crop to establish native bush on farmland?
- How do dairy farmers develop a composting shelter?
- Will electrocoagulation dairy waste treatment be cost-effective and enable water recycling?

A fourth round will open in December 2022 (closing early in 2023). This will be the final Rural Professional Fund as our Challenge is scheduled to conclude in mid-2024. Once again, we will be seeking applications for projects that target new ways of doing things, support diversification of land use and practices, and create behavioural changes.

If you have an innovative idea that aligns with the mission of Our Land and Water, please don't miss out on this next, and final, opportunity to secure some funding for its development and communication. In the meantime, we hope you enjoy reading about the outcomes of round 2.

Dr Jenny Webster-Brown is the Director of Our Land and Water.

How much nitrogen does asparagus need?

Collaborative research towards best practice nitrogen management in asparagus cropping

Why: To collaborate with growers across the growing regions, in order to collect data upon which we can build an understanding of nitrogen pools and dynamics, and together determine what best practice should be.

Where: On four properties in Hawke's Bay, Manawatu, Horowhenua and Canterbury.

Who: Dan Bloomer (LandWISE), John Evans (Canterbury), Braam Paans (LandWISE summer intern), Bruce Searle (Plant & Food Research), Iain Trotter (grower, Hawke's Bay), Sam Rainey (grower, Manawatu), Cam Lewis (grower, Horowhenua) and John Cunliffe (grower, Canterbury).

What:

- Current nitrogen fertiliser recommendations are not specific to New Zealand.
- There has been limited field work in New Zealand, meaning fertiliser recommendations and practice vary widely.
- While sufficient nitrogen fertiliser to grow healthy asparagus ferns should be applied during the establishing years, once established any applications should be based on replacing the nutrients removed during harvest.
- International research shows 75 kg N/ha could support a crop for three years without a detectable change in fern nitrogen concentration.

Read more: *Best practice nitrogen management in asparagus cropping*: ourlandandwater.nz/RPF2022

A project to develop a best practice guide for the use of nitrogen in asparagus crops in New Zealand was hampered by one of the worst seasons on record, but having uncovered a wide variety of grower practices research will continue.

When LandWISE manager Dan Bloomer initiated a project to analyse how New Zealand asparagus growers use nitrogen and to come up with a good practice guide for the industry, he did not anticipate a season so difficult that some growers left their crops unharvested and were unable to contribute to the research.

"We were starting to do the research, but with the Covid-19 lockdown, growers not being able to get staff and no way of exporting asparagus out of New Zealand because there were no aeroplanes, the whole thing became very difficult," he says.

Despite the difficulties, some insights were gained.

"We brought together some good information, so we now know the range of different practices that growers are using, and we got some good trials established comparing different nitrogen fertiliser rates. As we look at the current season's yields, we'll get the results we need to get full value out of the work we started."

The project had its origins in work that Dan and his colleagues at LandWISE did with vegetable growers in Levin, following concerns they were losing nitrogen to Lake Horowhenua. They produced a reasonably simple nutrient budget template that worked for most crops, but when Dan heard asparagus growers were interested in using it too, he realised its shortcomings for their crop because there were no reliable data or guidelines available.

Asparagus spears emerging in spring

Taking pre-season soil samples to full root depth to identify amount and location of nitrates

Anecdotally, asparagus has been considered a low-nitrogen crop but grower practices are not always reflecting this.

After some discussion with the New Zealand Asparagus Council, Dan successfully sought funding via the Rural Professionals Fund from the Our Land and Water National Science Challenge and the project started.

Research hampered by "the worst season"

The research team first reviewed the already published research and surveyed growers nationally to get a picture of how they used nitrogen, discovering widely varying practices and indicating no agreed industry best practice.

"Different growers have completely and utterly different ways of dealing with nitrogen from, 'I don't put any nitrogen on my asparagus, I save it up and put it on my broccoli', through to putting it on 'because Dad did', so there isn't an industry standard practice," says Dan.

Anecdotally, asparagus has been considered a low-nitrogen crop but grower practices are not always reflecting this. A 2019 survey of grower practices in Waikato suggested an extremely wide range of application rates and that typical applications exceeded crop exports, but there has been minimal in-field validation.

To address this, with growers' cooperation, the researchers designed a research plan to address key gaps in their knowledge:

- How much nitrogen is cycling in the system?
- How much is exported?
- How much is typically added?
- What is the maximum biomass and how much nitrogen does it contain?
- How does the nitrogen content in the root zone vary throughout the season?

A matrix of data collection points across space and time was developed, representing different regions, soil types, varieties and ages.

However, although the project intended to work with growers by separately harvesting trial plots and recording yields, the terrible season growers experienced meant the research had limited grower input.

"Growers had very little extra brain space to focus in on what we were doing and prioritised the business-critical stuff like, 'I can't get any staff, there're no backpackers or RSEs, what the hell am I going to do?'"

Some growers pulled the plug on the season all together and did not harvest. As a result, there was no research conducted in Waikato. But four collaborating growers in Hawke's Bay, Manawatu, Horowhenua and Canterbury did take part so that data could be collected, albeit incomplete.

What is best practice?

Although the season's issues limited data collection, the international literature review suggested the best time to apply nitrogen is after harvest and before the fern is allowed to grow. This will minimise leaching risk, especially on shallow or low water-holding soil types.

Once the crop is established and plants have reached their full size, it appears to need minimal additional nitrogen.

There is not a lot of nitrogen in the exported asparagus spears, which are all that need to be replaced. After harvest the ferns are left to grow, initially taking up soil nitrogen. As they grow and die down at the end of autumn, they transfer reserves back into the roots, and that drives production the following spring (see **Figure 1**).

"Whether asparagus growers are producing as much as they could if nitrogen was added wasn't really known."

"When you put nitrogen on you want to put it on at the start of fern growth because that's when it'll get sucked into the plant and be turned into big new storage roots for next season."

Next steps

"Whether asparagus growers are producing as much as they could if nitrogen was added wasn't really known," says Dan. That should be addressed with some additional work to be undertaken this spring.

"Our trials compared each growers' usual practice versus 'something else'. When we get their current season's yield data, we'll see if that extra nitrogen actually gives you extra yield down the track."

Tony Benny for the Our Land and Water National Science Challenge

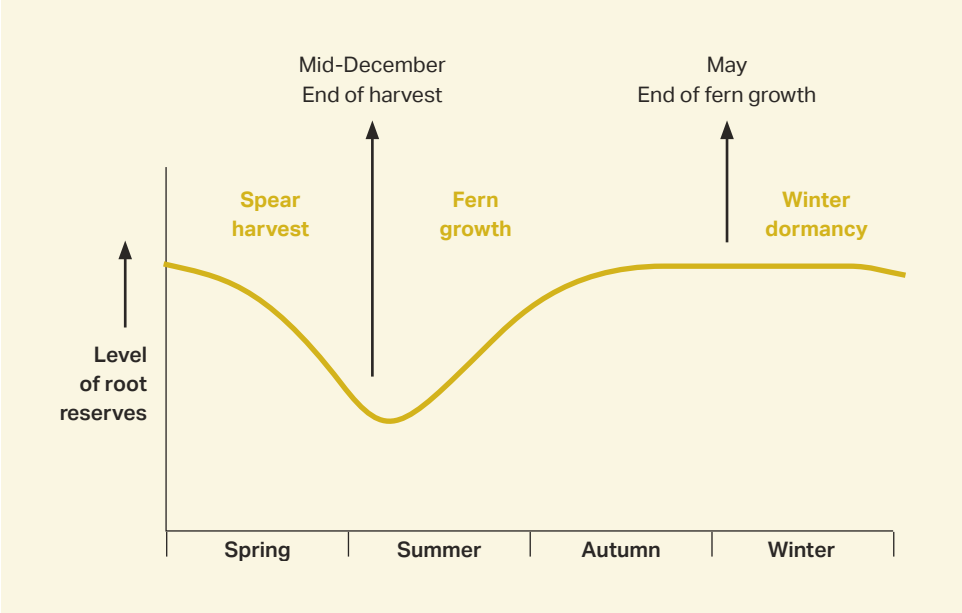


Figure 1: The depletion and rejuvenation of root carbohydrate reserves in asparagus through one annual cycle. Source. Brash, D, et al. (2005). Asparagus Manual

Orbiting kiwifruit water meters

Using satellite technology to monitor kiwifruit canopy water content

Why: To see if satellite monitoring of kiwifruit orchard canopies using microwave sensors called Synthetic Aperture Radar (SAR) satellites could more accurately show when irrigation is needed, given the variable soils within an individual orchard, and lead to better water management.

Where: Kiwifruit orchard on Matapihi Peninsula in Tauranga.

Who: Ash Neilson (RICADO Group), Colin Jenkins and Andrew Wood (Ngāi Tukairangi Trust), Phillip Green and John Huntingdon (RICADO Group), Dr Istvan Hajdu and Professor Ian Yule (PlantTech).

What:

- Data from SAR satellites is accurate enough to map the water content in kiwifruit canopies and can distinguish between varieties.
- Water content in leaves correlates with soil moisture from irrigation and weather events.
- The Harwood green variety of kiwifruit was found to store less water in its leaves than the gold cultivar.
- SAR satellites can provide data in any weather and at night, so passes should be more frequent (as close to daily as possible) to give the most accurate information.
- Modelling should be implemented soon to detect both water stress in vines and to avoid over-irrigation.
- Incorporating modelling into dashboards visualises orchard data, making it easier for orchardists to make better decisions around increasing yield, preserving freshwater resources and reducing fruit variability.

Read more: *Using satellite technology to monitor kiwifruit canopy water content*: ourlandandwater.nz/RPF2022

Satellites passing overhead could assess water in kiwifruit canopy leaves and help identify when irrigation is needed. As councils tighten up on water allocations, keeping track of water use in kiwifruit and other orchards is important and will become even more so as climate variability increases.

The kiwifruit industry is under the hammer. A serious shortage of labour due to Covid-19 is behind a drop off in the quality of export fruit. Our reputation in our overseas markets has taken a serious hit.

Repairing this damage will mean taking extra care with production and handling over the coming years. Getting irrigation right, especially in the crucial lead-in time to harvest through the heat of summer, has a direct impact on the quality of the fruit.

"Unless you test the plant you don't know if you're over-irrigating or under-irrigating," says Ash Neilson of RICARDO based in the Bay of Plenty. "For some orchardists it comes down to guesswork or gut feeling."

Compounding this, orchards can have variations in soil type that affect how much water is retained or lost in the soil.

The value of getting irrigation right isn't just reserved to upping fruit quality. Many of the orchards that RICADO manage take water from streams. Ash notes that regional councils are tightening up more each year on resource consents and allocations for water out of streams and bores.

"Some areas have also been over-allocated for water in the past, and councils are being much tougher

3D rendered image of satellite

with new resource consents and monitoring existing consents," says Ash. If the flow gets too low, water take can be restricted or stopped.

"There are a growing number of orchardists who are technology-minded and forward-thinking. They're already doing remote soil moisture testing," Ash says. "More and more managers are managing larger orchards and don't have the time to micro-manage. Their long-term goal is to get to the point where irrigation is automatic."

To do this, more accurate data is needed than is currently available.

Funding from the Rural Professionals Fund from the Our Land and Water National Science Challenge was granted to find out if Synthetic Aperture Radar (SAR) satellite technology, which uses microwave technology and isn't weather or daylight-dependent, could accurately gauge the water content of foliage in kiwifruit canopies and nail down when plants are stressed. The digital data could also be used on data platforms.

Getting underway

Trialling was held on Ngāi Tukairangi Trust's orchard blocks on Matapihi Peninsula in Tauranga from November 2021 to March 2022. The orchards are on highly productive, well-drained loam soils with flat-to-undulating terrain, and with six blocks in an orchard chosen. Two blocks were growing the Harwood green variety and four blocks the gold cultivar.

Soil moisture data was provided from remote soil moisture sensors. Teros 10 soil moisture sensors were installed in the centre of each block at 300 and 600 mm depths in October 2021, with raw data calibrated in accordance with the manufacturer's guidelines. Fifteen-minute readings gave near real-time data and were sent to RICADO's online network.

This data was then correlated with rainfall events from a local weather station just 3.2 km away at Tauranga Airport. Daily rainfall and soil water deficit datasets came from here using NIWA's national CliFlo open-access online climate database.

On days that the satellite was to pass overhead, leaves from the canopy were collected from the same bay in each block, sealed and sent for water content testing by technicians from Eurofins Laboratory.

Eye in the sky

Data from the orbit was to come from two SAR Sentinel-1 satellites operated by the European Space Agency's Copernicus programme. Operating since 2016, Copernicus allows a full and open licence to all Sentinel data for research. Following each other around sees one of the satellites cross over the orchard every four to six days.

But the research had only been underway for a month when one of the satellites malfunctioned. This saw data coming from the remaining satellite once every 12 days. The data collected by the remaining satellite was considered enough to prove the concept, and the trial continued.

