New Ground

INNOVATIVE IDEAS TESTED ON-FARM BY RURAL PROFESSIONALS FUND PROJECTS 2022–23

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OUR LAND AND WATER

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New Ground

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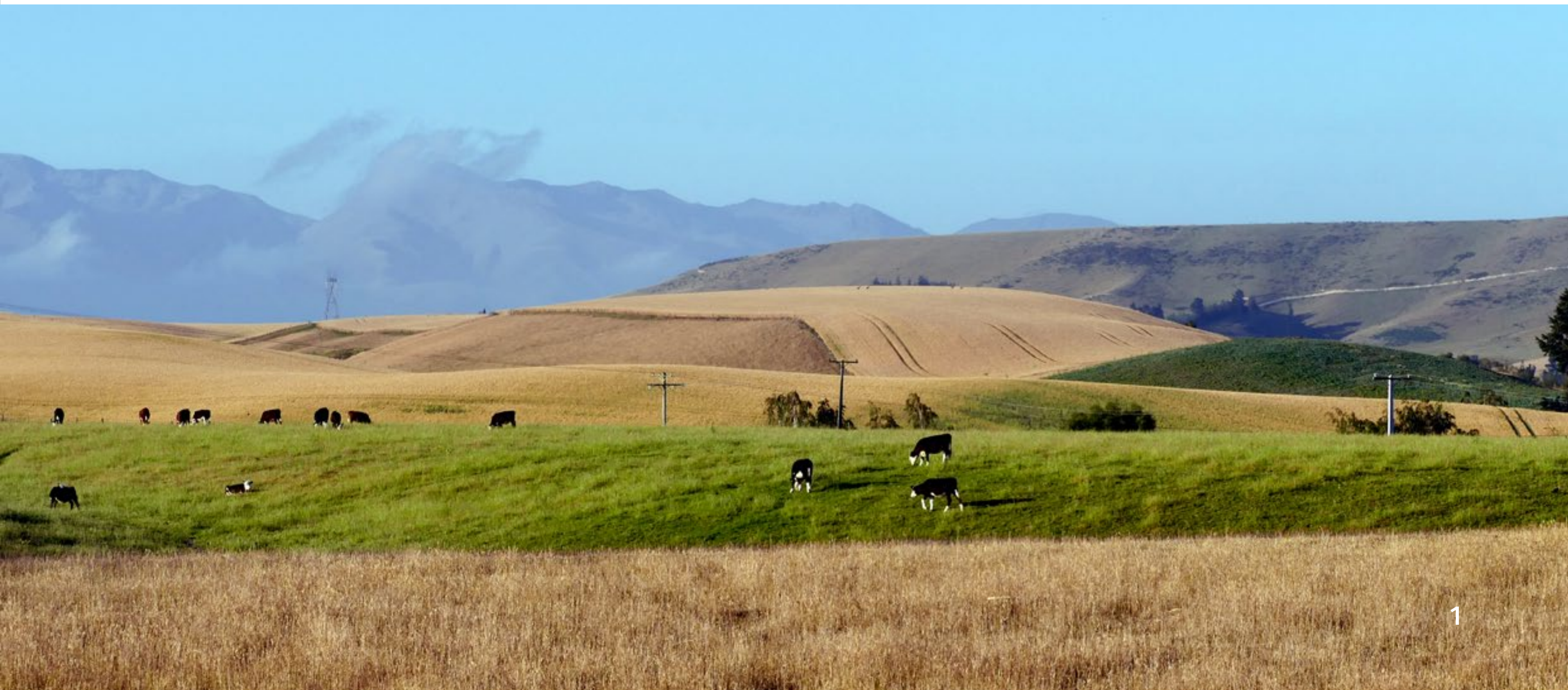


Investigate your ideas

Professor Rich McDowell

This third annual edition of *New Ground* outlines the findings of projects completed in the third iteration of the Rural Professionals Fund. As I write, the projects in the fourth and final fund are also nearing completion. It is therefore timely that I offer a few reflections about the Fund's aims and achievements.

The Rural Professionals Fund was established to provide rural professionals with the opportunity to test the ideas they have come across in their day-to-day business, interacting with farmers and foresters. Although the funding for each project was modest ($50,000-75,000), it was enough to test if the idea was good or not. Combined with a six – to nine-month duration, this is a 'fast fail' fund.

One of the interesting requirements of the Fund was that folk report results in reputable journals, including this one, and report failures. This is an anomaly in most reporting of science but is often just as important as a positive result. Often it is met with reticence.

The modern expression of science dates back to the time of Francis Bacon in the 16th century, and the binary decision that something was true or not. More recently, this has been formalised as statistical significance (relative to a distribution that says 'yeah that's right', or not). 'Significance' is important. We set laws based on it. Moreover, you'll provide advice that, except in rare cases, you will be right.

Often, science will not produce what you expect. This is a good thing. As a nation of innovators, we need to try things and, as a result, have succeeded in making ourselves different from our competitors. I'm proud of both the successes and 'failures' of the Rural Professionals Fund projects (and we've had more successes than failures).

You might be expecting a list of each ... well, I won't disappoint:

- The convergence of water use consent renewals and dairy shed renewals may be a catalyst for land use change in mid-Canterbury around the early 2040s.
- Bananas grow well in Northland (especially when supplied with effluent) and could provide a material source of summer forage.

- A web-based freshwater farm plan is now used by hundreds of dairy farmers (and is being looked at by other sectors for use).

You could argue that these successes were tempered by:

- Regenerative agriculture didn't result in major differences in the concentration of healthy fatty acids in beef.
- There wasn't a relationship between soil fertility and avocado quality.

In essence, I confess, the Rural Professionals Fund was to get you to think about your ideas, robustly test them, and most important of all – investigate.

I hope you find this issue of *New Ground* to be good fodder for thought. The final edition, sharing the 10 projects soon to finish, will be with you in winter 2024.

Professor Rich McDowell is Chief Scientist, Our Land and Water

Ground-cover plants could replace herbicides in orchards

Establishing perennial ground-cover species, as a management practice to suppress weeds in a pipfruit orchard's 'weed spray strip'.

Why: To test whether low-growing, perennial plants can be established as a ground cover in pipfruit orchards, as a replacement for a traditional 'weed spray strip'.

Where: On a mature 2D Breeze (Royal Gala strain) orchard in the Brightwater region of Nelson. The block is on M9 rootstock at an intensive planting of 2.5 m x 1.4 m.

Who: Aimee Lister and Craig Hornblow (AgFirst), Rob Holtham (Willisbrook Orchard), Anna Lambourne and Jake Tully (NZ Apples & Pears), and Rebecca Campbell (Plant & Food Research).

What:

- We can establish spring-sown perennial ground-cover species in a 2D apple orchard's weed spray strip. The ability of the species to 'cover ground' depended strongly on how well the species was sown and its individual growth habit.
- Sheep's burnett and plantain were the most successful, with the least weed species present at the end of the trial and good ground cover.
- The biggest hurdle was the ability to source specialised machinery for cultivating and sowing under/next to a canopy.

More:

ourlandandwater.nz/outputs/ground-cover-orchard-report

ourlandandwater.nz/outputs/ground-cover-orchard-case-study

Low-growing perennial plants grew well beneath the canopy in a Nelson pipfruit orchard in a trial designed to test whether ground-cover species could help reduce spray use without adversely affecting fruit production or tree health.

Growing ground-cover plants under the canopy in pipfruit orchards as an alternative to spraying with herbicide is a practical option, according to a trial conducted in a Nelson orchard.

Seven low-growing perennial species were established in the weed spray strip to determine their ability to establish and thrive in this area of low light, with poor structured bare soil. Soil testing showed signs of long-term herbicide use: low organic matter, low soil biology, low abundance of favourable soil organisms, and a high abundance of weeds.

"In the pipfruit industry there's a big drive towards spray-free targets. Our small trial is tied in with that, but also it's trying to find a practical management practice that a grower can adopt or trial for themselves," says researcher Aimee Lister of AgFirst. "Rather than just cutting sprays out, we tried an alternative to see what happened."

Bird's foot trefoil, narrow-leaved plantain, common yarrow, chicory, alyssum, sheep's burnett and strawberry clover were sown in spring. All but one of those species (alyssum) established well, covering the ground to various degrees, and competing with or shading out weed species.

"It's all about choosing the species right for the situation, so if you needed to mow something to keep it lower, then you would choose something you know

Spring-sown row on the right, autumn-sown row on the left (pre-sowing). Image taken in April 2023

would bounce back. With chicory, for example, if you cut leaves off, it would probably die back, so you'd choose something else that could come away again," Lister says.

Three aspects to trial

The trial had three aims: to determine the practicality and efficacy of this as a management practice, to understand any effect these plants may have on tree health and crop quality, and to understand what effect these perennial cover species may have on soil health and biology.

The trial was established on a mature 2D Breeze (Royal Gala strain) orchard in the Brightwater region of Nelson. Funding was provided by Our Land and Water's Rural Professionals Fund.

To ensure good seed-to-soil contact at sowing, the soil was first cultivated. The trial aimed to cultivate close to the tree trunks and far enough into the inter-row space that the entire weed spray strip would be covered without disturbing the permanent grass sward.

The trial included both spring and autumn sowing using a specialist piece of viticulture machinery and a row hucker that was rear-mounted on a tractor. Tilling to a depth of 8 cm during tree flowering, when the soil was warming up, was enough to establish a seed bed without damaging any tree roots that were close to the surface.

With no planting machinery available, each species was sown by hand at a heavier rate than would be standard practice to ensure good coverage (see **Table 1**).

"In a perfect world, you wouldn't be sowing the seed and covering it back up by hand obviously, it would be horrific. But if sowing ground-cover catches on, and those pieces of machinery are needed, somebody will make them," reckons Lister.

Irrigation in the form of sprinklers was set up for the spring sowing, in case of a dry season, but in this instance was only used twice during germination.

The autumn sowing was undertaken in a similar way to the spring sowing, except the trial plots weren't raked over. This resulted in less seed-to-soil contact, which is possibly why germination was much poorer than in spring.

Which species covered the ground best?

The spring-sown species all established well, although sheep's burnett was rated okay as opposed to good for the other plants. The trial team worked with Plant & Food Research and used a light meter placed on the orchard floor to understand the difference between each species' ability to cover the ground, and potentially reduce the level of light to the soil.

Measurements in February 2023 indicated that plantain was rated best at 70% light interception, sheep's burnett 65%, trefoil 60%, common yarrow 65% and chicory 70%. Alyssum grew well at first, but yellowed off in summer and rated only 20% for light interception.

Measurements were made again at the end of the trial. First equal were sheep's burnett and plantain, which had the least weed species present and covered the ground best, creating a low-growing ground floor 'canopy'. Sheep's burnett was assessed as having a better habit, staying closer to the ground rather than growing straight up as plantain did, potentially flowering in the pipfruit canopy.

Table 1: Spring sowing at the end of October with the soil warming up and rain forecast

Species	Sow rate	Seed weight
Plaintain	10g/m²	4,000 seeds/g
Sheep's burnett	16g/m²	140 seeds/g
Bird's foot trefoil	14g/m²	2,000 seeds/g
Common yarrow	14g/m²	1,700 seeds/g
Chicory	10g/m²	700 seeds/g
Strawberry clover	10g/m²	330 seeds/g
Alyssum	14g/m²	1,000 seeds/g

Chicory came second and covered the ground very well, but may have an issue over time as it will grow taller. Trefoil also covered the ground well, but its small leaves and wiry stems meant more light could get through its canopy. The researchers believe that this species may come away next spring and cover the ground better then.