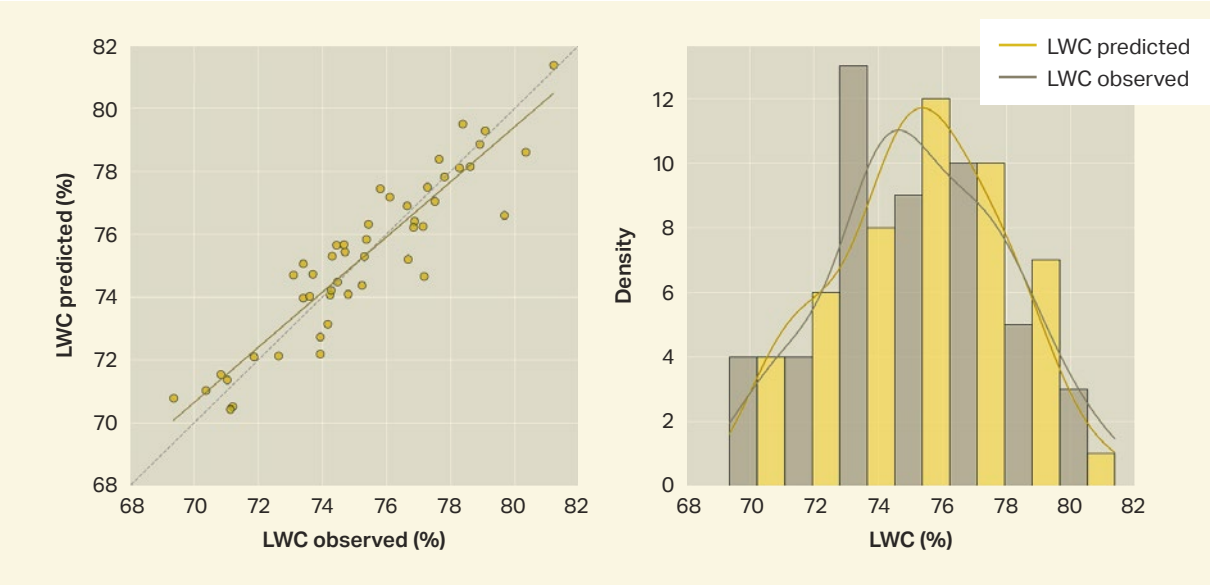


Figure 1: Model performance and histogram comparisons of observed and Sentinel-1 predicted LWC values at the block-scale

An alternative was then also sought, with Earth Observation company ICEYE's SAR satellites, which uses different radio wave lengths, providing separate data from mid-February. Results suggested it too would be accurate enough for its own modelling.

In the end, only the Sentinel data was used. This showed a close agreement with ground-based lab results for the water content in the leaves, which suggested the amount of water present in canopy leaves could be accurately predicted over time (**Figure 1**).

Some additional work might be needed around hail netting, because the satellite constantly over-estimated leaf water content on the single block that netting was used on.

Sensors and satellite agree

The soil sensors showed soil moisture increases after rainfall and irrigation, particularly at 300 mm, and falling moisture in the soil between these events. There was more and more constant moisture at 600 mm. Comparing soil moisture and leaf water content measured on the same day confirmed there was a relationship between them.

Significantly, it also showed the Harwood green variety stores less water in its leaves than the gold cultivar.

This difference was also picked up in the satellite data. Microwaves from the satellite were stronger as the leaves took in more water, as well as more microwaves bouncing back (backscatter) as the leaves got fuller. Backscatter from Harwood green foliage was generally lower than for the gold. This would need to be taken into consideration when both assessing data and with predictive modelling using SAR.

From there, modelling was used to create 3D maps of leaf water content on 100 blocks in the orchard.

ArcGIS Online is web-based software that allows interactive maps to be created and shared. Different layers of information can be incorporated into the maps. This type of layering is very good at separating out and visualising 'like' information from within large data sets.

The maps and data were uploaded into a dashboard created by the software. This meant different aspects of the data could be visualised, so trends could be seen between the different blocks and vine varieties in the orchard. This included thresholds for when blocks might be water stressed.

The group was pleased with the dashboard. This type of presentation of leaf water content data they felt would be a useful platform for growers to identify water stressed areas, as well as tracking changes in leaf water content. This would help optimise water use within different parts of the orchard with different soil types.

Incorporating other relevant orchard information included doing so on web-based grower networks like RICADO's, so that other real-time information could be visualised in this way, and this was also seen as a further improvement.

Delwyn Dickey for the Our Land and Water National Science Challenge

Measuring real-time nitrogen loss in cropping

Measuring real-time nitrogen leaching from a tile-drained Hawke's Bay onion field

Why: To compare data from a nitrate sensor installed in situ with data from grab samples, and to establish if in situ measurements could be used as a reliable source of information to enable real-time modification of good agricultural practices so as to reduce nitrate leaching losses.

Where: Vegetable paddock on the Heretaunga Plains, Hawke's Bay.

Who: Jamie Thompson (Ravensdown), Chris Zuierwijk (Bostock) and Bruce Searle (Plant & Food Research).

What:

- The data showed a strong linear relationship between the N concentration measured by a TriOS Nico nitrate sensor and in the grab sample. This indicates that the sensor can provide a good indication of sump nitrate-N concentrations, and that with calibration the accuracy can be improved further.
- The ability to measure real-time nitrate concentrations in the drainage water provided data showing clear links between management practices, rainfall events and N leaching.
- Both modelling and real-time data also showed that modified agricultural practices can reduce nitrate losses to groundwater, through reducing the depth of irrigation, applying smaller but more fertiliser applications through the growing season, and using catch crops.

Read more: *Measuring real-time nitrogen losses in vegetable production – part 2*: ourlandandwater.nz/RPF2022

Research showed it was possible to measure and reduce nitrogen (N) loss in real-time from a vegetable production paddock in the Hawke's Bay. How effective would a cover crop be in soaking up excess N from the paddock over winter?

In 2020, grower Chris Zuierwijk planted up a final conventional crop of onions on a 16 ha paddock near Clive on the Hawke's Bay's Heretaunga Plains. When the crop was lifted in January 2021, the paddock would see the end of conventional inputs and synthetic fertilisers.

The conversion from conventional vegetable production to an organic system was being undertaken by Bostock New Zealand. It was an opportunity not to be missed for Ravensdown consultant Jamie Thompson. While it was known rain and irrigation events were having an effect on the mass of nitrates leaching from fertiliser applied to paddocks, knowing how much was being lost and when was important, along with how to reduce these losses.

Hawke's Bay Regional Council is tightening up regulations around crop cultivation in the huge intensive export and process growing area through the introduction of Plan Change 9 (TANK). This includes minimising risks to waterways from nutrient loss, by requiring hundreds of horticultural growers in the area to develop management plans that identify and address these risks.

An initial six-month project to investigate using real-time monitoring to measure N losses from drainage after rainfall and irrigation was undertaken by Jamie in 2020, with funding from the Our Land and Water Rural Professionals Fund.

After the results from the successful trial led to the modification of some good agricultural practices, a small amount of funding from the Rural Professionals Fund was approved to extend the project into 2021. Chris was then able to continue monitoring the paddock for another six months as he put in a winter crop of oats. This crop wouldn't receive any fertiliser and it was intended to see how much soil N it would soak up.

The paddock's story so far

Poorly draining, the paddock had dense clay-rich subsoil sitting about 50 cm below the soil surface, along with a high water table in winter.

Tile-and-mole-drained, all the drains in the paddock lead to a single sump where Jamie installed a TriOS Nico nitrate sensor. This measures nitrate-N concentrations in wells and sumps.

By taking collected samples immediately for lab testing, this showed how accurate the sensor was in real-time, as well as the effects of irrigation and wet weather events on N leaching.

Soil samples were collected when the crop was planted, and when the crop had finished they were sent to Analytical Research Laboratories (ARL) in Napier for analysis (**Table 1**).

After the onions were planted fertiliser was applied four times, about a month apart, with a total of 153 kg of N applied per hectare.

Decagon sensors at the front and back of the field gauged the amount of moisture in the soil every couple of hours at 15, 30 and 60 cm depths, with two flow meters recording weekly drainage.

Hourly readings were taken by the TriOS Nico nitrate sensor in the sump, with a weekly sample taken to ARL and the nitrate concentration measured. Twenty onions from the final crop were taken to ARL to measure their N content.

Sensor results similar to grab samples

There was 113 kg/ha of mineral N in the soil at planting, with 86 kg/ha remaining in the soil (mostly near the surface) when the onions were lifted.

The sump sensor and weekly sampling showed some nitrate leaching whenever it rained, with losses of about 0.16 kg/ha each week. But a big downpour in November, within a week of fertiliser going on, saw a huge spike with 3.7 kg/ha of N lost in a week.

Leaching stayed high, gradually decreasing through to the end of cropping, with a couple more spikes from irrigation, and 9 kgN/ha in total eventually leaching off the paddock (**Figure 1**).

The TriOS Nico nitrate sensor and the grab samples showed similar results, with the sensor showing levels about 8% higher than lab results and a clear link between management practices, rain events and leaching. Calibrating the sensor would give more accurate real-time nitrate losses.

This would enable farmers to decide if they wanted to reduce the depth of each irrigation, use smaller fertiliser applications and increase application numbers through the growing season.

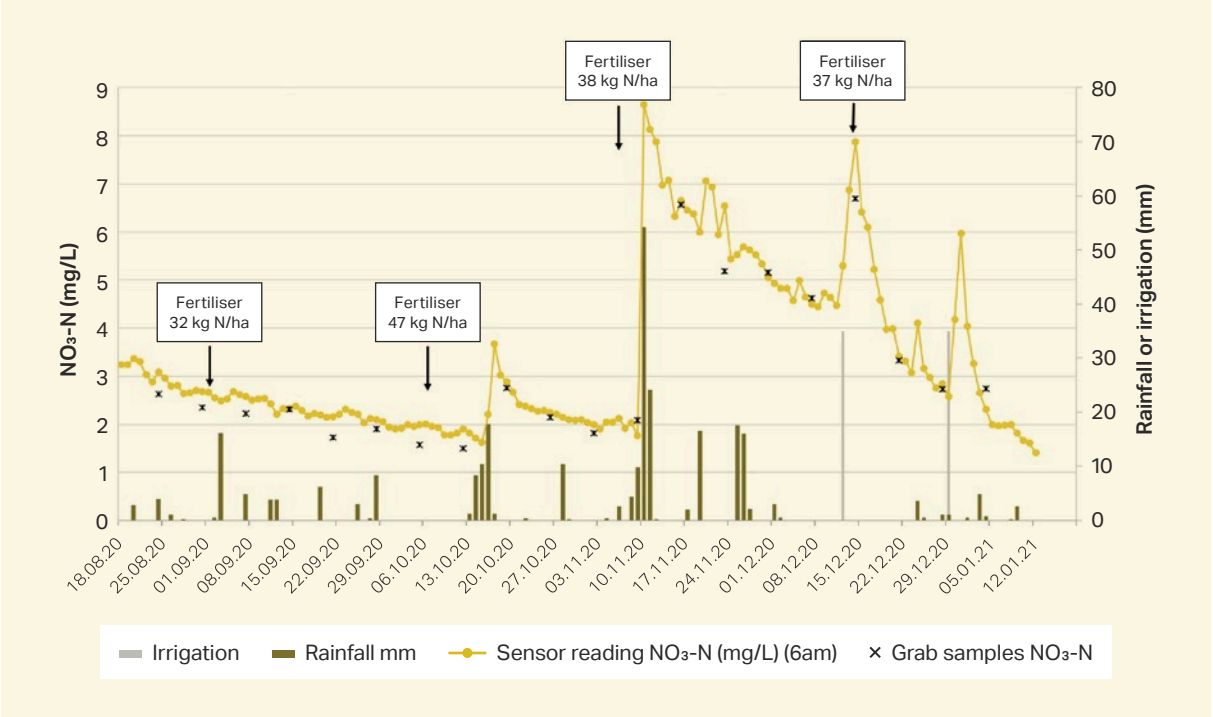


Figure 1: Nitrate concentrations in drainage water relative to rainfall and management events including irrigation

There was 113 kg/ha of mineral N in the soil at planting, with 86 kg/ha remaining in the soil when the onions were lifted.

The potential increase in eCO_2 from running machinery would be a consideration, as it was for this next phase of the project.

Confidence in the TriOS Nico nitrate sensor being accurate saw the second phase of the trial begin.

The story continues

Of the remaining N in the soil after the onion crop was raised, 80% was in the top 30 cm. Data from the sump sensors continued to come in and weekly samples continued to be tested.

N leaching dropped to almost negligible levels once the onions were lifted in January, with no irrigation and no heavy rain until late June. By this time the oats had been in the ground for three months without any fertiliser. They were mulched in early July and turned into the soil three weeks later when the paddock was ploughed. There were two heavy rain events around this time, which saw some leaching but substantially less than before.

OverseerFM was then used to model several scenarios to see what difference there would be to greenhouse gas emissions by leaving the land to lie fallow compared to planting it up in oats.

It found 23 kg/ha leached from the paddock over the year. The oats would have soaked up 18 kg/ha, reducing N leaching to just 5 kg/ha for the year. Greenhouse gases increased with the oats scenario by 25%.