Yarrow (with its very light seeds) was difficult to sow, but did cover the ground very well where the seed germinated well, its prostrate habit meaning it excluded most weeds. Where the seed was not so well spread, weeds persisted and grew through the trial species.

Clover suffered from rabbit damage with some being chewed off. The species did persist though, and where it formed a dense mat can suppress some weeds.

Alyssum germinated quickly and established well, but as the days became warmer and drier, the seedlings yellowed and by the end of the trial few plants had survived.

"I was happily surprised by the results," says Lister. "It was really pleasing having things work better than I expected. Depending on the species you choose, you could have a permanent crop under the trees, it's just choosing the right species and monitoring them over time."

A preliminary establishment guide is now being prepared for orchardists. "Hopefully that will be a really handy tool for growers," says Lister. She hopes the orchardist who participated in the trial will keep the plots in place and that trials can also be undertaken at different sites and different pipfruit situations.

Tony Benny for the Our Land and Water National Science Challenge

Sheep's burnett

Plantain

Green manure a viable alternative to artificial nitrogen

Effects of green manure crops on captured nitrogen and potato yields

Why: To quantify how much atmospheric nitrogen (N) spring green crops capture, how much biomass they produce, and the effect on potatoes grown in the lightly crop cultivated residue.

Where: Ferretti Growers, Brightwater, Nelson.

Who: Dominic Ferretti (Ferretti Growers) and Sjef Lamers (Sustainable Nutrition).

What:

- Using N fertiliser for vegetable production is subject to increasing costs and regulation, as well as contributing to environmental pollution.
- N fertiliser costs have doubled between 2020 and 2022 in New Zealand and are expected to keep increasing since they are derived from fossil fuels.
- Green crops can capture N in their biomass so offer an alternative N source. Biologically fixed N is renewable and less influenced by increasing production costs.
- Both legume only and mixed green crops were effective at capturing high amounts of N and subsequently improving yields in potato crops.
- Farmers can quickly build the required management experience from on-site green crop trials to maximise economic and environmental benefits.

More:

ourlandandwater.nz/outputs/green-crops-video

Green manure crops provided enough nitrogen to grow a bumper crop of top-quality potatoes, as well as improving the soil structure, in a trial designed to put some data around traditional horticulture practice.

Using green crops to provide the nitrogen (N) his organic vegetable crops need has been a huge success for Nelson market gardener Dominic Ferretti. A scientific trial just finished on his property has showed the practice will work well for any grower, organic or otherwise.

The research project by former scientist Ferretti and consultant Sjef Lamers showed green crops are an effective way to reduce N fertiliser bills while maintaining a high yield of quality potatoes.

Harvesting the N-fixing power of legumes is a traditional farming practice, but green crops have been replaced on some farms by nitrogen fertiliser such as urea. With the price of fertiliser now increasing sharply, green crops might prove more attractive for many farmers.

Ferretti turned to green crops to replace the mountains of compost he'd been making to replace N fertilisers.

"We were making compost on a big scale using sawdust and chicken manure, which does make great compost for growing vegetables, but there's a lot of labour and a lot of machinery and costs. I was getting really tired of it. Soil tests were showing we were getting too high in phosphorus, coming from the chicken manure, so we thought this imbalance isn't going to work long term."

His consultant, Lamers, talked him into trying green crops instead, sending him mountains of papers and articles from overseas to help convince him.

Market gardeners Dom Ferretti and wife Jeanette Ida in front of green crops they use to improve soil fertility for vegetable production

"We started using them and they seemed to work pretty well. After not too long, I thought, 'I'm going to give up making this compost and use green crops instead'. It didn't take too long to be quite impressed by the benefits," Ferretti says.

But while green crops were clearly working for him, Ferretti couldn't find any significant published New Zealand-based research about the traditional horticulture practice. He then realised his former occupation as a scientist made him the right person to do it.

"The papers that Sjef was sending me were all for Europe and North America. There was a whole lot of data, but it was hard to relate it to New Zealand. Some of the varieties they grow are different or the same thing with a different name, it's all in pounds per acre instead of kilos per hectare, and it's for growing corn and soya beans in America. It doesn't really make sense to the average Kiwi farmer."

Putting green crops to the test

Ferretti and Lamers designed a simple trial on the Brightwater property where two green crops were grown and a third plot was left bare as a control. The first crop was legume only (tic beans, *Vicia faba*) and the second a legume/grain mix (50:50 tic beans and black oats, *Avena strigosa*).

Each treatment was assigned a plot (48 m x 2.5 m) and replicated five times with a randomised arrangement.

"The legumes fix nitrogen out of the atmosphere. The oats, a grain, don't fix nitrogen but they're really good at mopping it up out of the soil, and they add more carbon but take longer to break down," says Ferretti.

After two months the captured biomass from the legume and mixed green crops were 9.7 t/ha and 9.9 t/ha, respectively. This input of about 10 tonnes of dry matter/ha is the equivalent of adding about 17 tonnes of compost/ha.

Captured N was 289 kg/ha for the legume green crop and 198 kg/ha for the mixed green crop. As the research findings note, measurements for the total captured N from the green crops are sufficiently high for the viability of many vegetable crops.

The crops were terminated at the onset of tic bean flowering. The start of flowering is the point when biomass is maximised before excessive conversion to carbon material. To speed decomposition, the biomass was reduced into smaller pieces by two passes with a slasher mower, then incorporated into the top 4 cm of soil with a rotary hoe cultivator.

A week later Agria potatoes were planted – a total of 185 kg of seed potatoes in 15 plots – and harvested 112 days later.

Table 1: Green crop dry matter (DM) biomass and captured N content (%N) for above ground (AG), below ground (BG) and totals. Differences between Legume and Mix are indicated by * for significance at the p<0.05 level and ** for significance at p<0.01. NS indicates differences are not significant

		DM (%)	DM (kg/ha)	%N	N (kg N/ha)	Total DM, AG+BG (kg/ha)	Total N, AG+BG (kg N/ha)
Legume	AG	11.2**	8,345, NS	3.2**	264**	9,673, NS	289*
	BG	13.3**	1,327*	1.9**	25**		
Mix	AG	13.1**	7,230, NS	2.3**	163**	9,904, NS	198*
	BG	20.4**	2,674*	1.4**	35**		

Potato yields were 33.5, 30.6 and 30 tonnes/ha from the legume, mixed and control treatments, respectively.

Potatoes were graded for quality. The legume treatment had the highest weight and number of marketable potatoes, as well as the largest mean tuber weight compared to the mixed and control treatments.

Throughout the nine-month trial soil tests were conducted, including the levels of the different forms of mineral N, as well as Olsen P, K, Ca, Mg, Na, total carbon and other elements.

The biomass of both the green crops and the potatoes was measured (see **Table 1**). "We had to cut the plants at ground level, weigh that material and then pull out the roots. We sent it all to Hill Laboratories where they carefully washed the roots, and analysed them and the tops for nitrogen content," says Ferretti.

"The overall results are enough to raise eyebrows," he says. "It was what we expected – the trial went well and we were very pleased."

Benefits for all farm systems

Ferretti says that it's not just organic vegetable growers who could benefit from the research. Any producer wanting to reduce their N fertiliser use should also take notice.

N fertiliser costs have doubled between 2020 and 2022 in New Zealand and are expected to keep increasing since they are derived from fossil fuels. Regulations for N use are increasing globally and freshwater farm plans will be required here by 2025 with associated implementation costs.

"We just wanted to get people talking and maybe get them to think, 'I might just try that down in the back paddock', or something. That's all we want people to do at this stage, because as soon as you try it you'll see the results and they'll speak for themselves – and it's a no-brainer from there."

It's not just organic vegetable growers who could benefit from the research. Any producer wanting to reduce their nitrogen fertiliser use should also take notice.

As well as effectively replacing artificial N, the research findings showed that the green crops observably improved soil structure. They can provide extensive benefits to soil and ecosystem health that can assist vegetable production, as well as vineyards and orchards.

Ferretti and Lamers have secured additional funding to produce a best practice guide for other growers, building on the knowledge gained in the trial.

"We actually found that we didn't need to do that much incorporating into the soil, mixing it in with a rotary hoe. It's actually best left on the surface as residues, a mulch, so that's even less fuel cost.

"I think Kiwi farmers are feeling the pressure. We've got heaps of regulations coming and I believe if we can just get the information to them to try this, even if just using a bit less synthetic nitrogen to begin with, that would be a huge success."

Tony Benny for the Our Land and Water National Science Challenge

Downsizing to upsize the local grain economy

Local grain economy

Why: To discuss whether small-scale regional milling could help arable farmers enter local food chains and give bakers more locally-grown and niche grain options.

Where: Bakers, arable growers and small-to-medium sized business owners with an interest in organic and regenerative practices, in multiple locations around the country.

Who: Angela Clifford (Eat New Zealand), Heidi McLeod (PhD candidate, Lincoln University), Hamish Glendinning and Simon White (Ludlow & Woodbrook Farms).

What:

- Wheat cleaning and milling infrastructure is required in both the North and South Islands to ensure food security. Whether this is on-farm or in-bakery is not significant. A regional overview of the number of on-farm mills is needed so farmers can work collectively, rather than in competition, ensuring viability.
- Interviews with regional businesses revealed beliefs that directly connecting with customers leads to initiatives that deliver positive environmental, social and cultural results.
- Bakers and farmers interviewed indicated that they often do not have good business information from millers to base decision-making on. Relationships and trust are variable along the supply chain.
- This research suggests that enabling producers to take responsibility for small-scale processing could help distribute more value to farmers and grow the local grain economy.

More: ourlandandwater.nz/outputs/local-grain-economy

About 70% of the wheat used for flour in baking in New Zealand is imported, then processed in a few large mills. High transport costs to move South Island-grown wheat to the North Island make it hard for our arable farmers to compete. Could smaller-scale regional milling be the answer?

Milling on-site has become part of OMGoodness Bakery and Mill's brand identity, and has enabled them to produce unique bakery goods such as New Zealand-grown buckwheat bread. Its bakeries in the Hawke's Bay and Auckland produce organic, gluten-free, dairy-free, refined sugar-free, paleo and vegan bread and bakery products.

Further south, a farming couple in Canterbury began growing buckwheat as part of their rotation and invested in an on-farm mill, Pure New Zealand Buckwheat. Two other local farmers have since come onboard, and as a collective they have significantly increased payments for their grain, making the 100-day crop a viable rotation in their mixed farm business.

Small-scale production like these examples was once the norm in Aotearoa New Zealand. Until 30 years ago New Zealand was self-sufficient in milling wheat, with most grown in arable farming areas on the Canterbury Plains.

Global context

Deregulation of the industry in 1987 eased import restrictions, which introduced competition between local growers and farmers growing on the vast plains in Australia, where most of our milling grain now comes from. It became cheaper to import Australian milling wheat through the ports of Auckland, Tauranga, Wellington and Christchurch to the

big processing mills close by than to buy locally grown grain.

Globally, flour for baking has become a commodity product and is largely fungible, regardless of where it is grown, and one batch of milling flour is much like another. This makes good sense for large-scale bakery operations, including supermarkets who want to be sure their recipes will produce goods (especially breads) that look the same, take the same amount of time to bake, and produce the same amount in each batch.

Angela Clifford, chief executive of Eat New Zealand, a group committed to connecting people to our land through our food, sees this as limiting our resilience in food production. "As long as we continue to fit in this commoditised space, we are open to the vagaries of the global market," she says.

Opportunities and issues

With funding from Our Land and Water's Rural Professionals Fund, Clifford and her team investigated current literature and industry practice, and interviewed bakers, growers and other regional business owners in the group's orbit about limitations and opportunities for arable farming of milling grains. They then put together an opinion piece on whether there was an appetite for smaller-scale milling of locally grown grain in the regions.

Most grain grown locally is used for animal feed, although there is room to also grow all our milling flour in this country, including by reducing livestock numbers and increasing on-farm diversity.

With most arable farming in the South Island, getting grain across Cook Strait to the mills near the bigger northern populations where most of the bakeries are is a serious issue, especially if you're growing a limited amount of specialist grain. With the large mills operating 24 hours a day, seven days a week, supplying supermarkets and other large bakery outlets, they don't have the capacity or ability to process small batches of grain. See **Figure 1** for a list of major commercial mills and smaller mills.

There are similar issues in the meat processing industry, where most processing is done in a few large-scale facilities, with much of the meat being exported. This has significant drawbacks for organic or heritage breed farmers who struggle to get their animals processed in smaller batches and want their meat returned.

Until 30 years ago New Zealand was self-sufficient in milling wheat.

Adding value with points of difference

The project sought insight from food producers in other sectors who are creating innovative ways to shorten supply chains to their customers. These small producers supply a niche market with product that has well-articulated points of difference, enabling them to seek competitive returns.

Food system innovator Glen Herud created milk processing and delivery company Happy Cow Milk to allow farmers to sell their milk in their communities. This involved designing new processes and equipment to meet the requirements of the Ministry for Primary Industries. Key selling points for the milk include its local production and animal welfare standards that keep calves with their mother.

Another innovator, fisher Nate Smith, created the Gravity Fishing 'pod' and app to connect fishers to customers for ordering and delivery, enabling fishers to process kai moana quickly and distribute it with certification and compliance handled through the app. A key point of difference for customers is the assurance that fishers use a hook and line, then kill the fish using the humane Japanese method ikijime.

For grain growers, country-of-origin labelling on food products is thought to be a selling point with the potential to add value to New Zealand-grown grain. Country-of-origin labelling is not required on bread, but a recent study by the Foundation for Arable Research found most people surveyed would prefer New Zealand-grown grain in bread. Half of those surveyed said they would pay around $0.55 more for a loaf with organic, environmental and health claims, while 35% would pay similar for a loaf with biodiversity and health claims.

A recent study by the Foundation for Arable Research found most people surveyed would prefer New Zealand-grown grain in bread.

Figure 1: Major commercial and independent flour mills in New Zealand

Mill at OMGoodness Bakery in Hawke's Bay. Photo: Heidi McLeod

The research team approached a baker in Auckland, Hawke's Bay, Wellington and Christchurch for their views. Comments from individual bakers indicated they were skeptical that people would pay more for New Zealand grains, and felt they were more interested in whether the bread or other products were baked in-store.

Quality and consistency of supply seem to be the biggest issues for the bakers who do use locally grown flour, with a need to shop around for suppliers. The higher cost of regionally sourced flour saw one baker blending with other New Zealand flours to keep costs down. One baker said after 10 years of trying to get hold of enough local organic flour regularly, they had now changed to regeneratively grown flour from Australia.

On-site milling appealed to some bakers, but it wasn't considered feasible for smaller high-rent premises, particularly in Auckland.

Benefits of locally grown grains

Small-scale arable farming close to big population centres would reduce transport costs and could give small-to-medium sized bakers the ability to request specific grains to help differentiate their businesses. The bakers reported increasing customer interest in organic and gluten-free grains.

Countrywide, this could see smaller cleaning and milling facilities set up regionally, possibly as part of an existing farm business where the costs of infrastructure could be more easily absorbed. Alternatively, they could be run as a co-operative on a member's farm, as with Pure New Zealand Buckwheat.

Another Canterbury arable and livestock farmer, Martin Spear, began trialling different grain crops after he became interested in 'ancient grains', and now mills them on-farm under the brand Minchins Milling.

Farmers Mill at Washdyke in Timaru, which opened its doors a decade ago as the first new mill in 25 years, is a larger-scale example. Unlike the bigger mills, Farmers Mill is grower-owned and operated and only mills New Zealand-grown grain. It gave local growers in South Canterbury the ability to mill their grain without prohibitive long-distance transport costs.

Along with smaller-scale milling, a push to raise awareness and the value of local flour is also needed, says Clifford. Farming practices (such as organically or regeneratively grown grains, if appropriate), and the type of milling (such as stone-milled), could also become part of a local flour's identity. Including locally produced grains in a food 'identity story' like that seen on wine labels or at farmers' markets would help convey their provenance. This could potentially encourage local bakers to pay more for them to produce authentically local goods.

With more emphasis on reducing livestock farming's emissions footprint, Clifford sees an opportunity for livestock farmers to diversify into lower emissions arable farming and, weather permitting, for arable farmers to contribute to local food chains rather than just to animal feed stocks. This would play a part in building a local food grain economy and making the country more resilient to overseas disruptions along the way.

"I want our farmers to imagine there is a different way – that there is a space to be small, and that this doesn't have to be all of their farming business," says Clifford.

Delwyn Dickey for the Our Land and Water National Science Challenge

Wheat shows promise in North Island

Spring milling wheat as a nitrogen scavenger in the North Island

Why: To investigate whether milling wheat can be profitably grown in the North Island to replace imported wheat, and how effectively the crop scavenges nitrogen (N) reserves in the soil, thereby reducing the risk of N leaching.

Where: On two properties in Ohakune and Wairarapa, and a virtual modelled Waikato dairy farm.

Who: Nick Pyke (Leftfield Innovation Ltd), Julie Lambie and Stuart Ford (The AgriBusiness Group) and Michaela Mcleod (Forages NZ).

What:

- Extreme rainfall throughout the growing season at both sites meant it was not a suitable season to investigate how effective spring-sown wheat was in scavenging N.
- In the Wairarapa, yield increased as applied N increased, or as N became available after GS32 (the growth stage where a second node is detectable), but was lower than forecast.
- A concurrent cultivar trial in the Wairarapa produced reasonable yields of milling wheat. Given the season's conditions the quality was very good, indicating milling wheat could be a valuable land use diversification.
- In Ohakune, yield increased as applied N increased, but was significantly lower than forecast and lower than in previous years. The soil N plus applied N was adequate.
- For Wairarapa and Ohakune, there was little difference in modelled N or phosphorus (P) loss between any of the treatments.
- For GHG emissions, there was a small increase in nitrous oxide and carbon dioxide emissions associated with fertiliser application.

More: ourlandandwater.nz/outputs/wheat-n-scavenger

Despite record-breaking rain, two North Island sites growing milling wheat showed good yields and quality could be achieved in a normal season, but it was not possible to investigate the effectiveness of spring-sown wheat in scavenging nitrogen.

"Growing milling wheat in the North Island, closer to New Zealand's major domestic markets, is a realistic option," says Wairarapa farmer Mick Williams, following a research trial on his property last summer.

"We were already growing a little bit of feed wheat, but the milling wheat ticks a few boxes in terms of feeding people rather than animals," he says.

"We obviously want the financial rewards too, and that's the idea of being involved in a project, to gather information that we can take to the consumer and say, 'This is why you should be using New Zealand wheat, particularly North Island wheat'."

The trial, conducted on two North Island farms, has shown there is potential to profitably grow milling wheat closer to major markets. This mitigates the prohibitive cost of shipping grain from the South Island, as well as showing that growing wheat can be an effective N mitigation technique.

Despite a summer of extreme rainfall that severely impacted yields and quality milling wheat, the researchers believe the cultivar field trials in Wairarapa and Ohakune showed growing wheat in a normal weather year could be a valid option.

While most New Zealand wheat is grown in the South Island, more of our population live in the North, and it's often cheaper to import wheat from Australia than ship it across Cook Strait.

"If we could grow enough high-quality milling wheat in the North Island, that would potentially reduce the reliance and reduce the risks associated with food security bringing wheat in from wherever in the world," says Nick Pyke of Leftfield Innovation, one of the research partners, along with The AgriBusiness Group and Forages NZ.

North Island farmers have other potentially more profitable options (for example, vegetables or fruit in Hawke's Bay), but Pyke sees a role for wheat too.

"The opportunity for wheat is that it can fit into a range of farm systems to utilise the N that is potentially available from the other farm system and reduce the risk of leaching. If it was fitted into a dairy farm system it could potentially reduce greenhouse gas emissions – but the issue is, is it viable?" he says.

The research team looked at regions that would normally have climatic conditions suited to growing wheat and identified Ohakune, in the rain shadow of the Kamai Range, and Wairarapa.

The trial's objectives at the two sites were to assess milling wheat cultivars for their grain yield and milling characteristics to determine whether wheat of milling quality can be produced in each region.

The cultivar field trials in Wairarapa and Ohakune showed growing wheat in a normal weather year could be a valid option.

The trial also aimed to understand N uptake from the soil by the wheat crop, by conducting deep soil N tests before sowing, after sowing, and after harvest, and applying N at different rates and timings.

On the Wairarapa site, Conquest wheat was direct drilled ex-rape and plantain for the N-replicated plot trial work. Another paddock was sown for cultivar evaluation.

At Ohakune, one large paddock was identified for the N-replicated plot trial work, and the cultivar evaluation was done in the remainder of the paddock. The paddock was ex-pasture and establishment was following minimum cultivation.

As well as the field trials, N and P loss and greenhouse gas losses were modelled using OverseerFM for four treatments:

1. Soil N only
2. Soil N + urea at planting (N to deliver 15 kg N/t wheat)
3. Soil N + urea at growth stage 32 (N to deliver 15 kg N/t wheat)
4. Soil N + urea at growth stage 32 (N to deliver 25 kg N/t wheat).

A Waikato dairy farm was modelled, based on a dairy unit in Morrinsville to represent a farm system in the area.

"We modelled with OverseerFM to ensure that the practices we were using in the field could be effectively modelled, and the field and modelled results were comparable," says Pyke.

For Wairarapa and Ohakune, there was no difference in modelled N or P loss between any of the treatments at either the block or whole farm level. In the Waikato, the highest modelled N loss was for a treatment with N applied at GS32 and the N was not used to generate yield (see **Table 1**).

For GHG emissions, there was a small increase in nitrous oxide and carbon dioxide emissions associated with fertiliser application.

Rain-impacted nitrogen tests

While the sites were chosen because they had the right climate to grow wheat, conditions were testing from the start of the trial. The 503 mm of rain in the Wairarapa during the growing season was 188 mm above the 10-year average, and the 954 mm of rain in Ohakune was 390 mm above the 20-year mean.

The unusually rainy season meant it was very difficult to interpret the nitrogen (N) results with any confidence. These weather conditions could have had three unplanned impacts on N use:

1. Reduced N uptake to grain due to lower yields than forecast.
2. Reduced N uptake after application at planting due to N leaching below the root zone of the developing plant.
3. Greater leaching and loss of more N from the lower profile.