"Because the ground is so waterlogged over winter, turning the oats in would have seen nitrous oxide emissions increase, along with emissions from tractor use," says Jamie. Growers need to carefully consider the effects of trade-offs between nitrate losses and greenhouse gas emissions.

"The project has been very successful," he says. "The results of the initial project saw a lot of interest in the technology and installing sump sensors is now likely to become more standard practice."

Zespri has also shown interest in installing sensors on kiwifruit orchards, with interest also from national agriculture and horticulture consultancy business AgFirst.

Jamie is hopeful that tracking N losses in real-time will raise people's game and lead to improved management practices.

Delwyn Dickey for the Our Land and Water National Science Challenge

Shelter from the storm

Composting shelters offer shade from the summer sun, and keep cows and staff warm and dry in winter while reducing pasture damage and nitrate leaching. But how do they fit in with our pasture-based grazing systems?

Impact of composting shelters on dairy farm systems

Why: To compile knowledge from farmers using composting shelters about animal welfare, staff wellbeing, and the economic, environmental and operational impacts on a farm system.

Where: Six farms from Waikato to Southland with composting shelters in place, plus a Waikato Māori-owned case study farm.

Who: Rachel Durie (Perrin Ag Consultants), Keith Woodford (AgriFood Systems), Kokako Pi Karere LP and six composting shelter farmers.

What:

- Significant reduction in winter feed compared to a 24/7 outdoor system.
- Correctly maintained bedding material holds urine and dung in the shelters with no effluent capture needed.
- Improved cow welfare, body condition and feed utilisation can see more efficient and higher milk production, and an extended milking season.
- Significant reductions in nitrogen leaching possible – a 45% decrease to 28 kg N/ha/yr modelled on the case study farm.
- Amount of milk produced per kilogram of nitrogen lost doubled in the base composting shelter system, along with a 36% reduction in nitrogen surplus.
- Research required to determine impacts to greenhouse gas emissions.

Read more: *Whole systems impact of composting shelters in New Zealand*: ourlandandwater.nz/RPF2022

Animal welfare concerns during winter were at the top of the list of reasons farmers chose to look at integrating composting shelters into their dairy farming operations.

Keeping their animals warm and dry, out of the cold and the mud and on a non-concreted floor had a lot of appeal for them, as did less stress on staff.

Avoiding damage to pasture from pugging during wet weather and improving pasture management were other reasons.

These were just some of the findings by Perrin Ag farm consultant Rachel Durie, after interviewing six dairy farmers who had recently integrated composting shelters into their farming operations.

Rachel led the project with technical support from Keith Woodford (AgriFood Systems). They researched how these structures are used and how successful they are, including from a financial perspective, for various farming operations – with funding through the Rural Professional Fund from the Our Land and Water National Science Challenge.

With at least 30 composting shelters up and running around the country already (and more being built), there is growing interest in them, particularly as environmental regulations increase. The structures are new to New Zealand – with the first one less than 10 years old. They are also a farmer-led initiative, with little formal research completed as yet to support farmers in managing them as they integrate them into our pasture-based systems, or for other interested farmers to follow.

The owner of a Canterbury-based operation has been using a composting shelter for the last couple of years and says concerns over the animal welfare side of winter cropping is behind him getting his animals off the land during winter.

Cows resting in Waikato composting shelter

Cropping in winter is common practice in Canterbury, Otago and Southland. "While the animals look good at the end of winter from good quality feed, the process is hard on them," he says. "They're out in the weather all the time, the rain, the mud and everything that goes with it."

Added to this was the anxiety of sending animals off-farm for winter grazing with *Mycoplasma bovis* in the area. This led to him looking for an alternative system that would give better outcomes for the animals, while becoming largely self-sufficient and keeping all their animals on-farm.

"While we dropped stock numbers to do this, running costs have absolutely flattened out and profitability has risen.

"It's taken a lot of stress off the cow shed and the staff," he says.

New winter cropping rules coming into effect from November won't affect the operation, nor concerns over nitrate loading.

"We're in a high nitrate area and need to get that loading down by 36% by 2035. This new wintering system gets us there now."

Reducing heat and human stress

The interviews showed two different types of operation. One was a wintering-only system to replace cropping used for a farm in Canterbury and another in Southland. The animals were outside the rest of the year.

The other was a hybrid indoor-outdoor system where the animals are in the shelters for a portion of the day, most of the year round. The cows are usually brought inside at night during autumn and winter, and during the day in the hotter parts of the year.

One farm has automated gates so the cows can choose when they move into the shelter. This tends to be when the temperature rises to between 20° and 25°. Other farmers have temperature gauges that prompt them to collect their cows and bring them inside.

Heat stress is likely to become more of an issue as the climate warms, Rachel advises, along with more extreme weather events. Being able to move animals under cover is likely to become increasingly important.

Calving is one of the most stressful times of the year on dairy farms and can be pretty miserable for both staff and animals out in bad weather. Farmers found the shelters really shone during this time, with calves born into warm, dry conditions and staff also not stressed.

"One of the ways to take the stress out of the system for the staff is to take the stress out of the system for the animals," one farmer commented.

Keeping the animals more comfortable, where they're not using energy to keep warm or getting heat stressed, is also good for production, with more milk and a longer milking season possible.

Bedding is a key factor

The shelters have a high roof and no walls, although sails have sometimes been set up to stop excess rain getting onto the bedding. Some structures have a solid roof, while others have a material-covered tunnel roof.

Good airflow through these open structures, and turning the thick layer of dry bedding material (often wood chips or sawdust) that goes onto the shelter floor into compost, is at the heart of the system.

Current recommendations are for the bedding to be around 600–800 mm deep. Urine and dung are absorbed into the bedding and tilled. In a well-managed shelter there is no effluent to manage and no odour. Turning the material each day aerates it, providing a warm dry environment. At the end of its life, this compost can be spread out onto pasture, potentially reducing fertiliser costs.

There is still plenty to learn about getting the most out of the bedding, and this is an area where more research is needed, Rachel says.

Stocking rates of bedding material ranged from 5.5–9 m^2 per cow, with this usually replaced every one to two years, and with one farmer aiming for three years.

An operation running 440 cows could see over 3,000 m^3 of bedding needed to fill a shelter. With bedding the biggest expense after the structure itself, keeping it in good condition makes good financial sense.

With climate change mitigation measures ramping up, one farmer thinks this could put a lot of pressure on forestry waste for bedding in the future. With this in mind, he is looking at establishing a plantation of miscanthus. Growing up to 4 m high, this grass plant is being grown more often specifically for use as bedding. If they spread one-third of their compost each year they should be able to grow enough to replace it, he reckons.

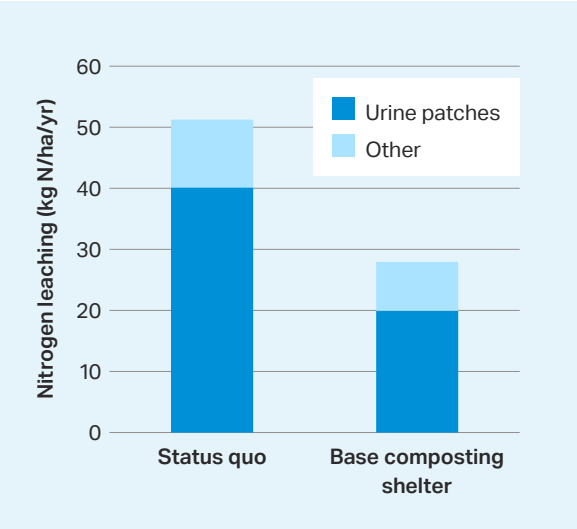


Figure 1: Urinary nitrogen (N) loss and other N loss as a proportion of total N loss in the status quo and base composting shelter scenarios

With no guidebook, learning as you go is common among the farmers. One farmer learnt the hard way that bedding needs to be dry when it goes in the shelter after having to sort out pooling when his wet sawdust didn't absorb as much waste.

Despite the high cost of getting the shelters erected, the farmers were pleased with their investment, with few if any negatives noted and none wanting to return to their previous system.

Modelling return on investment

The information gained from the farmers' experiences was used to support modelling for different composting shelter scenarios on a case study farm (**Table 1**).

The farm was Kokako Tuarua in South Waikato, owned by Kokako Pi Karere LP, with the owners also keen to see how the composting scenarios performed in relation to their current system.

Environmental, physical and financial performance were the key areas looked at, taking impacts to animal welfare and staff wellbeing into consideration.

Two composting shelter design structures were modelled in the investment analysis. High and low capital cost versions with a solid roof ($2.6 million and $2.3 million), and high and low capital cost versions with a material tunnel roof ($1.9 million and $1.6 million), were modelled.

The extra costs in the high capital scenarios come from concrete infrastructure for compost retaining walls, cow standing areas for feeding and lanes for tractor access. These can be replaced with gravel and timber which, while cheaper, have additional ongoing repair and maintenance costs.

However, in many situations farmers were opting to minimise concrete in the builds due to cost, effluent management and animal health considerations, Rachel says.

The shelters were modelled to operate as a hybrid year-round indoor-outdoor grazing system. Financial analysis considered both a 25-year investment period and a 50-year investment period, recognising a longer-term Māori view which would also be the expected lifespan of the structure.

Table 1: Key physical and financial indicators for the status quo and base composting shelter scenario for a 172 ha farm wintering Friesian cows

	Status quo		Base composting shelter scenario	
Cows wintered	580 (230 off-farm 4 weeks)		580	
Mean calving date	24-Jul		24-Jul	
Mean dry-off	10-May		4-Jun	
Production (kg MS)	231,650		263,719	
Days in milk	273		292	
Nitrogen use (kg N/ha)	150		150	
Total N loss (kg N/yr)	10,341		5,714	
N loss per hectare (kg N/ha/yr)	51		28	
Feed	**t DM/ha**	**t DM/cow**	**t DM/ha**	**t DM/cow**
Total feed eaten	17.2	5.3	18.3	5.6
Total imported feed eaten	5.3	1.6	4.4	1.4
Pasture and crop eaten	12	3.7	13.6	4.2
Summer crop	Turnips (6 ha)		none	
Winter crop	Oats (3 ha)		none	
Feed conversion efficiency (kg DM/kg MS)	12.8		12	
Financial indicators	**$/ha**	**$/kg MS**	**$/ha**	**$/kg MS**
Net cash income	12,928	9.62	14,658	9.58
Farm cash working expenses	8,104	6.03	8,246	5.39
Cash operating surplus (EBITDA)	4,823	3.59	6,412	4.19

The whole business return for the case study farm was 6.3%. Depending on infrastructure decisions, the whole business return for the composting shelters ranged from 6.8% for the high-cost structure to 7.4% for the low-cost structure. The return on the actual investment itself over a 50-year period ranged from 8.4–12.4%.

Modelling suggested that at a $9/kg MS milk price, milk production on the case study farm needed to increase by 31–43 kg MS/cow, depending on capital costs, to get the same return as the base system. This was achieved in the modelled system with an additional 57 kg MS/cow projected due to increased pasture growth, improved feed conversion efficiency and the mitigation of heat stress.

Where operating costs can be significantly reduced, as would be the case where intensive winter cropping is replaced with in-shelter wintering, the extra production would be less.

Overall, the project found the economics of the composting shelter scenarios appeared sound.

From an environmental perspective, modelling in OverseerFM v6.4.3 found the shelters resulted in a 45% reduction in nitrogen leaching on the case study farm (see **Figure 1**). This was largely put down to reduced urine on pasture.

More research is needed to discern how the shelters perform in relation to greenhouse gas emissions. While reduced urinary nitrogen on pasture should lead to less overall nitrous oxide emissions, the impact of the in-shelter aerobic composting process on emissions is yet to be investigated. More research is needed to confirm this.

The composting scenario on the case study farm also fitted well in a te Taiao context, being good for land, animals and people.

Delwyn Dickey for the Our Land and Water National Science Challenge

The supplement struggle

New Zealand's dairy industry is so reliant on internationally produced supplements that production and profitability would be impacted significantly if this food supply was interrupted. New Zealand-grown supplements could free us from this reliance, but the transition will be slow.

Moving to zero-supplement dairy systems

Why: To determine the productivity, profitability and sustainability impacts of removing all internationally produced supplements (IPS) from New Zealand dairy farming systems.

Where: Two dairy farms in Waikato.

Who: Regan McCorquindale (RECO) and Sean Nixon (Agriconcepts).

What:

- Analysis was performed on two dairy farms to determine how reliant these properties have become on internationally produced supplements (IPS).
- The current system was used as the base and three scenarios were modelled: zero IPS (ZIPS), substitution for New Zealand produced supplement (NZPS), and a lower stocking rate with ZIPS (LSR).
- The outcomes and additional data were scaled up to a national level, and this uncovered that without IPS, efficiency would rapidly decline if dairy cow numbers and farmed area remained the same. Production and profitability would be impacted significantly.
- If the dairy area was reduced and IPS was substituted for NZPS, some of the losses would be mitigated, but there would be product access challenges.

Read more: *Moving to zero-supplement dairy systems*: ourlandandwater.nz/RPF2022

Trucks frequently visit New Zealand dairy farms, but Regan McCorquindale from RECO worries how many of them are loaded with imported feed. He wondered what could happen to New Zealand's dairy industry if it lost access to this food source.

Internationally produced supplements were needed to maintain dietary requirements as stocking rates increased on New Zealand dairy farms. But this has left the sector in a vulnerable position, with fluctuations in production and logistical challenges. There are also mounting pressures to drive efficiencies and produce 'more from less' as cow numbers decrease.

Keen to understand what feed opportunities lie ahead for the New Zealand dairy sector, Regan and Sean Nixon from Agriconcepts teamed up to explore the topic. They wanted to understand what the potential impacts could be if internationally produced supplements were removed from the system and whether the value of New Zealand produced supplements could be increased.

"It is a worry how reliant the New Zealand dairy system has become on internationally produced supplements to sustain production levels and animal welfare," Regan says."You struggle to go to a farm nowadays that doesn't have truck tyres coming in the gate, but we need to look at other alternatives. What can be controlled within New Zealand's agricultural system and what can't."

He recognises there will always be a place for internationally produced supplements, but wanted to explore how the sector could rely on them less.

The project used data from two Waikato dairy farms **(Table 1)**. FARMAX modelling and some system optimisation models allowed them to explore the net effects on production if all internationally produced

Regan McCorquindale with supplement

supplements were removed from the system. They also looked at what system changes would be needed if imported supplements were substituted with New Zealand products, and both scenarios were scaled up to determine the impacts on a national scale.

The results highlighted there would be significant impacts if the sector faced a sudden shift to remove all internationally produced supplements, as it would reduce production and profitability greatly, posing risks to business sustainability.

The good news was that substituting with domestically produced supplements has the potential to maintain production, although the biggest challenge is the availability of land to grow alternative crops.

They concluded the shift will need to be gradual and farmers will need to look at options to mitigate risks and reduce their reliance and control as much as they can to protect their businesses into the future.

Supported by supplement

The levels of internationally produced supplements used in New Zealand constantly change. For the two farms analysed, imported feed made up 28% (System 4) and 19% (System 3) of the herd's diet. The modelling showed if supplement was removed from those systems entirely, milk production would reduce by 14% and 24% and profitability would decline.

"There is too much volume coming in, our sector couldn't handle an abrupt stop to imported supplements. But the current system is too reliant on shipping and transport," says Regan.

"Farms don't have the storage capacity, so they rely on human input to estimate when they need another delivery, and usually there are a lot of farms wanting it at the same time which affects availability. Not to mention the skyrocketing transport and logistic costs."

The research didn't suggest farms should move towards lower intensity systems (System 1 or 2) with less supplement, says Regan, but farms do need to have infrastructure to store the product and not be so reliant on the timing of a truck turning up.

Increasing product value

New Zealand-produced supplements, such as maize silage, or barley and wheat grain, could be used to mitigate the production losses. The challenge would be access to product and how much land would need to be removed from the dairy platform, which also means a reduction in cow numbers.

"It would be great to see New Zealand supplements feeding our own dairy systems and create a premium on that product. But our biggest challenge is the availability of land to grow the alternative crops."

Table 1: Two Waikato dairy farms modelled through FARMAX and the three different scenarios without the use of IPS

Parameter	Farm A				Farm B			
	Base	ZIPS	NZPS	LSR	Base	ZIPS	NZPS	LSR
Number of cows (peak lactation)	530	530	530	495	191	191	191	170
Stocking rate (SR: cows/ha)	2.9	2.9	2.9	2.7	3.4	3.4	3.4	3
Comparative stocking rate (CSR)	84.5	91.5	86	86.8	84.1	95	84.3	90.8
Net pasture growth (t DM/ha)	15.3	15.3	15.3	15.3	16.6	15.7	16.8	14.8
Pasture consumed (t DM/ha)	13	13	13	12.8	15.5	14.7	15.6	13.7
Total feed consumed (t DM/ha)	18.3	16.8	18.3	16.8	22.8	19.7	22.7	18.3
IPS consumed (kg DM/cow)	441	0	426	0	740	0	700	0
Total imported feed/total feed (%)	28	21.7	27.9	22.9	18.8	9.3	18.2	8.9
Annual MS (kg/cow)	429	375	427	408	421	320	422	347
Annual MS (kg/ha)	1,250	1,093	1,244	1,111	1,436	1,092	1,438	1,055
Annual MS (as a % of liveweight LW)	83.6	73.8	81.9	78.8	83.8	66.3	83.7	72.1
LW (kg/ha)	1,496	1,481	1,518	1,409	1,717	1,647	1,718	1,464
Feed conversion efficiency (kg DM: kg MS)	14.2	14.8	14.2	14.6	14.2	15.9	14.2	15.3
Days in milk	286	286	286	286	266	267	266	265
Body condition score	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
Greenhouse gas (kg/farm ha)	526	492	524	486	623	550	622	523
Operating profit (NZ$/ha)	3,330	2,417	2,901	2,524	1,584	780	1,187	818

Note: Fonterra's Final Farmgate milk price for the 2018/19 season which was $6.35 kg MS has been applied to both the farms, however the cost structure used was different. Farm A cost structure was reflective of the same season, whereas Farm B has been compiled from the 2020/21 season. Therefore, comparisons between both properties' operating profit/ha is not recommended, within-farm comparison is acceptable. The values in red are NZPS/cow in substitution for the IPS.

For production to remain the same as the 2020/21 season, they predicted 183,000 ha would need to be retired from the dairy platform to yield the required tonnage of New Zealand produced supplements (New Zealand Dairy Statistics, 2021). This equates to 10.8% of the area currently under dairying and cow numbers would also need to be reduced by 500,000, meaning per cow performance would need to lift roughly 11% to 442 kg MS/cow to maintain the current level of milk production nationwide.

Even by maintaining production, profitability would reduce. They saw a reduction of almost 13% and 25% for the farms modelled in this project, largely because local supplements cost more.

Getting ready

The process to reduce reliance on internationally produced supplements is going to be gradual, but there are steps farmers can take now to help prepare them. Regan is a big advocate for matching supply and demand, and he recommends farmers monitor pasture production and move calving spreads to match the 'new' climate.

"Pasture is the cheapest form of feed, but not if cows aren't calving to match the curve. It pays to look back at patterns and move calving if needed."

He also talks about farms doing more from less, considering lower stocking rates and creating greater surpluses through spring to redistribute in summer, depending on climatic conditions.

"For farmers it's about controlling as much as they can. They shouldn't let themselves get too exposed to the seasonal variations and keep an open mind about how they can do things better from less."

Samantha Tennent for the Our Land and Water National Science Challenge

Summer salads for hill country cattle

Summer-safe multi-species cattle pasture

Why: To evaluate the performance of a variety of diverse summer seed mixes against a monoculture single graze crop, with the aim of developing more resilient forage crops that provide high-quality feed economically with lower inputs.

Where: An 0.07 ha plot study and two case study paddocks on a beef finishing property at Te Pahu in the Waikato.

Who: Phil Weir (AgFirst), Katherine Tozer (AgResearch), Tracy Dale (AgResearch), Angus Peterson (Farmlands), Hamish Johnston (Agricom) and John Foley (PGGW Seeds).

What:

- Simple mixtures provided a viable alternative to a brassica monoculture based on energy yield and energy costs. The most promising option was a simple rape-dominant mixture, which contained rape, plantain and a cereal (see **Table 1**). It had a high energy yield, low weed abundance and a low metabolisable energy cost.
- Hyper-diverse mixtures did not provide energy yield or energy cost advantages when compared to a simple mixture.
- Plantain contributed little to total dry matter in mid-summer, but provided forage at the end of February for a second grazing.
- The cereal established rapidly and reduced weed ingress in the rape-dominant mixture harvested in mid-summer.
- A diverse mix may have lower weed ingress, but herbicide options are also limited.

Read more: *Summer-safe multi-species cattle pasture*: ourlandandwater.nz/RPF2022

As climate variability increases, farmers need resilient summer forage crops. With pasture quality falling during mid- and late-summer this project explored mixed-species, single-graze forage crops that can fill the feed gap.

Phil Weir is a busy man. Along with running a family dry-stock farm in the Waikato he is also a farming advisor with Agfirst and has recently completed a Nuffield Scholarship.

With a changing climate that is becoming more variable, and seeing warmer and drier summers with droughts becoming more common in northern Waikato and Northland, Phil sees a need to move farm systems away from using supplements over these drier months as they will only increase in the future.

"Every time you turn on your tractor to feed out, in a dry-stock context, you're losing money," he says.

His operation grows dairy and dairy-beef calves year-round. Summers have become tough as pasture quality suffers in the dry and the heat.

"Summers are hard for all animals, but particularly on calves," he says. "Trying to increase their weight from 100 kg to 200 kg over the first summer can be difficult.

"All the options available for feeding in summer create an imbalance in your workload. You're losing your repair and maintenance time or having to take on casual staff. Ideally we're looking for an in situ crop instead," he says.

Phil sometimes grows a monoculture crop like kale for his animals. He hopes that adding multiple species of plants that grow well in the area would result in less pest pressure, less weed burden, less spraying and more dry matter. Less tractor use would also see lower emissions.

Phil Weir and Katherine Tozer assess multi-species options to support hill country dry-stock farmers to fill summer feed gaps

Phil believes that with more calves likely to be coming onto the market due to Fonterra signalling changes with bobby calves, there needs to be a way of making it easier. This is what prompted him to get involved with AgResearch scientists Katherine Tozer and Tracy Dale to find summer-safe multi-species mixes for summer forage crops as part of a Rural Professional Fund project funded by Our Land and Water, with trialling carried out on his farm.

The trial process

The study was narrow – focusing on the agronomics of the various mixes. This range of simple four-species mixtures along with a couple of hyper-diverse mixtures containing over 10 species were compared with a brassica monoculture.

The most diverse mixture included 21 species: rape, oats, plantain, red clover, cocksfoot, prairie grass, chicory, tall fescue, meadow fescue, sulla, sunflower, perennial ryegrass, hybrid ryegrass, lupin, lucerne, timothy, strawberry clover, crimson clover, balansa clover, white clover and vetch. The 11-species mixture included: rape, plantain, red clover, chicory, buckwheat, phacelia, pea, crimson clover, white clover, vetch and Triticale kudos.

Rape (a brassica) was the monoculture crop and was also used in the simpler mixes, along with a cereal (oats), plantain for ground cover and red clover.

Preparation for the trial involved spraying off the site with a mixture of both a non-selective herbicide and insecticide, with fertiliser applied a week later. Discing, power harrowing and rolling followed.

In mid-October, multiple plots of about 20 sqm were established. Seeds were drilled in at a depth of 1 cm with a width of 1.5 m and row spacing of 15 cm.

There were multiple plots, including a monoculture plot of rape, oats, plantain and red clover. Others had each of the species dominating a mix at a ratio of 61% by weight and 13% for each of the rest, another had equal amounts of the seed. As there were concerns some of the seed could be buried too deeply this wasn't rolled. Diammonium phosphate was hand broadcast and an application made of Slugout.

The seed bed on the two paddock-scale case studies, which were about 1.3 ha in size, was prepared the same way as the smaller plots. A Kuhn Triple disc drill was used to sow seed in the paddocks. The first paddock was rape-dominant with the second the 11-species mix.

Sprays to control broadleaf weeds and insects were used in November with the monoculture rape crop sprayed for white butterfly in January.

It became clear things weren't going quite to plan when the red clover seed had a very low germination

Table 1: Herbage production, metabolisable energy content, energy yield and energy cost for three mixtures in the small plot study, and the two case study paddocks, on a dry-stock farm in Waikato. SED: standard error of difference

Treatment	Herbage production kg DM/ha	Metabolisable energy MJ/kg DM	Energy yield MJ ME/ha	Energy cost ($/100 MJ ME)
Small plot study				
Rape monoculture	10,860	11	119,780	0.99
Rape-dominant mix	13,350	8	106,720	1.16
11 species mix	9,470	8.3	78,200	1.31
SED	999	0.27	10,820	
Significance level	P<0.01	P<0.01	P<0.05	
Case study paddocks				
Rape-dominant mix	13,250	10.8	143,070	0.86
11 species mix	8,530	8.4	71,660	1.43

rate – less than 25% compared to well over 70% for the other seeds, and 97% in the case of oats. This saw the four-seed mixes become three-seed mixes. This would normally be picked up through emergence testing of the seed in a glasshouse prior to the trial getting underway. But Covid-19 restrictions stymied this step, with testing taking place at the same time as the start of the trial.

While there was more rain than usual during spring, which got the plants up and running, a dry summer followed. This may have been behind the plantain failing to thrive over the heat of summer, only coming into its own in late February for a second grazing.

Before the crops were ready for grazing in mid-January, samples were taken to determine how much dry matter was produced across each of the plots and what that meant for metabolisable energy. This saw plant matter cut to ground level, weighed, shredded and dried.

Challenges, costs and benefits

Many of the species in the 21 species mix didn't perform well.

"A lot of the species established, but then died and contributed little to the overall yield," says Katherine. "There was also a high proportion of yield from sunflowers. but they're poor in terms of feed value."