Table 1: N fertiliser applied, yield and nitrate-N leached from each site and cultivar (modelled using OverseerFM)

Site – cultivar	Treatment	N fertiliser applied (kg N/ha/yr)	Yield (Mg/ha)	N leached (kg/ha/yr)	P loss (kg/ha/yr)	Total CO_2-equivalent (kg/ha/yr)
Wairarapa – Cochise	1	0	6.38	39	0.4	3,180
Wairarapa – Cochise	2	24	8.02	39	0.4	3,185
Wairarapa – Cochise	3	24	8.5	39	0.4	3,184
Wairarapa – Cochise	4	104	9.13	39	0.4	3,204
Wairarapa – Conquest	1	0	6.38	39	0.4	3,180
Wairarapa – Conquest	2	31	8.02	39	0.4	3,186
Wairarapa – Conquest	3	31	8.5	39	0.4	3,185
Wairarapa – Conquest	4	111	9.13	39	0.4	3,201
Ohakune	1	0	5.45	98	0.2	1,868
Ohakune	2	83	6.35	104	0.2	1,916
Ohakune	3	83	6.61	98	0.2	1,914
Ohakune	4	183	7.67	98	0.2	1,974
Waikato	1	0	10	54	0.8	13,938
Waikato	2	24	10	59	0.8	13,952
Waikato	3	24	10	58	0.8	19,351
Waikato	4	104	10	69	0.8	13,999

Table 2: Grain yield and grain tests – cultivar comparison (modelled using OverseerFM)

Cultivar	Grain yield (t/ha)	Grain moisture (%)	Test weight (kg/ hectolitre)	Dressing loss (%)	TGW (g)	Protein (%)	Falling number
Wairarapa							
2208	8.0	12.7	72.3	1.2	44.0	13.9	150
Sensas	7.8	13	74.5	0.8	42.4	13.5	270
Cochise	7.8	11.2	63.9	5.1	42.2	13.5	126
Discovery	6.8	11.2	63.2	4.9	41.0	13.6	135
Reliance	6.5	10.3	63.9	4.8	40.2	15.1	120
Conquest	6.5	10.4	67.7	2.8	34.6	15.2	139
Ohakune							
Viceroy	7.11	18.3	62.7	7.6	37.8		
Cochise	6.91	19.5	74.4	1.4	41.6		
Conquest	5.72	16.5	69.5	4.5	33.8		

As a result, it was not a suitable season to investigate how effective spring-sown wheat was in scavenging N, one of the project's objectives.

The falling number is a measure of alpha-amylase activity in wheat that indicates the ability for bread made from it to rise. It is strongly affected by rain at harvest time.

"The rain not only delayed harvest but caused that falling number to drop through the floor," says Pyke.

The falling numbers were representative of the very wet season and harvest and were very low in the Wairarapa and reasonable in Ohakune. Visible sprout was evident at both sites.

Despite the wet season, the Wairarapa site did produce reasonable yields of milling wheat.

"The yield in Ohakune was about half of what they got the year before. In the Wairarapa we got two-thirds the previous yield, so that was disappointing – but encouraging given they never really saw the sun at either place," says Pyke. "The quality, with the exception of falling number, was very good, indicating milling wheat could be a valuable land use diversification."

He also says that in normal conditions a wheat rotation could rank favourably against most N mitigation techniques because it is a technique that has very little cost.

Despite the wet season, the Wairarapa site did produce reasonable yields of milling wheat.

Despite a season "where it rained and rained and rained", the trial did provide encouraging results.

"I know we can grow a good crop of wheat and get decent yields, it's not that difficult. It's how we grow it to get the quality we need and utilise the nitrogen available in the system that's the challenge," says Pyke. "At the end of the day, it looks like there's significant potential."

Despite the terrible conditions over the season, farmer Mick Williams has seen enough to convince him to grow milling wheat again. "We definitely want to carry on with it. We'll still do a bit of both feed and milling wheat, but the milling wheat interests me more, trying different varieties and hopefully making a connection with the end user. It'd be nice to able to go in and see bread that we know was made with our flour."

Tony Benny for the Our Land and Water National Science Challenge

Farming sunshine

Solar energy integration with livestock farming

Why: To establish how solar arrays could be incorporated into livestock farms to provide environmental benefits, as well as shade and shelter for animals, while generating renewable energy for financial gain.

Where: Mid-Canterbury dairy farm and North Canterbury sheep and beef farm.

Who: Anna Vaughan and Megan Fitzgerald (Tambo), Alan Brent and Ellie Wright (Victoria University of Wellington), Jasper Kueppers (Infratec) and farmers.

What:

- Available agrivoltaic array designs with tilt and tracking systems (suitable for sheep and cattle and allowing for movement of farm equipment) were reviewed.
- Livestock benefit from the shade panels provide, but standard commercial design sets panels too low for livestock larger than sheep and may have a negative impact on pasture.
- There are good financial gains for sheep farming under agrivoltaic systems, but the costs to raise and strengthen structures for cattle may be prohibitive on dairy farms.
- Cost of installation is a barrier to farmers, along with lack of confidence.
- A closer relationship between farmers and solar developers may be needed to incorporate agrivoltaic systems on more sites.
- A guide giving farmers more information on solar arrays and agrivoltaics has been developed, along with an interactive tool to assess property suitability.

More:

ourlandandwater.nz/outputs/integrating-solar-livestock-report

ourlandandwater.nz/outputs/integrating-solar-livestock-booklet

ourlandandwater.nz/outputs/agrivoltaics-assessment-tool

As solar energy generation ramps up in this country, what should farmers consider when looking at integrating solar into their livestock farming operation – and does powering up a paddock stack up financially?

As the number of solar farms has increased globally, especially over the past decade, farmers and environmentalists have raised concerns that the sites had become ecological wastelands, with grass and weeds under the photovoltaic panels controlled by mowing or spraying.

Agrivoltaic systems respond to these concerns by allowing the dual use of land for producing food and electricity, with extra benefits for food security, biodiversity, and meeting future needs for more renewable energy production.

Overseas, some cropping is being done under solar panels, and some farmers have developed a ‘solar grazer’ business model, running sheep under the panels on pastoral farms. Sheep are popular, as the panel structures do not need to be reinforced or raised to allow them access.

Farmland is the focus for new solar developments in this country, with more than 14 large-scale sites in the pipeline already. Including smaller sites sees this number jump to more than 200, with more planned in the future.

Dual land use

Solar developers have been largely determining how the panels are set up. They aim to capture the maximum amount of energy, rather than designing for optimal dual land use, or for it to be incorporated into the surrounding farming systems (see **Figure 1**).

“They’re just running a few sheep underneath, not designing the layout of the panels to preserve pasture production,” says farm consultant Anna Vaughan of agricultural consultancy Tambo.

Vaughan approached Alan Brent, chair in sustainable energy systems at Victoria University of Wellington,

Sheep grazing among solar panels

to find out what dual-purpose designed arrays would look like and how would they stack up financially for Aotearoa New Zealand farming operations. Along with members of the Infratec team, they applied for funding through the Our Land and Water Rural Professionals Fund to find out.

The National Policy Statement for Highly Productive Land, introduced in 2022, requires local councils to map, manage and maintain highly-productive land to prevent it falling out of food and other primary production.

Even in areas that do not fall under the highly productive land classification, local councils may well be reluctant to allow rural land needed for solar developments to be used solely for electricity production, and many of the solar developers have indicated they intend to incorporate agrivoltaics in their resource consent applications. Dual land use is not currently a requirement but may be a possibility for the future.

Technical considerations

A desktop study undertaken by Vaughan's team combined what scant information there was available on agrivoltaics in an Aotearoa New Zealand context with overseas studies. This included previous research that had shown around 80% of our agricultural land was suitable for agrivoltaic systems, including much of Canterbury. The assessment took into account a location's solar resource, slope and orientation, and distance from transmission lines.

Mounting structures for the various agrivoltaic designs were investigated, as the cost of these can have a big impact on economic viability. In a pastoral setting, panels are typically set in rows with wider spacings to allow farm machinery to move between them. Panels set out in a row rather than a checkerboard pattern are the most efficient for energy gathering.

Fixed-tilt systems have panels running east to west and are permanently facing north. Single-axis tracker systems run north to south, and panels track the sun as it moves across the sky during the day. Tracker systems are more efficient, but are likely to need more maintenance and be affected by wind at height.

Raising panels significantly higher off the ground for large stock, as well as strengthening for wind shear at height, adds significantly to the cost and is likely to be a deal breaker for many developers.

Inverters are needed on-site, so power produced can connect with the national electrical network. If producing more than 10 MW (a site around 20 ha), a developer or farmer would need to be registered as a generator provider. Approvals from Transpower or local lines companies are needed because not all substations can carry an increased load from solar and this will directly affect whether a site is suitable for development.

While Transpower is upgrading its systems, Brent says there are likely to be more issues in the short term with the local line companies.

Pros and cons of dual land use

Shade and (to a lesser extent) protection from inclement weather are the biggest gains for livestock on agrivoltaic farms.

There are significant advantages in providing shade to ward off heat stress in livestock, which affects animal wellbeing, as well as weight gain and increased milk production. Wooled sheep start to feel heat stress over 19°C. As the climate continues to warm this will take on even greater relevance.

Panels provide and retain more soil moisture, as well as keeping soils cooler during dry months, with wind also reduced under the panels.

Standard commercial heights for panels, however, create shading that leads to poorer ryegrass and clover pasture performance. Higher panel heights are recommended.

"The reflective surfaces of the panels can impact insect behaviour but not to a serious degree," says Brent, "and wouldn't interfere with honey production should a farmer look at diversifying by growing native plant biodiversity and flowering plants for bees instead of running livestock under the panels.

"When panels reach the end of their commercial life, at around 25 to 30 years, they will still be producing about 85% of what they were when new, and will likely last another 10 years or more. While there may be options for donating these panels for social development projects, there are currently no recycling plants in Aotearoa New Zealand, something that will need to be looked into seriously in the coming years," says Brent.

Sheep and beef farm case study

A sheep and beef farm and a dairy farm – both in the Canterbury region – were used as case studies to model agrivoltaic array design and potential impacts on farming systems. Both sites would use bi-facial panels able to capture light on both sides, with fixed-tilt and tracking systems modelled for each farm.

Removing the panels at the end of their life, waste management, and turning the land back into farmland were not part of the calculations, although replacing inverters once during the lifetime of the development was accounted for. All costs associated with the solar developments for the farmers were assumed to be covered by borrowing.

A 5.8 ha paddock on the 1,300 ha sheep and beef farm in the Hurunui area was modelled. With around 800 ha effective hill country and 300 ha of effective flats the farm winters 7,500 stock units.

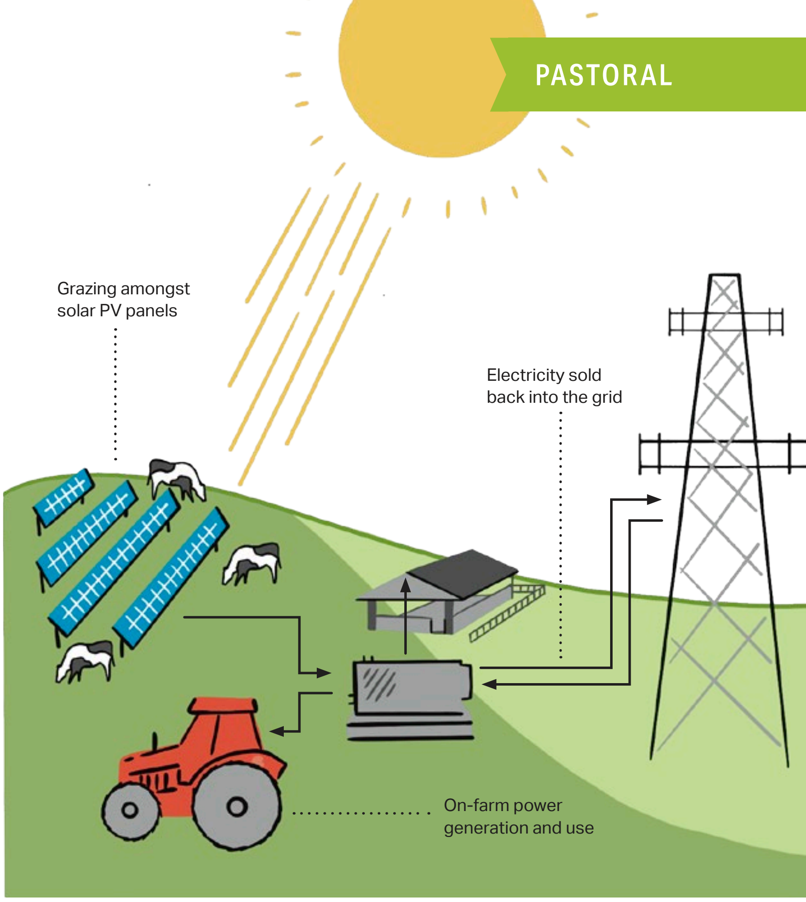


Figure 1: The scale of the solar system and the on-farm loads determine the required infrastructure configurations to enable the direct supply of electricity for on-farm usage

Heights of the solar panels were standard and suitable for sheep, although rows were wider apart than on a typical solar farm to allow farm equipment to move between the rows, and were placed further from the paddock boundary.

Overall, costs to establish either fixed or tracking panel systems were similar. Project development, consenting and grid connection cost around $625,000, and the design and build between $4.3 million and $6.3 million. This would generate, at peak, between 2.2–2.5 MW of electricity for the grid.

A comparison was made between the status quo (no solar) and the 5.8 ha area having a 30% reduction in stocking rate due to the installation of panels and subsequent shading. A total removal of stock from the area was also modelled.

The results showed that net profit (after debt servicing and depreciation) for the farm increased by $420,484, with a 30% decrease in stocking rate under that area. Return on asset increased significantly, as did return on equity (see **Table 1**).

The modelling showed a solar set-up would work well financially for the sheep and beef farm.

When viewed through a purely financial lens, the numbers for a standard commercial solar set-up stack up better than for an agrivoltaic one. However, there are still significant financial gains from the agrivoltaics system over the status quo.

Dairy farm case study

On a 235 ha farm milking 860 cows, a 2 ha dryland area used for supplementary feed production on the edge of an irrigated paddock was modelled.

The panels needed to be 2.5 m above ground level to enable adult cows to move underneath. For greater stability at that height, and given Canterbury wind speeds, a more expensive dual-pile system was recommended for the fixed-tilt panels. Again, rows were wider apart than on a typical solar farm to allow farm equipment to move between the rows, so they were placed further back from the paddock boundary.

Project development, consenting and grid connection costs came in at around $350,000 to $390,000, with design and build between $2.1 million and $2.9 million, for around 1 MW of power generation.

Comparison was made between the status quo (no solar), and the farm operating the array without stock underneath, due to this area being dryland and not typically included in the grazing feed budget for this farm.

Results showed that net profit dropped by $64,400 due to increased borrowing, as the interest rate was not covered by increased income. The return on asset and the return on equity also dropped slightly.

Financially, there was little benefit in installing a solar array on the higher income dairy farm, including the extra infrastructure costs and buying in supplementary feed. There could be some benefit from being able to use the electricity in the dairy shed and with irrigators if the agrivoltaic system is of appropriate size and properly embedded into the farm infrastructure.

Considerations for the future

A group of interested Canterbury farmers who attended a workshop on agrivoltaics, as part of this research, felt the arrays ticked boxes for animal welfare by offering shade to stock, along with contributing to their 'social licence' to farm.

While the workshop raised their interest in agrivoltaic systems, the high costs associated with installing the arrays was a barrier. The farmers didn't feel confident or informed enough to tackle agrivoltaic projects themselves, although some felt they would be up to the challenge with more clarity over costs. They also felt that without leasing or partnering with energy companies, fewer agrivoltaic projects would likely go ahead.

Solar energy companies setting up a standard system with no regard for optimising agrivoltaics, and then running sheep underneath while claiming dual land use, was one of the concerns Vaughan's team also had.

Should local councils take dual land use and preservation of productive land seriously, getting resource consent approval for a straight commercial solar set-up may become harder in the future.

"It would be a missed opportunity if in five years' time all the approved solar sites, which will be in operation for 30 or more years, have a standard commercial design," Vaughan says.

Research is also needed on how pasture and livestock perform under panels, along with cropping, re-seeding and other farm management systems and health outcomes for lambs and calves.

Delwyn Dickey for the Our Land and Water National Science Challenge

Table 1: Return on investment – sensitivity analysis (sheep and beef farm case study)

		Solar energy generation annual revenue per hectare ($/ha)						
		$81,000	$89,000	$97,000	$105,000	$113,000	$121,000	$127,000
Capital investment $/ha	$615,625	3.67%	4.04%	4.40%	4.76%	5.13%	5.49%	5.76%
	$678,000	3.34%	3.67%	3.99%	4.32%	4.65%	4.98%	5.23%
	$741,000	3.05%	3.35%	3.66%	3.96%	4.26%	4.56%	4.79%
	$804,000	2.81%	3.09%	3.37%	3.65%	3.92%	4.20%	4.41%
	$865,625	2.61%	2.87%	3.13%	3.39%	3.65%	3.90%	4.10%

Assumptions: Accumulated 30-year depreciating income (decreasing to 85% by year 30) over initial capital investment requirements. Does not account for cost of funds, cost to remove and remediate land at end of 30-year term, or any maintenance costs.

Mooving in on the soggy West Coast

Composting mootels on the West Coast

Why: To compare different composting shelter (or 'mootel') structure designs, and best practice for compost maintenance, in challenging wet conditions.

Where: Three dairy farms with recently constructed mootels on the West Coast.

Who: Robb Macbeth (Peak Agricultural Consultants), Josh Brown and Harry Millar (Rural Consulting), Keith Woodford (Agri-Food Systems), Gaye and Murray Coates (Prospect Farm), Carmel and Matt O'Regan (Mangawaro Farm), and Wendy and Tegel Oats (Turkey Creek Farm).

What:

- OverseerFM modelling and pre- and post-mootel integration for Prospect and Mangawaro Farms indicated an average nitrogen (N) root zone loss reduction of 47% (Turkey Creek Farm was lower, at 18.2%).
- Cows in mootels were more efficient at feed conversion. Utilisation also increased. As a result, the need for intensive winter grazing was reduced.
- Farmers observed anecdotal evidence for improvements in cow and staff wellbeing through reduced exposure to winter weather and soft, dry bedding for the cows.
- Mootel construction ranged from $1.2 to $2.9 million. Noting inflation, prospective mootel farmers should consider a range of $3,500 to $6,000 per cow, plus annual woodchip bedding of 3 m³ per cow at $25 to $35/m³.

More:

ourlandandwater.nz/outputs/west-coast-mootels

ourlandandwater.nz/outputs/composting-mootels-summary

On the West Coast, where annual rainfall is measured in metres, life has been cosy for dairy cows and staff in new composting shelters, especially during cold wet weather.

Aside from the remoteness of where they farm, some of the biggest challenges for West Coast dairy farmers in the South Island are around winter management and the sheer volume of rain they receive.

"The conundrum with winter grazing is, do you winter cows on freer-draining soils and risk increasing nitrate loss, or go to heavier soils where you could have issues with pugging?" says farm consultant Harry Millar.

"Heavy rainfall means there are probably fewer options on the coast," he says. "This is especially true when considering where policy settings are heading and the focus on intensive winter grazing."

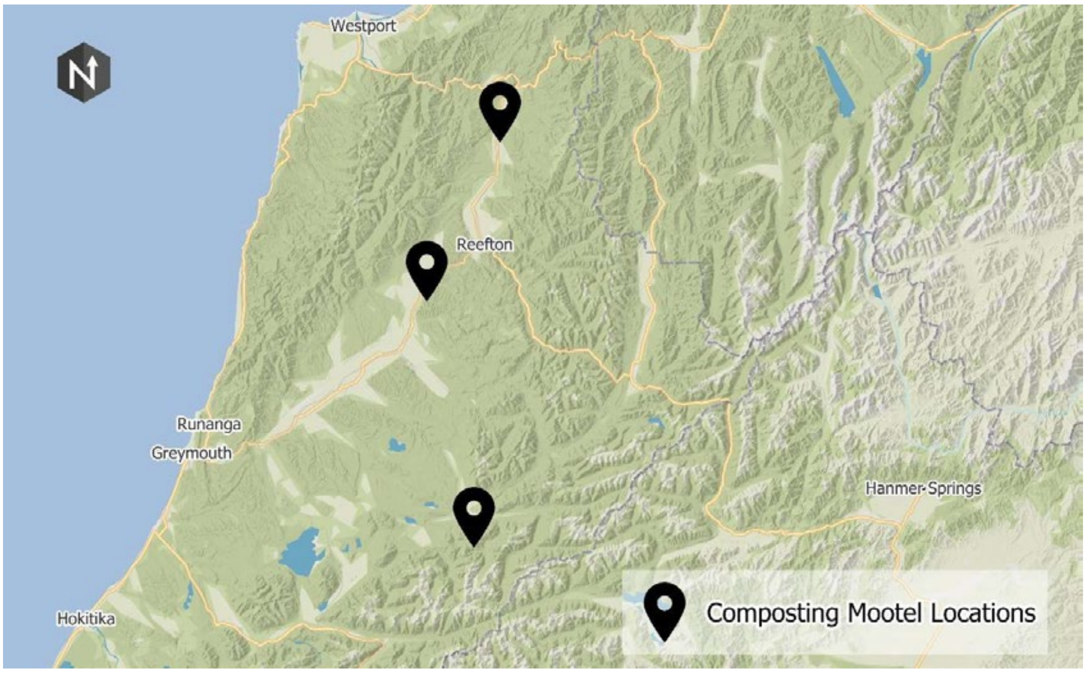
Composting shelters, or 'mootels', are now another option. Mootels see cows housed off-paddock over winter and fed supplements undercover, with urine and dung absorbed into bedding material for compost.

After observing West Coast farmers erecting composting mootels (see **Map 1**), farm consultant Robb Macbeth of Peak Agricultural Consultants, along with Josh Brown and Harry Millar of Rural Consulting, applied for funding from Our Land and Water's Rural Professionals Fund. They sought the funding to assess the farmers' key considerations, particularly for structure design and compost management in their wet environment.

Farmer motivation

The welfare of their cattle during winter was behind the farmers looking into mootels, with other factors including regulatory pressure, future business sustainability and potential staff benefits.

Map 1: Case study farm locations



"The composting process would provide fertiliser, but the compost soon became as much about cow comfort as about nutrients for pasture," says Millar.

The farmers felt incorporating mootels into their farm systems would help ease social licence concerns and regulation around winter grazing, while lifting milk production and profit.

The farmers had visited several farms with different structures available, talked to current users of composting shelters, and checked local council consenting requirements. Seeing a cow slip on a concrete floor in a different shelter type clinched the soft-floored composting mootel decision for one farmer.

Structure design

Two of the West Coast mootel case studies had solid roofs, and a third with a translucent plastic tunnel-roof mootel came on board a little later in the project (see **Table 1**). All the structures were positioned to take advantage of prevailing winds.

Mootel construction costs ranged from $1.2 million to $2.9 million – around $3,200 to $4,000 per cow – and included site work, concrete, bedding, and plant and equipment. Costs have since increased due to inflation. Depending on the farm, an increase in milk production of 11%–16% was needed to break even on the investment, says Macbeth.