While the 21-species mix had reasonable dry matter and metabolisable energy, sunflowers can be a bit 'hit and miss' with cattle. "While cattle will eat the leaves, they will sometimes avoid sunflower stalks if there is other feed available," she says. The stems make up a big portion of the sunflowers' dry matter.

Adjustments for this saw the mix slide in energy value as a consequence.

"The cost of producing metabolisable energy with the 21 species mix was more expensive than the rape monoculture because the cost of the seed is so expensive. Even with no weed or pest control, it was still more expensive because of the seed costs," Katherine says.

Oats in mixes proved to be very effective at suppressing weeds, even at low sowing rates. But oats fell down in a big way by going to seed well ahead of the rest of the forage crop. By the time the stock were put on in mid-January it was in very poor condition.

Recommendations

Both Phil and Katherine recommend Triticale should be looked at as the cereal in the mix in the future. It might not be as aggressive at suppressing weeds, but its seedhead timing fits better.

By the end of the trial the most promising option was a simple rape-dominant mixture that contained rape, plantain and a cereal. It had a high energy yield, low weed abundance and a low cost per unit of metabolisable energy.

Katherine emphasies that while the results are interesting, this was one summer trial on one farm. More research on more farms over several years is needed, she says.

Delwyn Dickey for the Our Land and Water National Science Challenge

Regenerative agriculture – opening up the wallet

Regenerative agriculture has potential as a selling point for our export markets, but how do the numbers stack up for farmers?

On-farm economics of regenerative agriculture

Why: To help people understand the financial implications of adopting regenerative farming practices.

Where: Sixteen regenerative and conventional sheep and beef farms, nationwide.

Who: Steven Howarth (AgFirst), Bill Garland (farmer), Alex Bromham (farmer), Phil Weir (AgFirst) and Katherine Tozer (AgResearch).

What:

- A desktop study compared the farm revenue of conventional and regenerative farms.
- There is reduced revenue on regenerative farms.
- Farm expenditure is similar for conventional and regenerative farming.

Read more: *On-farm economics of regenerative agriculture*: ourlandandwater.nz/RPF2022

Regenerative farming has captured people's attention globally over the last few years with the possibility it could be a model for farming in the future – easier on the environment and more sustainable.

Beef + Lamb New Zealand are also enthusiastic, seeing it as a potential selling point for our meat overseas and possibly fetching a premium. Robust science is needed, they say, to back up any claims and avoid greenwashing.

Pastoral farming is one of the fundamentals of regenerative farming practices. As our farming systems are pasture-based rather than using feedlots, as is common in the US, this puts New Zealand on a strong footing already and would make a transition to this type of farming easier for our farmers than for some others.

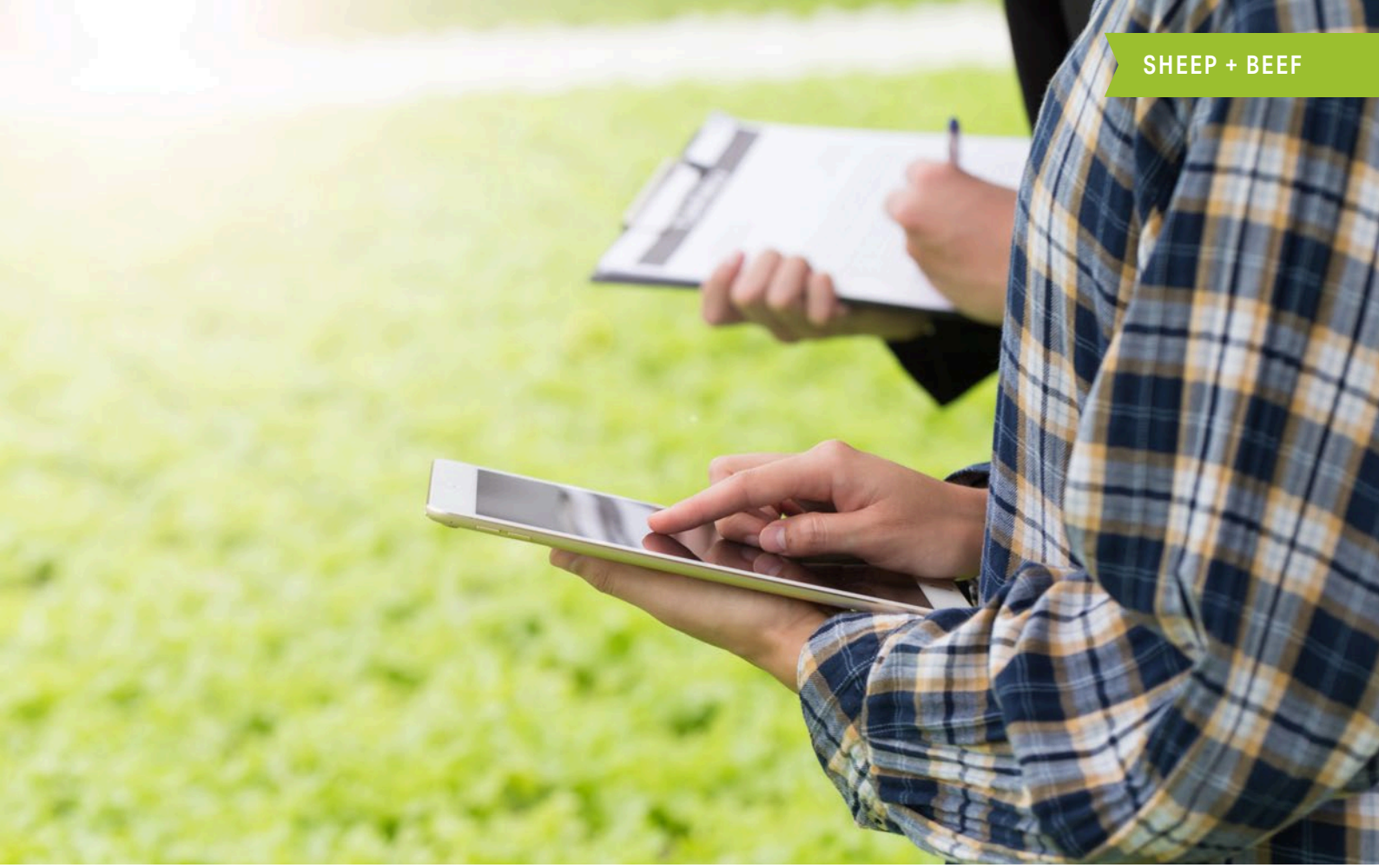
"There's a risk that if we don't have New Zealand-based data we fall back to overseas data that may not be relevant," agricultural consultant with AgFirst Steve Howarth says.

"While having independent data is important, so too is looking at regenerative agriculture with clear eyes and not over-hyping its benefits," he says. "We've seen that before – where there's been comparisons made between feedlot farming overseas and regenerative farming to portray the benefits. In a New Zealand context with our pasture-based farming that just isn't correct.

"Because there is so much interest in regenerative farming, and people who are interested are really passionate about it, it's important not to let this enthusiasm get in the way of objective data. Farmers need to see clearly what changes there would be with regenerative farming," he says.

In 2021, Steve was involved with a previous regenerative farming study, also funded by the Our Land and Water National Science Challenge via its Rural Professionals Fund. The study looked at whether there was any significant difference between meat quality from animals raised on regenerative beef farms and conventional beef farms.

If the meat of animals coming off regenerative farms was of superior quality, this could bolster the export vision for it.



Management practices between the farms were compared, along with the biodiversity of pasture species. Replacing synthetic fertiliser for other types of plant and soil nutrients on regenerative farms was one of the most obvious differences in management.

In the end, the type of pasture the animals were eating was similar, without a big difference in biodiversity and a similar number of pasture species. When the meat from animals raised on both types of farm was tested, there was little difference.

"While there was curiosity among the conventional farmers about regenerative practices, and they could see the regenerative farmers were clearly making a living from their farms, many were wary to even consider a move over to this system without seeing the economics first," Steve says.

For farmer Alex Bromham, who was involved with the trial, the focus on getting the most financially out of the land is not necessarily a key reason why regenerative farmers farm the way they do. The desire to improve the health of the soil, add biodiversity to pastures and reduce nutrient loss to the waterways is important. "Get that right and the financial side follows on from there," he says.

With funding from the Rural Professionals Fund, Steve led a team to see how regenerative sheep and beef farming were faring economically compared to conventional farms.

Gross revenue differences

A total of 16 regenerative and conventional sheep and beef farmers were surveyed to gather four financial years of revenue and expenses.

While there were different spending priorities and management approaches, with the condition of the farm seeing focused spending in certain areas, there were no significant differences in expenditure. It appeared that whether the farm was regenerative or conventional was not a driver of expenses.

But in the revenue stakes, the conventional farms in the study were bringing in more revenue per hectare of effective farmland. The total gross revenue for the conventional farms averaged $1,473/ha compared to $1,091/ha for the regenerative farm (**Table 1**).

To try and nail down how that difference came about, farm modelling software FARMAX was used to look at revenue differences for a single year across the farms.

The gross farm income from the conventional farms was $1,705/ha compared to $1,060/ha on the regenerative farms.

Table 1: Summary profit and loss data based on the 2017/18 to 2020/21 financial years for conventional and regenerative farms

	Conventional	Regenerative	P-value
Total gross revenue ($/ha)	1,473	1,091	0.022
Total farm expenses ($/ha)	1,017	1,085	No difference
EBITRm ($/ha)	613	273	0.050

The answer in part may come down to pasture. More pasture was being eaten on conventional farms, with 7.3 tonnes of dry matter/ha compared to 5.5 tonnes on the regenerative farms.

Secondly, more meat was being produced per hectare on the conventional farms. This amounted to 326 kg/ha compared to 201 kg/ha on the regenerative farms.

"The results held no surprises for Alex as regenerative farmers generally carry fewer stock anyway," Steve says. The aim is to carry as many stock as your land can support without pushing it to perform beyond its natural limits. This was also good business, he reckons.

The year under the microscope saw the gross farm income from the conventional farms was $1,705/ha compared to $1,060/ha on the regenerative farms.

Adding greenhouse gas (GHG) emissions to the mix saw some interesting results. Emissions per kilogram of meat from the conventional farms produced 16.3 kg CO_2e/kg of meat compared to 20.2 kg CO_2e/kg of meat on the regenerative farms. The conventional farms harvested a greater amount of pasture, which in theory would lead to higher total emissions per hectare. However, the current study did not find a significant difference, most likely due to the variability between farms.

In future, a larger study with more farms is required to understand how regenerative farming affects FARMAX modelling of GHG emissions. Future research could also study nitrogen loss on an area and productivity basis.

Price premium would encourage transition to regen ag

"We are seeing plenty of interest from the end consumer in regenerative agriculture," says Steve. "However, this project indicated that to provide a solid value proposition in regenerative farming for New Zealand sheep and beef, premium pricing is needed to offset the reduction in production.

"Currently there is no such premium through the major processors, which creates a barrier for conventional farmers given that financial performance is one piece of the puzzle for those considering the switch," he says.

The enthusiasm now is reminiscent of that surrounding organic farming 25 years ago, he reckons. Organic attracts a premium, and there is a good market for it which continues to grow, but there are real changes to farming practice that go with it and generally lower production.

For some farmers, there are other considerations that will make the change to regenerative practices worthwhile. The regenerative farmers involved in this project saw their farms as a functioning ecosystem, placing stock performance, soil health and biodiversity above economics. "All of the farms involved had goals for all these areas, and all were aiming to improve, it is just the relative priority of each that differed," says Steve.

Altering farm management systems and moving to regenerative farming practices may be easier here than for some countries. But the onus now falls on customers, who will need to pay more for what they see as a more sustainably produced product.

To expect them to do that will likely need some form of proof – and could well lead down the certification pathway or similar, as is the case with organics.

"When the rubber hits the road is, are people prepared to pay more for it?" asks Steve.

For his part, Alex wouldn't like to see regenerative farming go down the same route as organics with auditing and certification and input rules as it would impose restrictions on how they farm.

"We're not on a mission to convert everyone to regenerative, we just want to farm the way we do. People can look at it for themselves. If they want to try it, they should just crack on with it." he says.

Delwyn Dickey for the Our Land and Water National Science Challenge

Alternative kale feeding

Dispersed forage feeding to minimise negative impacts on soil and water quality

Why: To compare the environmental, farm management and economic impacts between harvesting greenfeed (kale) and feeding to stock in dispersed locations and the traditional method of grazing it in situ.

Where: Drystock farm (sheep, deer and cattle) in Waikari Valley, North Canterbury.

Who: Sarah O'Connell, Jon Manhire, Dave Lucock, Stuart Ford, Julie Lambie (The AgriBusiness Group), Scott Hassall (farmer), Dr David Scobie (AgResearch), Simon Thorne (Frame Grain & Seed) and Dr Dave Saville (retired biometrician).

What:

- Baseline data of the soil physical properties were gathered for two paddocks that were identified to be sown in kale.
- At the time of sowing both paddocks were divided, with half to be grazed and the other half harvested to provide a direct comparison between the systems on the same soil types.
- Although there was no evidence of a difference in soil properties after the kale had been fed, modelling suggested that there were benefits, such as mitigating nitrate leaching.
- The farm management benefits exceeded expectations and drove efficiencies during and post the crop-feeding period for the farm in the project.