High moisture content from urine and dung leads to lower temperatures in bedding, and can slow down the composting process. Should composting stop, the bedding becomes anaerobic and starts to rot. Good airflow is needed to help moisture evaporate and keep compost temperatures high.

Good water collection off the roof and drainage is important to keep water out and feed dry. The two mootels with solid roofs had an 18-degree roof pitch with ridge venting. Both ends of the tunnel shelter were fully open.

The two solid-roof mootels had two five-metre-wide concrete feeding lanes for vehicles inside the structures, while the tunnel shelters had external feed bins along the sides of the structure.

Not connected to the farm effluent systems, bedding absorbed the manure and urine. While the mootels had sub-surface drainage as a precaution, no drainage was seen during the study.

Bedding management

Pinus radiata woodchip was used for bedding on all three farms as it broke down slower than materials like sawdust or straw.

Chipping on-site was seen as a cheaper option by two farmers, while also being able to dictate chip size and with the contractor able to cart it into the shelter. One cubic metre of log gave between 2.4–3 m^3 of chip. Between 5.2–7 m^3 of material per cow was used initially to fill the shelters, with a top-up during the year of around 3–4 m^3 per cow.

Tunnel roof mootel at Turkey Creek Farm

Forestry material from a hectare of on-farm mature radiata pine was estimated as enough to supply bedding material for between 400 to 550 cows annually. Storing logs for at least a year to dry out before for chipping is a possibility, with composting temperatures rising when this drier chip was added during the year.

Bedding temperature samples were taken for the mootels between October 2022 and May 2023 at depths of 200 mm, 300 mm (see **Figure 1**) and 400 mm.

Recommended compost temperatures of between 50–60°C at a depth of 15–30 cm weren't being reached in the solid-roof mootels, although the composting process was still taking place. Lower temperatures, more moisture and some anaerobic composting were seen next to the feed lanes, where cows urinated and defecated more while eating.

The tunnel house compost reached these higher temperatures at times, with less clumping next to the feeding lanes. A stocking rate of 9.3 m of space per cow in the tunnel house compared to 6.5 m and 7.4 m in the others may be behind this, and possibly muted light through the plastic roofing. Skylights are now being considered by one farmer.

More frequent and deeper tilling, and adding more material, were tried. Scrapping was also used by one farmer. Concreting this strip was considered a possibility, or feeding in an area separate to the mootel connected to the farm effluent system.

To reduce the moisture content in winter, palm kernel extract or feed concentrate were considered, along with growing maize for lower moisture silage instead of pasture silage.

Tilling frequency varied, and more tilling may help reduce moisture. When cattle were in the shelters full-time, tilling was at least once a day. If the shelters were only used for a couple of hours a day, tilling dropped to every second day, and to less than once a week when the animals were out on pasture full-time.

The carbon-to-nitrogen (N) ratio of the compost was used to gauge when it was ready to spread, with a 12–15:1 ratio hitting the mark. A top-up at this point would possibly see the compost life extend up to two years, reducing replacement costs.

Table 1: Case study farm details

	Prospect Farm	Mangawaro Enterprises	Turkey Creek Farm
Location	Haupiri	Inangahua Landing	Mawheraiti
Milking platform area (ha)	315	185	169
Peak cows (2022–2023)	800	540	370
Stocking rate (cows/ha)	2.5	2.9	2.2
Mootel system	2 solid roof mootels	1 solid roof mootel	2 tunnel roof mootels

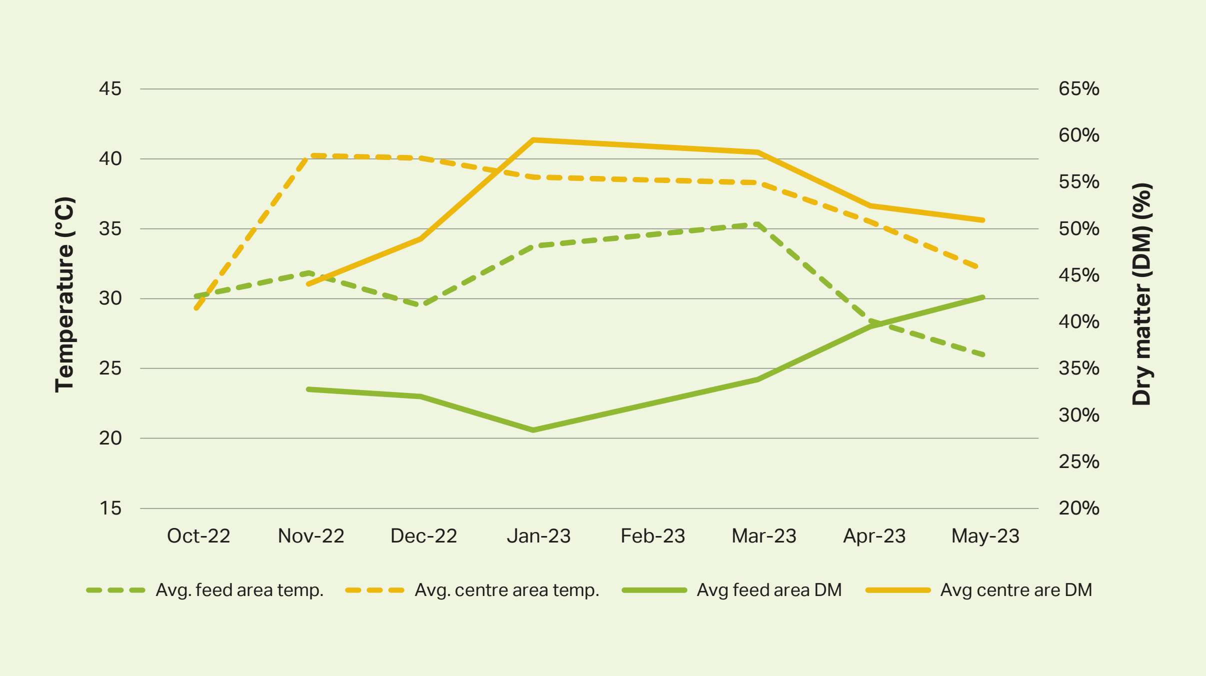


Figure 1: Average compost temperatures and dry matter content at 30 cm

After a year the compost should have enough nutrients to replace one application of N or potassium, and about 25% of annual phosphorus or sulphur fertiliser needs.

Cow health

Cut-and-carry crops have replaced winter cropping on two of the farms, which sees significantly higher feed utilisation by cows and more control over feed intake generally. Better cow health and injury checks are also now possible.

Although body condition scoring was carried out, no pre-mootel scoring was available for comparison. However, farmers were adamant their animals were happier, calmer and less stressed – as were their staff. Having access to the shelters for shade during warmer months and heavy rain events was a big part of this.

Mastitis levels and somatic cell counts remained unchanged with the shelters, although there may potentially be an increased incidence of *E. coli* mastitis.

Cow deaths were significantly down on all the farms, particularly around calving, and there were fewer metabolic issues.

Modelling woes

The inability to accurately model greenhouse gases (GHGs) following the introduction of these composting structures is a cause for concern.

After a year the compost should have enough nutrients to replace one application of nitrogen or potassium, and about 25% of annual phosphorus or sulphur fertiliser needs.

While modelling suggested N root zone loss over the farm may halve for two of the farms, there was little confidence in results for methane emissions from effluent in the mootels. No modelling was possible for the composting process and potential increase in nitrous oxide emissions.

“More solid research on GHGs in the animal housing context is a crucial factor if we’re moving toward pricing emissions,” says Millar. “This is important so we’re not making gains in one area only to be causing problems in another, and ensures innovative farmers are rewarded for any improvements in emissions management.”

Delwyn Dickey for the Our Land and Water National Science Challenge

Lifting the game for West Coast wintering

How to winter better

Why: There is little information for farmers about wintering options in high rainfall areas to improve outcomes for the environment, animal welfare and spring pasture production.

Where: Interviews with West Coast farmers running various farming systems and modelling two dairy farms on the West Coast.

Who: Laura Bunning and Andrew Curtis (Primary Insight) and eight West Coast farmers.

What:

- Interviews, workshops and farm modelling showed there is no one-size-fits-all approach to better wintering on the West Coast.
- Covered infrastructure options should be considered in higher rainfall areas, where soils are vulnerable to pugging, where there is a sensitive downstream environment, and in response to animal welfare needs.
- In some circumstances, stand-off pads or a sacrifice paddock will continue to be the best option.
- A decision-making tool was designed to help farmers narrow down the range of wintering options and develop a better understanding of their environmental and animal welfare risks, management and financial constraints and goals.
- Once key risks and limitations have been identified, a farm-specific economic and environmental analysis should be undertaken to identify the best solution.
- Farmers should avoid infrastructure investment until they have determined it is the best solution for their situation.

More: ourlandandwater.nz/outputs/west-coast-wintering

With high rainfall and extreme weather events, winter on the West Coast can pose significant challenges to dairy farmers. What are the options for farmers looking to improve their environmental outcomes without breaking the bank?

The West Coast of the South Island has one of the most rugged, but beautiful, landscapes the country has to offer. Extreme weather events are common, including extended periods of continuous rainfall. These can create a challenging work environment for farmers, staff and their stock.

While the Coast is New Zealand's wettest region, there are significant variations in temperature and rainfall as you move from north to south, says Primary Insight farm consultant Andrew Curtis.

"Pugging, resulting in sediment and pathogen run-off into waterways, is of particular concern," says Curtis. "From a production perspective, impacts on spring pasture growth and animal welfare are also of concern."

Stand-off pads and sacrifice paddocks are common on the Coast, but recently there has also been a lot of interest in composting shelters (or 'mootels', see page 21) and solid-floored herd shelters.

The recent winter grazing regulations have put an increased focus on management in this high rainfall environment.

Andrew Curtis and colleague Laura Bunning applied for funding through Our Land and Water's Rural Professionals Fund to look at wintering issues for farmers on the Coast. This included an analysis of the costs, benefits and environmental outcomes for various wintering management options.

Along with looking at what options were suitable for West Coast conditions (see **Table 1**), they spoke to

Each farm's landscape and animal welfare risks were taken into account when selecting the modelling options.

farmers with different wintering systems to better gauge the issues. They asked why individual farms had chosen their current winter management system, and what farmers would do differently if they were starting over.

Assessing the wintering options

While structures like composting shelters can have good animal welfare, environmental and pasture management outcomes, they are not a cheap option and would see most farmers heading to the bank seeking significant finance. They also need to be managed more intensely, with good access to supplementary feed.

The challenging farming conditions on the West Coast means more lower input farm systems, reflected in the lowest price per hectare of farmland anywhere in the country. This makes many farmers unwilling or unable to take on the debt required for high-cost structures. Farmers also have concerns about potentially over-capitalising their properties, especially if they are looking at selling in the short to medium term.

Farmers were keen to see how other options stacked up against the housing structures.

Three different wintering options were modelled on each of two local dairy farms. One of the farms was a system two and the other a system four.

Each farm's landscape and animal welfare risks were taken into account when selecting the modelling options, along with farm system and management limitations, farm financial constraints, and the goals of the farm owner.

Table 1: Benefits and considerations for the different wintering options on the West Coast

Options	Considerations
Forage Crop	**Benefits** - Cost-effective option, particularly when used in conjunction with a Stand-off/ Feed pad **Situations requiring careful consideration** - Soils susceptible to pugging; sensitive downstream environments; exposed sites
Grass & Supplementary Feed	**Benefits** - Cost-effective option, particularly when used in conjunction with a Stand-off/ Feed pad **Situations requiring careful consideration** - Soils susceptible to pugging; exposed sites
Uncovered Stand-off pad	**Benefits** - Effective option when used in conjunction with forage crops or grass & supplementary feed systems; milking-season use **Situations requiring careful consideration** - Soils susceptible to pugging; exposed sites; effluent constraints
Uncovered Feed Pad	**Benefits** - Effective option when used in conjunction with forage crops or grass & supplementary feed systems,; milking-season use. **Situations requiring careful consideration** - Soils susceptible to pugging in prolonged rainfall environments; exposed sites; effluent constraints
Covered Stand-off pad	**Benefits** - Effective option when used in conjunction with forage crops or grass & supplementary feed systems; milking-season use **Situations requiring careful consideration** - Soils susceptible to pugging; exposed sites.
Covered Feed Pad	**Benefits** - Effective option when used in conjunction with forage crops or grass & supplementary feed systems; milking-season use. **Situations requiring careful consideration** - Soils susceptible to pugging in high rainfall environments; exposed sites
Herd home (hard floor)	**Benefits** - Decreases animal health risks; favourable work environment; milking-season use as stand-off; calving use; undercover effluent storage **Situations requiring careful consideration** - Short-term management arrangements; no cost-effective feed supply; high debt; pro-longed within milking-season use.
Composting Barn	**Benefits** - Minimises animal health risks; favourable work environment; milking-season use for prolonged rainfall events; calving use; no effluent **Situations requiring careful consideration** - Short-term management arrangements; no cost-effective feed supply; high debt.
Wintering-off - Land purchase/ lease	**Benefits** - Effective infrastructure alternative; removes the risk of land over-capitalisation **Situations requiring careful consideration** - TRansfering the issue to other land where soils susceptible to pugging; sensitive downstream environments; exposed sites, milking-season rainfall protection required
Farm system change (de-intensify)	Situation specific, typically option favours older owner-operators with no succession plan or those looking to diversify their operation

Dairy farm on West Coast. Photo: Phillip Capper/Flickr

The risk of nitrogen (N) loss was assessed by a simple N balance from Farmax, although it was acknowledged that OverseerFM would have provided a better estimate of N loss. "However, sediment and *E. coli* are also generally of bigger concern on the Coast than nitrogen," says Curtis.

System two farm overview

The system two farm grew its own forage crops and maize silage, while also using palm kernel extract (PKE), and had a small feed pad in place. A lease block was used to help with wintering and raising young stock. Milking 2.2 cows/ha, the farm had an N balance of 69 kg/N/ha and an operating profit of $3,131/ha.

Three options were modelled for this farm.

- **Option 1: Self-Sufficient All Grass System** saw the farm drop to a system one to become a self-sufficient grass-fed system, with no imported feed or lease block. Herd size reduced as did labour and operating costs. The N balance dropped to 63 kg/N/ha, but operating profit also dropped by 13%.
- **Option 2: Forage Crops** saw the maize silage crop switched to a brassica forage crop, with the remaining pasture in better shape for spring. The herd and production remained the same, but with lower production costs when compared to the current maize crop. Good feed or access to supplements for the rest of the season would be needed, along with a window for re-grassing. The N balance dropped to 64 kg/N/ha, with operating profit increasing 15%.
- **Option 3: Additional Land Purchase** enabled the current farm system to become completely self-sufficient. Production increased from the additional feed available to offset the interest costs on the land purchase. N dropped slightly to 66 kg/N/ha, with operating profit staying the same.

System four farm overview

On the system four farm, young stock are grazed off-farm, with the milking herd wintering on an adjoining lease block with supplementary feed (maize silage grown on-farm and PKE). A loafing pad is located near the dairy shed. Milking 2.4 cows/ha, the farm had an N balance of 98 kg/N/ha and an operating profit of $3,026/ha.

- **Option 1: Covered Feed Pad** investigated covering the current loafing pad near the dairy shed and a trough feed system put in place for the supplementary feeding of maize silage and PKE. The additional effluent generated fitted within the current system capacity, meaning there was little additional capital needed for this. An 8% increase in cows was modelled, along with a 5% increase in milk production per cow. The N balance dropped slightly to 95 kg/N/ha, with operating profit increasing by 12%.

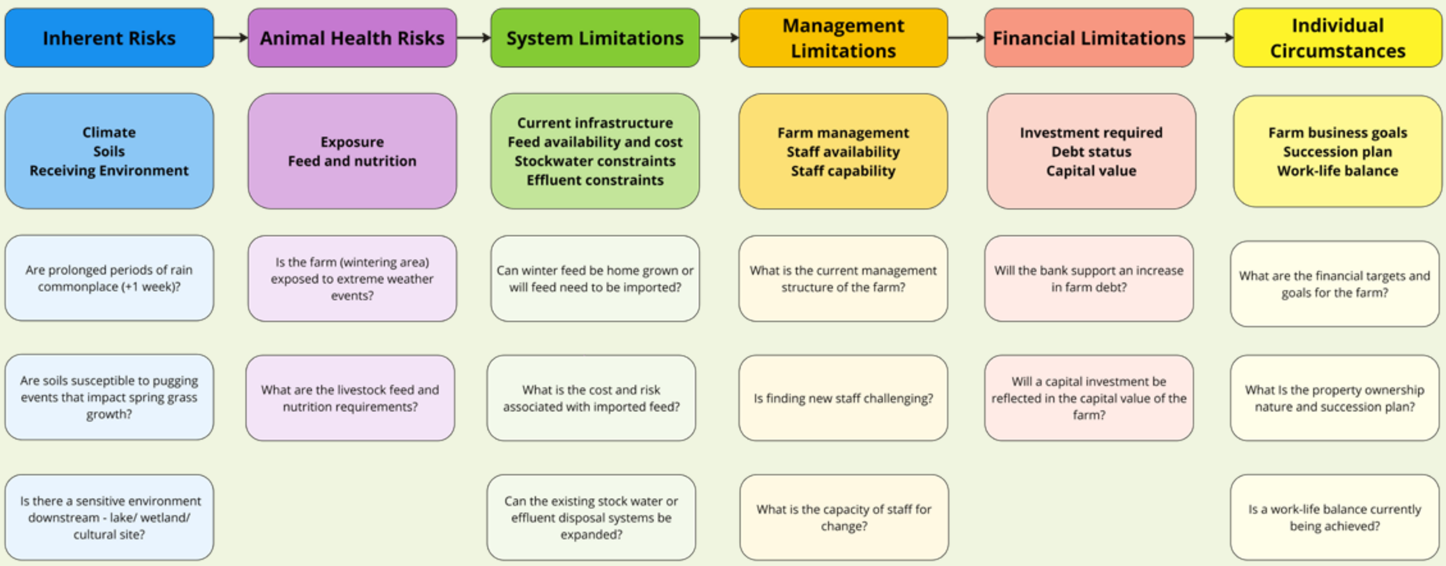


Figure 1: A decision-support framework was developed to help West Coast farmers identify the most suitable wintering options for their farm

- **Option 2: Composting Barn** added greater flexibility for management. This included feeding supplements, particularly during winter, and managing through adverse weather events. This saw the herd size able to be increased by around 8%, resulting in a 5% increase in production, while feed supplements stayed around the same. With a loafing pad already in place, production gains were not as great as had been previously modelled for other farms. The N balance dropped to 90 kg/N/ha, with operating profit increasing by 7%.
- **Option 3: Diversifying System** saw a reduction in the dairy herd size by 20%, along with an accompanying reduction in replacement animals, and the introduction of dairy-beef finishing on the farm rearing all calves through to 12–14 months. This saw lower production levels, but also lower staffing and input costs. The N balance dropped to 94 kg/N/ha, with operating profit down 11%.

No single best option

"From a financial perspective, combining forage crops with low-cost stand-off pads may be a better solution for some farms, while becoming self-contained, purchasing additional land and diversifying into beef may be harder to justify," says Bunning.

"However, soil type and the downstream receiving environment need to be carefully considered to avoid environmental issues," she says. Although not quantified, previous research in Southland and Otago has shown sediment and *E. coli* losses can be reduced by two-thirds under better wintering practices (equal to a one-third reduction annually).

Covering feed pads would see improvements for animal welfare and reduce soil damage, with the ability to keep animals off-pasture for longer periods of time. But in areas that experience very high rainfall and serious pugging issues, the more expensive covered structures like herd shelters or composting shelters may be a better option.

"Many farmers were hoping for a definitive answer as to the best option for the Coast, but the research confirmed that the optimal solution is always location-specific," says Curtis.

"As a result, the key output from this project has been a decision-making framework for farmers and their advisors. This includes consideration of landscape, catchment and animal welfare risks, farm system and management limitations, financial constraints and the goals of the farm owner" (see **Figure 1**).

Delwyn Dickey for the Our Land and Water National Science Challenge

Seeing the big picture

A replicable workshop has supported farmers and rural professionals to think in systems.

Systems thinking for future farm design

Why: To help farmers develop a whole-of-farm perspective, explore how different parts of their system are connected, and identify their most effective options for positive change.

Where: Two strategic workshops between leading Canterbury farmers and their advisory teams.

What:

- A strategic workshop process tested the use of systems-thinking principles and two tools, for rural professionals and their farmer clients to use together.
- Results from two test workshops showed that a systems-thinking approach is a good fit for farming challenges.
- The process created a constructive space for rural professionals and farmers to raise confronting questions and share challenging perspectives. The process removed emotion and reduced reflexive pushback, leading to wider discussion and new insights.
- Farmers left the workshop with fresh perspectives on their underlying worldview, and identifiable actions they felt could deliver system-wide change (as opposed to 'quick fixes'). These included changing organisational structure and better integration of technology into the system to enable more transparency.
- Systems-thinking principles were reviewed through a mātauranga Māori lens, which suggested that both bodies of knowledge share underlying principles around identifying relationships between factors and prioritising holistic solutions.

More: ourlandandwater.nz/outputs/systems-thinking

Richard Wright's farming business has a lot of moving parts: beef, dairy, cropping, a pasture-to-plate meat brand, honey ventures and native restoration, to name a few. Behind it all is his team, with community, catchment groups and council to also factor in. Don't forget the mega-trends either – staying up to date with climate change, markets and technology.

"To do well, we're expected to know everything about everything – or at least to be a jack of all these trades," says Wright. "Unsurprisingly this means we spend time learning and doing things that sometimes just aren't that useful in the long run.

"We have limited time and what seems like an increasing list of things we could be doing. So, when we're looking at a problem, I want us to be looking for the root cause. When we're thinking about investing time and money, that action needs to drive real impact for us."

Six months after a facilitated workshop applying systems-thinking principles to his farming business, Wright points to both intangible and tangible outcomes.

"It's hard to draw a straight line with these things, but I think we're looking at problems a bit differently now. The systems-thinking tools were a good way to engage the team – to get them sharing perspectives and talking about impactful actions. We've also stepped up our local catchment work and focus on irrigation – that's the point in the wider system we think will drive the most positive change for us going forward," he says.

Like Richard Wright, many farmers are finding that challenges to the farming system – be it weather, market, people, regulations, or others – are coming at them faster, with more force and at greater frequency.

To respond, they are being told to think and act more 'holistically' and move from 'quick fixes' to more long-term solutions, but without any training or support to help them sift through the mountains of information available and identify what 'holistic' action looks like on their farm or in their community.

Leverage points

Systems thinking shows promise as a method where farmers like Richard Wright can step back and see their system as a whole. By taking time to find patterns and consider the relationships between factors on the farm (like people, environment, regulations and profitability), farmers will be better able to identify 'leverage points' – actions that have the most positive impact in the system.