Read more: *Impacts of dispersed forage feeding*: ourlandandwater.nz/RPF2022

Greenfeed crops can be an important winter feed source, but intensive grazing needs careful management. This project found environmental and management benefits to harvesting kale to feed out to livestock, but less difference to soil compaction or water infiltration than anticipated.

Feed shortages and winter grazing woes had Sarah O'Connell from The AgriBusiness Group contemplating what alternative tools could help farmers navigate winter.

Talking about feed shortages at a winter seminar, Sarah learned of an alternative method that local North Canterbury farmer Scott Hassall had adopted to feed harvested kale to his livestock last year. She approached him to learn more about what he was doing and proposed a project to compare whether his method had less environmental impacts than traditional grazing.

When pasture production is slow during cold winters or dry summers, greenfeed crops can be an important feed source to help fill the gap. But grazing greenfeed crops, such as kale, bring environmental and management challenges for farmers and new winter grazing rules have added to the load.

Intensive grazing needs careful management to protect paddocks from pugging and to mitigate water quality risks from nitrate leaching and sediment run-off. "It gets highlighted every winter when animals are in mud up to their knees and it always gets me thinking about how we can reduce the concentration of animals in a small area," Sarah says.

Harvested kale being deposited before loading to be fed to livestock

"What Scott was doing was doing exactly that. He was harvesting the greenfeed kale and feeding it to his stock in pasture-based paddocks, which meant there was minimal pugging, leaving nice clean paddocks without any surface damage."

From his positive experiences the previous season, Scott was already sold on the idea of continuing to harvest his kale crop to feed his stock, so he was more than happy to be involved in the project.

Management benefits

From Scott's perspective, the major benefits sit with farm management. He praises being able to feed every class of stock on his property, which includes deer, cattle and sheep, as well as the total utilisation of harvested feed because everything gets chopped up small.

It takes about an hour every two days for Scott to harvest the kale. He says he would rather sit in the tractor than navigate break-feeding kale, and because he is feeding-out he still sees the stock every day.

"It takes a bit of preparation to break-feed crops and the stock always leave heaps of stalks behind, but when we harvest the kale we don't have to worry about preparing marks for breaks. It gets chopped close to the ground and the whole plant gets chopped into bite-sized chunks that the stock clean up," Scott says.

The cleanly harvested paddocks recover quickly, and Scott finds he is able to direct drill without any ground preparation work, which creates efficiencies that save him time and effort.

"Not having to do any cultivation is a huge benefit for me, and it's such a relief to just get on with the next stage so easily."

Measured and modelled results

The big advantages Sarah found through the project were from an environmental perspective, especially for farmers needing to navigate the new regulatory landscape.

"It's a tool that farmers and their support can consider when planning winter feed. Harvesting provides flexibility, it doesn't need a consent, and it gives farmers options to consider paddocks with higher slopes," she explains.

For the project they compared two paddocks with similar soil properties that were sown with kale. Each paddock was split in half. One side was grazed traditionally with deer and the other harvested, to allow a direct comparison between the systems on the same soil types.

To assess the soil before and afterwards, visual assessments and measurements of compaction and

water infiltration were taken on the paddocks, via measurement by a penetrometer and bulk density. There was no visual damage or pugging in the harvested areas, unlike the grazed areas. However, the measurements didn't show any statistically significant differences to the soil physical properties between the two areas.

Sarah wonders if it would have made a difference if they grazed cattle rather than deer, or if with more replicates a bigger study might produce a statistically significant result.

The team then used OverseerFM modelling to understand the nutrient losses of the project and potential nitrate losses if they were to implement alternative management practices on the paddocks (**Table 1**). This found a reduction in nitrate leaching, which is a huge benefit for farmers and waterways.

A financial analysis illustrated little difference in the cost of the systems when they are compared on a feed value basis. On a pure cost basis, the costs are higher in the harvesting system ($721/ha) than in a grazed in situ system ($593/ha).

Equipment is the limiting factor

"By harvesting the crop, farmers don't need to have large numbers of animals grazing in a small area, which has numerous benefits for the environment," says Sarah, "particularly around pugging and leaching, as well as public perception risks.

"When poor weather conditions are predicted, the method could also be utilised to keep stock off crops to reduce the incidence of pugging, surface run-off and undesirable grazing conditions."

Table 1: OverseerFM nitrogen block summary

Scenario	Paddock 1 (imperfectly drained soil) (kg N/ha/yr)	Paddock 2 (well-drained soil) (kg N/ha/yr)
Base (grazed in situ)	25	17
Harvested	16	21
Harvest and grazed	20	16

But Sarah points out that a big consideration for farmers is the reliance on equipment availability. Farmers who have their own gear, like Scott, can utilise equipment that would otherwise be parked at that time of the season. He also had the luxury of having three tractors available, which meant he could leave various implements attached and switch tractors between jobs rather than changing implements each time.

Further work to explore the economics of utilising contractors would be helpful. There could be opportunities for farmers to form or join syndicates to provide access to equipment, suggests Sarah.

The project was short and Sarah would love to follow a system over several years to get a good understanding of the extensive impacts. However, the project has confirmed that feeding-out is a tool farmers have available to support winter feeding.

Samantha Tennent for the Our Land and Water National Science Challenge

Residual of grazed and harvested areas

New test for biological soil health

A quick way to assess the biological health of soil has been developed using molecular techniques to measure earthworm activity, but this needs more work before it's ready for use on New Zealand farms.

Biological test of soil health using molecular techniques

Why: To develop a molecular test to measure the number of earthworms within the soil profile as an indicator of soil health.

Where: On three properties in King Country, Waikato and Canterbury. We thank Ngāi Tahu Farming for allowing the use of their whenua.

Who: Roger Hill (Hill Laboratories), Lisa Hsu (Hill Laboratories), Sara Loeffen (Hill Laboratories), Nicole Schon (AgResearch) and Bob Longhurst (Pastoral Nutrient Management).

What:

- This study has shown that earthworm eDNA in the soil can be measured successfully and, in many cases, correlate well with the earthworm counts by traditional visual assessment.
- The project identified suitable primers for the most common earthworms found within each earthworm ecological group in New Zealand.
- The test was sensitive to changes in earthworm abundance at individual sites. Further data needs to be collected prior to the test becoming commercially available to ensure confidence in the test developed, and the ability to predict earthworm abundance and diversity.

Read more: *Biological test of soil health using molecular techniques*: ourlandandwater.nz/RPF2022

Roger Hill of Hill Laboratories imagines a day when farmers can not only test the fertility of their soil but, using the same samples, also get an assessment of their soil health based on the level of earthworm activity from traces of their DNA found in the soil.

"Currently earthworms are assessed by going out to a field and taking a spade-square down to the depth of the spade, taking that soil, breaking it up and counting the earthworms. We realised that perhaps we could use our capability with DNA testing to develop a faster and more convenient earthworm test," Roger says.

He also says that interest in the health of our soils, beyond the common measures of fertility, is growing both among farmers and consumers.

Soil is one of our most important natural resources and is essential for a range of soil functions and ecosystem services, such as sustainable plant production, nutrient cycling, water purification and regulation, carbon sequestration and greenhouse gas regulation, and the maintenance of soil biodiversity.

Earthworms are a key component of the soil biology and abundant populations are recognised as a sign of a healthy soil. Current methods used to identify earthworm populations are labour-intensive, requiring soil to be physically broken up and earthworms collected.

Roger says that while much is known about how to test the chemical and physical properties of soil, assessing its biological properties is less well developed.

"From what I've read, less than 5% of the organisms that live in the soil have been identified. But when you talk about soil biological health, one of the first things that comes to mind is earthworms, and people associate good earthworm activity with healthy soil," he says.

Roger Hill (Hill Laboratories) collecting worms from a spade-square sample

The research process

This study involved three different species of common New Zealand pasture earthworms – *Lumbricus rubellus* (epigeic), *Aporrectodea caliginosa* (endogeic) and *Aporrectodea longa* (anecic) – being hand sorted from soil samples (20 × 20 × 20 cm) collected from farms in Waikato, King Country and Canterbury.

Hill Laboratories' scientists Lisa Hsu and Sara Loeffen worked with AgResearch scientist Nicole Schon on the project, funded by Our Land and Water via its Rural Professionals Fund.

"There was published information about DNA for those three types of worms, but when we took the literature data and designed a test around those it wasn't completely successful," Roger says.

"So our scientist Dr Hsu got some earthworms from Dr Schon and sent samples away for the DNA to be characterised and we went right back to first principles to develop the tests."

Next was to develop a reliable way to assess actual worm populations from the DNA test results. Spade-square samples were taken, the worms counted and then DNA levels in adjoining core samples measured. The intention was to establish a correlation, and therefore derive a conversion formula that could then convert the DNA result into units that people are used to (i.e. numbers of earthworms per sqm).

Soil samples collected from five sites showed a good correlation between molecular and morphological assessment, good extraction efficiency and precision.

Further samples analysed during the validation stage of the project reduced the strength of correlation between the molecular and morphological assessment of earthworms. Investigation into the factors causing this are ongoing.

"Initially the first few samples looked promising, but then as we added more soils from different areas the correlation weakened significantly, to the point that as we finished the project we thought, 'This isn't good enough'," says Roger.

Next steps

Work is continuing beyond the initial trial to improve that correlation, self-funded by Hill Laboratories and with the support of AgResearch scientists.

"To work out why the correlation is not as good as we would have expected, we need to understand more about the stability of DNA residues in the soil and the

Figure 1: Earthworms were collected and sorted manually into three separate species – *Lumbricus rubellus* (epigeic), *Aporrectodea caliginosa* (endogeic) and *Aporrectodea longa* (anecic) (A & B). Two earthworms of each species were placed in 50 mL falcon tubes for 48h prior to DNA extraction (B). Soil around earthworms (red circle) was collected and the environmental DNA from soil was extracted before PCR and sequencing (C)

behaviour of earthworms," says Roger. "In particular, we need to quantify the uncertainties associated with each of the two approaches (DNA sampling and physical counting)."

Factors now being studied include the stability of DNA in fresh soils, earthworm behaviour after heavy rain compared with when soil is dry, and the accuracy of taking spade-square samples in a paddock for assessing worm populations. Several hundred samples will be taken to better understand those issues.

Roger says good progress was made in the Our Land and Water project, but not yet good enough for a reliable test that can be offered to farmers commercially, as was hoped.

"Because we do many thousands of samples a year for fertility testing, we would like to be able to do this test on the same soil sample as it has already been collected, dried and ground for the other tests. If it's just a tick box to say, 'I'd also like also an earthworm assessment', from a commercial point of view, that's very convenient for everybody."

What the uptake of such a test would be among farmers is difficult to estimate, Roger says, although he expects those interested in the biological health of their soils are likely to be very interested.

"With something like phosphate availability, a soil test may show it's very low, and if you put phosphate on you can expect a significant improvement in production. This new test won't be quite like that, it's more to provide insight about earthworm activity in the soil."

Roger believes that with our overseas clients showing increasing interest in whether their food is produced in a sustainable manner, there could also be marketing advantage for Aotearoa.

"To be able to say to our overseas customers that we are monitoring the soil's biological health with regular testing for earthworm activity, I think it could be useful as a marketing ploy, especially in terms of selling our produce at the top end of the market."

Tony Benny for the Our Land and Water National Science Challenge

Adapting land for a climate-changed future

Farmers are keen to understand the changing climate at a granular, local level and initiated this project looking at adaptation in mid-Canterbury. Farmers said it makes good business sense to understand what is coming so they can futureproof their business.

Richard Fitzgerald knows that weather and the climate are topics close to every farmer's heart. A farmer himself with an active involvement in an intensive irrigated mid-Canterbury-based family farm, Richard is living proof that a deep understanding of the changing climate is fundamental to successful farming. His experience as an agribusiness executive and consultant, and as a past CEO of NZ Young Farmers and the Red Meat Profit Partnership, means he has first-hand experience of farmers basing critical business decisions on many years of observing and experiencing the local climate.

Alongside his farm work, Richard is currently the Agriculture Portfolio Advisor at the Ashburton District Council. Here he has been working on a project with funding from Our Land and Water's Rural Professionals Fund looking at how the changing climate can be included in farmers' decisions about their business lifecycle, on-farm infrastructure and consent conditions.

Richard and researchers from The Agribusiness Group considered a range of factors, such as the breadth of climate change work currently available, which organisations are involved, and the decision tools available for farmers to use. The purpose of the review was to identify gaps in climate change information and understand if there are barriers that could be addressed to enhance engagement with farmers.

The researchers also gathered data from the Ashburton District Council and Environment Canterbury records, and used this to analyse the economic life of key assets, such as dairy sheds and irrigation consents. This enabled understanding of the timing of major strategic decisions affecting land use.

The project then ran several focus groups in the Ashburton District to gather farmer perspectives on climate change and explore themes identified in the desktop review. The focus group composition considered farming type (dairying, arable, sheep and beef farming), business career stage (early, mid- and late-career), and the location of their farm businesses (lower-, mid-, upper-plains and high country). Each focus group was facilitated by a respected local farmer.

Farmers need tailored information

The key finding of the research was that farmers already adapt naturally to changes in the system and are willing to change further once they have a sound reason. Climate information needs to be practical and tailored to farm type and location for farmers to make financial decisions with good environmental outcomes. This was well expressed by a dairy farmer from a focus group:

> *I think we've changed; I mean as technology and science have changed in the farms. We put in water monitoring. It wasn't because of climate change; it was just because our water was reasonably pricey. So, we wanted to make sure that we make good use of it. ... I don't know if we've necessarily been doing it for climate change, but it will help if it becomes more noticeable.*

The project found that if farmers better understand the severity, duration and probability of extreme events on their own farm in a climate-changed future, they are better equipped to adapt their farming systems. The research found a willingness to change once their own situation becomes clear. As one livestock farmer said:

> *... if the humidity goes up and the cows are hotter ... they're going to struggle with heat and drink more water. They might drop in production. You're gonna have to think about your decision-making and how you*

Supporting land-use adaptation for a climate-changed future

Why: To improve farmers' knowledge of a changing climate and enhance their ability to apply that knowledge to action on-farm.

Where: Ashburton (represented by 12 dairy farmers, six arable farmers, five livestock farmers and four agri-industry representatives).

Who: Richard Fitzgerald (Ashburton District Council), Andrew Parrish (ECan), Angela Cushnie (Kānuka Canterbury Regeneration Trust), Hamish Marr (farmer), Kerry Harmer (farmer), Louise Webster (Ideas Accelerator), Matt Bently (farmer), Mel Brooks (MHV Water), Nick Giera (farmer), Rebecca Whillans (Ashburton Lyndhurst Irrigation), Richard Bowman (Barrhill Chertsey Irrigation), Steven Bierema (farmer), Tony Finch (DairyNZ), Treena Davidson (Aoraki Environmental Consultancy) and Turi McFarlane (FAR).

What:

- Existing climate change research was reviewed 'through the eyes of a farmer' by farm business consultants, The Agribusiness Group. The review identified several points to improve farmer engagement and encourage response to a changing climate.
- Meaningful climate information at a granular 5 km x 5 km resolution would give farmers confidence to make change that would improve their farm's circumstances.
- Effective, trusted channels giving practical, evidence-based information can have a significant impact on farmers' decision-making.
- Critical farm infrastructure, access to water and consent conditions strongly influence land use. The timing of large infrastructure consents, such as replacing dairy milking sheds, may drive land-use decisions.
- This project is part of Ashburton District Council's work on economic development, supporting strong and healthy businesses and the four wellbeings of local government. The project forms the early investigative stages of a wider piece of work called the Resilient Business programme.

Read more: *Supporting land-use adaptation to climate change*: ourlandandwater.nz/RPF2022

make things work. You're probably going to have to change your system, and it's a case of what are the sorts of things you might have to change.

The researchers found that farmers were cautious about some scientific research. One farmer discussed recent scientific findings where they were told that there would be increased winter biomass production, which could enable higher stocking rates and greater livestock production over winter. At the same time, it suggested that summer pasture growth would become less reliable, suggesting stocking rates should be reduced in summer. The farmer decided that a reasonable response was to wait for greater clarity or observable climate change effects on his pasture production before implementing systems change. One arable farmer said:

We need research that's relevant ... that you can actually do. I want to go home from a field day and say, I can do that. I can do that tomorrow. What I see coming out, it's a lot of big pictures and it's not something that I can change.

Action in response to a changing climate will range from refinements to the farm system to broad-scale land-use change, also known as climate change adaptation. As one dairy farmer commented:

How much can we improve the genetics of our herd, dropping our stocking rates to 3.3 cows per hectare and still be as profitable? And that's kind of low-hanging fruit. I see that resource efficiency gain with what seems to be a win-win for the environment and the bottom line.

Adaptation at a farm level must be driven by farmers as farmers are best placed to respond practically to a changing climate. As with most businesses, farm system change and adaptation will require a positive return on investment and economic profitability for it to be a considered option. As a livestock farmer said to their focus group:

We think that climate change is pushing the limits of what we can do [in our farming operation], we're going to need to make more investments to cope with the extreme events we are experiencing.

The research also found that, when looking at implementation of adaptation practices, farmers' kinaesthetic learning style should be acknowledged. As one dairy farmer said, touching and doing is an important enabler for learning and building confidence:

In order to adopt new technology or new farming systems, you need to see credible examples like demonstration farms.

Cows on a Canterbury farm with flooding. Source: Kathryn Taylor/TrueStock

Infrastructure costs and consents

Ashburton District, or mid-Canterbury in the central South Island, is traditionally a sheep and grain-growing district. However, over the past 20 years irrigation has changed the land use. Irrigated farming now covers approximately 65% of the Ashburton District Plains, or 220,000 ha. The plains between the Rakaia and Rangitata Rivers and the hill country swelling into the Southern Alps have seen a shift to dairy farming and specialised crops, such as seeds. Dairy farming now accounts for $1.13 billion of the local economy and 63% of net farm income for the district.

After examining resource consents, the researchers found that around 40% of all dairy milking sheds in the district were built between 2007 and 2015. Using the IRD calculation of a 33.3-year economic life for a dairy shed, those 230 sheds will reach the end of their economic life between 2040 and 2048, meaning nearly half of all dairy sheds may or may not be replaced during that period. These sheds represent a large proportion of dairy farming in the district.

The research indicated that, before replacing any major infrastructure, dairy farmers will assess the merits of dairy farming compared to alternative land uses. Replacing an aging dairy shed is a significant capital investment, and a decision whether to replace a milking shed will be carefully considered in the light of climate suitability, regulations and the prevailing economics of dairying compared to other land uses.

The researchers found that between 2030 and 2040, 78% of all water use consents in the district will expire. However, the area of land involved in this process will be even greater, as the water consents of all three irrigation companies will fall due (**Figure 1**). The renewal process is significant because the implementation of the National Policy Statement for Fresh Water Management (2020) may introduce new or different consent conditions for water use. This may change the viability or feasibility of some land uses under those new conditions, especially if the fortunes of dairy farming do not compare as favourably as other land-use options.

The water use consent renewal process is currently underway. An analysis of the location and number of consents shown in the map indicates clusters of consents, particularly near the Ashburton and Hinds Rivers.

The research found the convergence of water use consent renewals and dairy shed renewals may be a catalyst for land-use change around the early 2040s. However, these thoughts didn't appear to faze the farmers in the focus groups. They emphasised that they are business people first, and that business logic drives their land-use decisions. They would change in response to new or different opportunities if they make good business sense. As one dairy farmer reported:

> *Market signals have been the strength to date, for driving land-use change in Canterbury. We only go to*

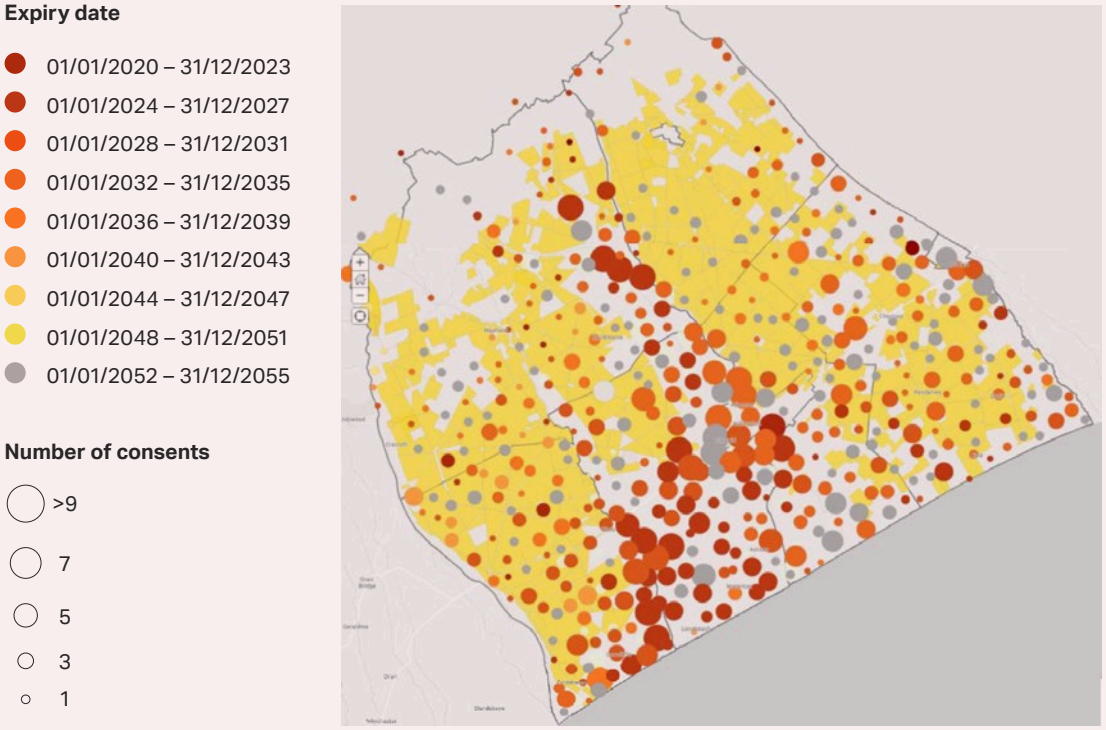


Figure 1: The distribution and timeliness of water use consent renewal in the Ashburton District

where the profits are, and if the profit is in dairy we will go there. Something else and we will go there as well. [Dairy farming] has been our biggest strength today, but that may not be the case in 5, 10, 15, 20 years' time. Effectively, we're going where the market is.

The project also examined Ashburton District Council consent records for both arable farming and sheep and beef farming to identify equivalent critical infrastructure, such as grain drying facilities and shearing sheds. Only a small number of building consents have been issued for those structures, and the data set was considered too small to make a credible judgment about infrastructure renewal as it might influence land use.

Where to next?

From small tweaks to existing practices, to wholesale land-use change, climate adaptation spans a wide variety of action. Determining what land-use response is appropriate ultimately rests with farmers. They need to be supported with quality research and science to make timely, well-informed decisions.

The next step in the Resilient Business Project is to produce a user-friendly report that demonstrates the emergence of new potential growing conditions that will support alternative land uses or highlight how the future climate will impact some current land uses. This will lead into a land-use options analysis report that explores a range of factors such as agronomy, regulations, value chain and market returns. A matrix will identify the contribution of different land uses to meeting environmental requirements and signal potential unintended consequences with different land uses.

The research will then offer farmers the opportunity to explore diversification, new or alternative land-use options for their businesses in response to the changing climate.

Ashburton District Council's Chief Executive, Hamish Riach, says that by working together supported by industry and the scientific community, farmers can understand what the climate future will look like and what to do about it. "If we give farmers research they can take home and use straight away, rather than high-level theory, then they will minimise risk and utilise the opportunities emerging through a changing climate," he says.

Ceridwyn Roberts for the Our Land and Water National Science Challenge

Next generation key to future of whenua

Futureproofing Māori Land Trusts

Why: To develop an implementation plan for two Māori Land Trust case studies that will bridge the gap between aspirations for the future of the land blocks and the next generation of shareholders.

Where: Two Māori Land Trust-owned sheep and beef farms in Otago.

Who: Ray Mohan and Rhys Millar (Ahikā Consulting), Stephen Owens (Akapatiki A Block Incorporated), Nicola Taylor (Pūrākaunui Block Incorporation), Joy Smith (Ngāi Tahu Māori Law Centre), Haines Ellison (MPI Māori Agribusiness) and Paul Hansen (University of Otago).

What:

- Both blocks run by the Māori Land Trusts in this project are currently farmed as sheep and beef operations, and the respective management komiti are exploring opportunities to diversify land use in alignment with their goals around restoration of the whenua.
- Earlier research into land-use opportunities highlighted the ongoing difficulties in connecting with and engaging younger generations of shareholders. This needs to be addressed to allow for succession planning and the transfer of knowledge between different generations.
- A preliminary survey of shareholders was completed to understand the barriers to visiting the whenua, as well as the preferred method of engagement for whānau.
- A second survey will engage with shareholders and rangatahi to hear their perspectives and thoughts on a range of topics relating to proposed land-use opportunities.

Read more: *Futureproofing Māori Land Trusts*: ourlandandwater.nz/RPF2022

Case studies of two Māori Land Trusts aim to identify a pathway that will engage a new generation of kaitiaki to protect historically and culturally significant sites.

About 30 minutes north of Dunedin lies Pūrākaunui, a small settlement centred around a beautiful tidal inlet. It is an area with rich cultural and historical significance, and it is home to a block of land owned by a Māori land incorporation. Like many such blocks throughout Aotearoa, the shareholders are grappling with the complications of ensuring the futureproofing of the whenua.

A small section of pine forest, an area of leased farmland, and a big chunk of native bush and wetlands make up the 208 ha block of land owned by Pūrākaunui Block Incorporation. A newly signed covenant with the Department of Conservation, Ngā Whenua Rāhui, will provide resources to plant indigenous species and regenerate the land.

Nicola Taylor, chair of the management komiti for Pūrākaunui Block Incorporation, says the multi-generational dynamics and complex ownership structures of such entities are complicating the development and implementation of land-use plans.

"We have a komiti of six people and about 90 shareholders on our register. Of that number, only about 30 are active in terms of attending annual meetings or responding to mail," Nicola says. "Last year we received funding from MPI to create a development plan for the block, and we kept coming back to the issue of succession. We realised that this topic was actually the most important of all the things we're grappling with."

Nicola says the most active shareholders are those who feel a strong connection to the land, whether that's through their own memories of weekends and holidays spent on the block, or through stories passed down over generations. These shareholders

The tidal inlet of Pūrākaunui, north of Dunedin, is home to land owned by Pūrākaunui Block Incorporation. Photo: Tony Palmer

History of the land

The 208 ha Pūrākaunui block was created out of land set aside for Māori following Walter Mantell's 1848 survey.

"When Walter Mantell came to Pūrākaunui, he recorded about 45 individuals living in the district. In 1868, the reserves were allocated and that tiny handful of whānau were the original trustees or beneficiaries," Nicola explains. "Wind forward to 1967, and the passing of a piece of legislation called the Māori Affairs Amendment Act."

The Māori Affairs Amendment Act 1967 introduced compulsory conversion of Māori freehold land with four or fewer owners into general ownership, resulting in further alienation of Māori from their land.

To keep the land block intact and in Māori ownership, the late John McLachlan – a descendant of one of the original beneficiaries – had the foresight to form Pūrākaunui Block Incorporation in 1973. Since then, the management komiti has been tasked with the stewardship of the land, balancing its economic potential against aspirations around preservation of its history and environmental restoration.

have a clear vision for the future of the land and readily volunteer their time to support its ongoing management. The goal is to foster a similar sense of connection across the entire group of current and future shareholders in the hope of fostering a new generation of kaitiaki.

Pūrākaunui Block Incorporation is one of two case studies in *Futureproofing Māori Land Trusts*, a research project led by Ahikā Consulting with funding from Our Land and Water's Rural Professionals Fund. The second case study is Akapatiki A Block, another Māori land incorporation that owns a block on Otago Peninsula near Portobello.

Project lead Ray Mohan (Ahikā Consulting) says that she hopes to leave each management komiti with a pathway forward to engage with the next generation of shareholders.

"When we first started working with these komiti our focus was on land-use opportunities that align with their values – things like carbon credits from native bush restoration or kōura farming," says Ray. "We put together all the reports and the glossy maps and they came back to us and said, 'Look, it's nice to have maps, but who's going to do this mahi?'

"This project is an opportunity to bridge the gap between the identified whenua opportunities and implementing them by identifying the roles and responsibilities involved."

The similarities between the two case studies are likely to be shared by Māori land trusts and incorporations across Aotearoa.

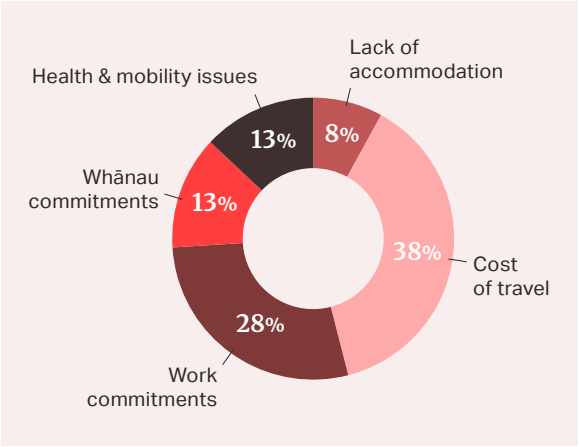


Figure 1: Barriers to visiting whenua

Diversification for future generations

Both blocks are situated in unique coastal environments and have ancestral significance. They are both currently farmed as sheep and beef operations, and the respective komiti are eager to diversify land use in keeping with aspirations around restoration of the whenua for future generations, sustainable ventures that enhance and protect te Taiao, and ensuring cultural and social benefits for shareholders.

Perhaps most significantly, the management komiti for each block is largely comprised of whānau members in their sixties and older, who are searching for potential successors and the opportunity to share their knowledge.

The similarities between the two case studies are likely to be shared by Māori land trusts and incorporations across Aotearoa, and Ahikā Consulting intends to address this by consolidating their research into a template that can be implemented by other groups.

The first stage of the project has been completed – a survey that sought to understand the main barriers that whānau face when it comes to spending time on the whenua (**Figure 1**). This information will play a key role in developing the workplan and making recommendations to the komiti about how they can foster a greater connection.

This survey also identified that the preferred methods of communication were email and in-person, which will influence recommendations about ongoing engagement to generate the highest uptake amongst whānau.

The project is ongoing

This research is not yet complete. "You can't rush things when you're working with big whānau groups," Ray says.

The first consideration was how to navigate the complex and layered family dynamics of each incorporation. "It's not a commercial venture where it just comes down to the profit margin of one option over another. All the whānau dynamics come to the surface and our role is to help them find a common thread without telling them what to do," she says.

Three outputs are planned for the project – a template for wider use by Māori land trusts, a tailored workplan for each komiti, and capturing stories from the current members and active shareholders.

The workplans will identify the preferred land-use option based on the preferences identified as part of this research, and recommend steps to foster a greater connection to the whenua amongst shareholders. These steps may include creating access to the land via walkways and shared spaces, as well as communication tools to share stories of the land, past and present.

Ahikā Consulting is now working with both komiti to develop a second survey that will engage with current and future shareholders to hear their perspectives on the proposed land-use opportunities for each block.

"We are using the 1000minds platform to deliver this survey, which essentially will ask whānau their preference between a number of options." Ray explains. "Each option is based on weighted criteria and will give us an understanding of the biggest drivers for whānau."

As the project continues, the team from Ahikā Consulting are working closely with management komiti to support widespread uptake of the survey across the shareholder group.

"We want everyone to have the opportunity to share their perspectives on what futureproofing looks like, and to make sure that we're capturing the viewpoint of the entire group," Ray says. "Navigating the occasional conflict is worth it because it shows that shareholders are really passionate and do really care about their whenua."

Anna Brankin for the Our Land and Water National Science Challenge

Sensors increase understanding and interest

Improving water quality outcomes through real-time water quality monitoring

Why: To use real-time water quality monitoring to show the impact farm management can have on freshwater quality.

Where: Dairy farm bordering Opihi River near Fairlie, Canterbury.

Who: Charlotte Senior (The AgriBusiness Group), John and Sarah Wright (dairy farmers), Nicole Holliday (Ballance Agri-Nutrients) and Dr Blair Miller (Lincoln Agritech).

What:

- Three HydroMetrics GW50PC nitrate sensors installed on a Fairlie farm showed real-time nitrate levels in groundwater as it passed through the farm, capturing nitrate spikes.
- Real-time sensors require an initial investment, but provide rich and consistent data (8,760 hourly readings p.a.).
- The likelihood of nitrogen (N) spikes is dependent on rainfall events. The higher N concentrations over winter surprised the farmer, highlighting that other farmers may learn from this.
- The upper and lower sites were correlated, and demonstrated that N concentrations in groundwater flow could be detected coming from the top to the bottom of the farm.
- There are increasing variations in climate from season-to-season, making it difficult to determine 'typical' results.

Read more: *Real-time water quality monitoring*: ourlandandwater.nz/RPF2022

Real-time nitrate sensors increased farmer understanding of contaminant pathways through their farm and the impact of rainfall events, and grew community interest in water quality improvement.

John and Sarah Wright's farm is in one of the most beautiful areas in the country. And despite being close to the wilderness areas of the Southern Alps and the beautiful mountain lakes, water quality is a problem in their wider catchment.

The Opihi River has its origins in the Sherwood and Ben McLeod Mountain ranges and wends its way through the patchwork of farms and forestry. At the town of Fairlie it swings gently with its arm cradling John and Sarah's farm, Wainono Dairy, before it plunges through the Opihi Gorge.

The farm sits at the southern end of the Fairlie Basin, which has been identified as a High Nitrogen Concentration Zone by Environment Canterbury, with reductions in N leaching losses from farmland required to reduce nitrate concentrations in groundwater. Groundwater running under the farm comes from within the basin and empties into the gorge. This means John and Sarah's operation isn't solely responsible for all the nitrates in this water.

John has been testing the water quality on the farm quarterly for nearly 10 years, taking water samples every three months and sending them off for testing. Despite having lots of data, he knew that wouldn't catch the immediate after-effects on nitrate levels from sudden weather events or irrigation using this infrequent method.

Charlotte Senior of The AgriBusiness Group with a nitrate sensor

With tighter regulations around nitrates and groundwater more likely in future, John wanted to create a robust set of baseline data now, to make it easier to supply the kind of data that will be needed for compliance purposes later.

"If there are any issues identified coming from the Upper Opihi, John doesn't want the finger getting pointed at him," says agricultural consultant Charlotte Senior. "Data from this project will help understand the farm's impact on the catchment and whether efforts to improve freshwater are on the right track."

When Charlotte first posed the idea of real-time sensors at a catchment meeting about 10 farmers put their hands up to trial them. "There's a lot of interest," she says.

Charlotte and John applied for funding through the Our Land and Water National Science Challenge Rural Professional Fund. The project ran from October 2021 for a year.

Setting up the sensors

Because the farm has a shallow impervious layer of mudstone lying beneath the surface, water does not drain from the upper unconfined aquifer. Rather, it flows quickly over the top of the pan and under the topsoil.

Three HydroMetrics GW50PC nitrate sensors developed by Hydrometrics, a division of Lincoln Agritech, were installed along the direction of groundwater flow. One at the top of the farm – marked O'Neils – was in a pumped gallery and an indicator of what was going on in the catchment above the farm.

The Novaflow sensor was at the bottom of the farm in a Novaflow pipe where water exited just before the Opihi Gorge. The sensors would measure nitrate-N concentrations hourly, with data uploaded to a data portal hosted by Hydrometrics.

Once it was all up and running, they found it took about two days for N spikes caught by the sensors at the top of the farm to show up at the bottom end. The two sensors were leased for the project while John bought another one – not a small undertaking at nearly $10,000 each.

John's sensor – Paddock 2 – was also a deeper sensor in a pumped gallery just above the mudstone in the middle of the farm, on the theoretical flow path between the top and bottom sensors. But it seemed to pick up other N sources periodically, and may have had a more localised response influenced by a cropping paddock close by that was growing kale during the project.

Although the kale crop represented only 6% of the total farm area, OverseerFM modelling estimated it was responsible for 12% of the farm's total N losses. The fodderbeet crop, on the other hand, had negligible N loss. Fodderbeet has lower crude protein concentrations, reducing dietary and urine N concentrations, points out Charlotte.

Results

"It was clear drainage from big rainfall events was the main driver behind nitrogen losses," says Charlotte, "with the nitrogen originating from urine patches."

N fertiliser inputs were relatively low for a Canterbury dairy farm. In the 2021-2022 season, an average of 144 kg N/ha/yr was applied on paddocks.

"John has good fertiliser management practices," Charlotte says, "putting it on little and often, not applying when the soil moisture is high, and ensuring

Figure 1: Extract from Appendix 3 – Nitrate results from the 3 sites (mg/L), daily rainfall (mm) and irrigation events (on/off)

soil temperature is high enough to be sure of plant uptake. We couldn't see those fertiliser applications in the data." This would be expected because fertliser is taken up by pasture, eaten by cattle, and the N leached from urine patches that have an N excess.

Generally, the Novaflow bottom sensor saw sharp increases in N concentrations following significant rainfall events. The sensor was close to the surface and quickly picking up changes and increases to drainage and shallow groundwater. As might be expected, given the different type of installation, this saw the site with the highest average monthly N concentrations for most months.

Mid-July saw the first big rain event since the project started with a 36 mm downpour. The Novaflow sensor had the first response, while the upper site and middle site were delayed by five and nine hours, respectively (**Figure 1**).

After the three biggest big downpours during the project, which all happened in July, the impacts of the catchment above the farm draining through it were clear. The O'Neil sensor at the top of the farm continues to show rising nitrate levels, while the middle site seems to have peaked and is on the decline. The Novaflow is still elevated.

"As John has been transparent about his data, the community response and from other farmers has been very good," Charlotte says, "We have observed a high level of interest in the health of the waterways.

"It's been good for them to be able to see the results of rain events," she says. "We had a wet summer and it was clear from the data – it gave people confidence in what they were seeing."

Since the project got underway, Opuha Water, the farmer co-operative operating the irrigation scheme, has started doing free water testing for nitrates for local farmers in the area. The catchment has high irrigation use and this will give the co-operative a better understanding of what is happening there.

With the project at an end, Charlotte is looking at keeping all the sensors operating for a time. "The data is too good to waste," she says. "It has also revitalised interest in the catchment for the people who live there."

A community-driven water quality monitoring and management programme would be a powerful tool to improve the reach of monitoring programmes, concludes the project's report. Despite strong collaboration among the host farmers, scientists, rural professionals, the irrigation scheme and local catchment groups, there is only so much good one farmer can do alone. Leveraging these networks to conduct large-scale water quality monitoring across the catchment could open a huge opportunity for learning.

Delwyn Dickey for the Our Land and Water National Science Challenge

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