A systems-thinking workshop process was designed for farmers and rural professionals by Agri Magic and collaborators, as part of a Rural Professionals Fund project funded by Our Land and Water.

Example leverage points discovered through the process included changing team roles, upskilling people, working more with others or finding new technology. Overall, systems-thinking principles and tools were found to offer farmers a way to step-up from 'quick fix' thinking, enabling them to focus on redesigning critical parts of their farming system to be more fit-for-purpose for the future.

The workshop design

To enable farmers to take a systems-thinking approach to their farming business, the project team designed a series of workshops that were held between Richard Wright and another Canterbury farmer, alongside their rural professional advisors. The first, a strategic workshop, covered three parts:

1. **Setting the scene.** A brief overview of systems thinking.
2. **The Iceberg Model, a systems-thinking tool.** Like an iceberg, a large part of what is occurring in a farmer's world is hidden from view. The tool focused on moving through four layers (see **Figure 1**), reflecting and discussing how each layer might be influencing any individual event. The Iceberg Model helps make underlying assumptions visible, opening up questions about how this or that worldview shapes their farm systems. Critically, it also creates space to hear other perspectives that may challenge these assumptions. One example in the workshop included:

   a. **Event:** A new winter grazing requirement.

   b. **Patterns:** 'Regulations are intensifying', 'dairy support requirements are increasing', 'water quality is declining', 'extreme weather is increasing'.

   c. **Structures:** Consents, grazing plans, irrigation schemes, standard operating procedures, catchments, councils, tikanga and protocols.

   d. **Models (or worldview):** 'Farmers can make big differences', 'does council want to control or collaborate with farmers?', 'is winter cropping bad for the environment?', 'do we need to shift our diets?'.

   Here, farmers were invited to physically draw the patterns of factors influencing the events (patterns of behaviour over time). By creating a visual representation of the complexity of their farming systems, the team were able to step back and start to see the general areas where leverage points might be found.

The Iceberg Model was then used for a second time, with the farmer moving upwards from the worldview, through structures and patterns to events. In this task, farmers were asked to consider what a future worldview of theirs might be, and how that might influence the layers differently and result in different events. In this way, one farmer recognised that their own current worldview around technology could be limiting their ability to provide more automation for their staff and transparency across the business. As a result of this insight, the team considered designing a plan to support future technology adoption in the business.

3. **The causal loop diagram.** A causal loop diagram is a map of a system, making relationships between factors clear and enabling farmers and rural professional teams to identify leverage points (see **Figure 2**). By taking time to map out the wide range of natural, human, technological, business and other factors in running a resilient farming business, and noting down how each might affect the other, leverage points within the system started to appear. In one example, 'operational management controls' quickly stood out as a central part of the system – changes here would have the greatest ripple effect across the other factors.

Better relationships and open dialogue

Project co-lead Anna Higginson, an Agri Magic senior consultant, points out that "the real gold is within the conversations – this ability to step back, look at issues with fresh eyes and maybe develop a new mindset that could shape decisions going forward."

While the outputs of the workshop (particularly the causal loop diagram) outlined some tactical, everyday changes the farmers could implement, the farmer's ability to look at problems from a fresh, systemic perspective was the key outcome.

The project leaders found that the facilitated strategy session was an effective way to capture ideas and provoke discussion. The process was not necessarily about fundamentally redesigning farming systems. Rather, it was a starting point where worldviews and assumptions could be questioned, gaps identified and leverage points considered.

One of most impactful aspects of the workshop process was the ability for farmers and their rural professionals to ask hard questions of each other. Coming into the workshop, one farmer noted that advisors tend to shy away from asking difficult questions of their clients – meaning the opportunities that come from challenging debate can be missed. This wasn't the case on the day. The framework helped to remove much of the emotion and bias often associated with controversial issues. Indeed, taking the opposing view was an important part of the exercise.

Notably, both farmers went on to use the Iceberg Model with their farm teams in the hope that this non-confrontational approach would enable better perspective sharing across their teams.

Mātauranga Māori

The principles of systems thinking were also reviewed through a te ao Māori lens. The principles

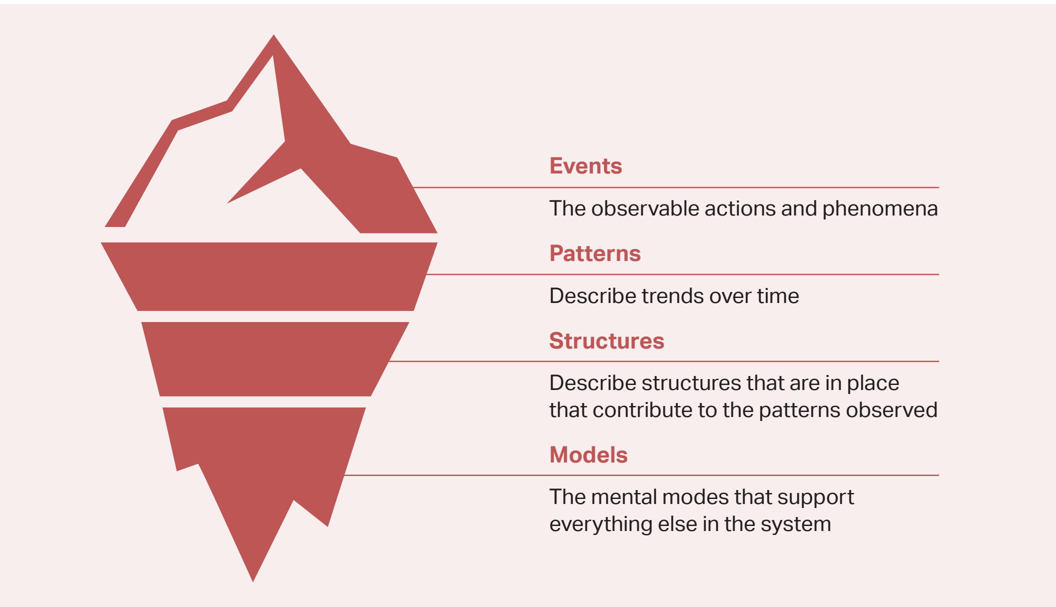


Figure 1: The Iceberg Model

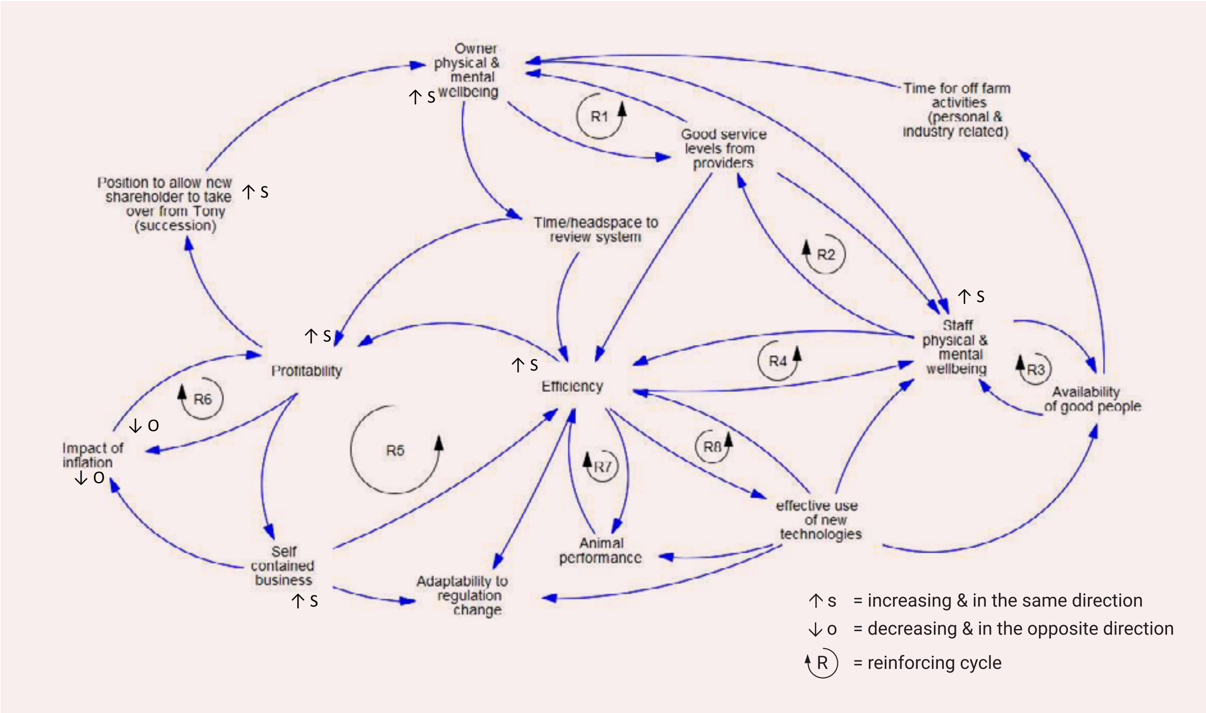


Figure 2: Causal loop diagram workshopped by project participants

of mātauranga Māori were found to align well with systems-thinking frameworks. The two approaches share a holistic perspective: that no individual or system exists in isolation; and that recognising the intricacies of the connections that make up the whole results in lasting, positive action.

This part of the research has gone on to inform a Masters' research project, and has implications for how future workshops may be redesigned to better reflect systems thinking in our cultural context.

Setting up for success

While the project clearly identified that systems thinking in general is a good fit for farming challenges, and that a facilitated strategy session enabling farmers to take a whole-of-system approach was valuable, there are several prerequisites that set the workshop up for success. These include:

- Training in systems thinking on the part of the rural professional.
- A trusted client-advisor relationship – knowledge of the farming business and existing rapport.
- Knowledge of challenges outside the farm gate – a broad understanding of the modern farming landscape by both parties leads to more compelling insights.
- Facilitation skills – careful preparation, the right framing, creating a space for constructive dialogue, asking thought-provoking questions, and actively listening and managing group dynamics are all critical to the workshop.
- Mātauranga Māori – an understanding of these principles helps to explore the cultural context of the farming business. Taking a te ao Māori view enables farmers and rural professionals to better understand their Resource Management Act obligations grounded in the principles of Te Tiriti o Waitangi – and how better engagement with local iwi, hapu and whanau might help to meet these. Understanding their environmental values and practices through the lens of kaitiakitanga (guardianship) may also provide a rich new worldview for farmers and rural professionals, enabling them to value these differently in a farming system or connect with like-minded others in their community.

Where to from here?

Farmers who are interested in exploring a systems-thinking approach to their farming problems should inform their rural professional about this research. For rural professionals looking to better support their farmer clients to manage the myriad of challenges facing their business, this replicable workshop offers a fresh, fit-for-purpose framework.

Daniel Eb for the Our Land and Water National Science Challenge

eDNA reveals awa's secrets

eDNA as a holistic measure of pastoral landscape effects on taonga species

Why: To enable farmers to see where wildlife and farmed animals are contributing to environmental DNA (eDNA), provide a method to detect positive change in future, and give communities a way to connect more deeply with their awa and its ecosystems.

Where: Dairy farm at the culturally significant headwaters of the Manawatū River in the Ruahine Ranges.

Who: Arapera Paewai (Taiao Ora Contracting), Penelope Drysdale (Te Miro Farm/Drysdale Dairies), Adrian Cookson (AgResearch), Shaun Wilkinson and Amy Gault (Wilderlab Ltd).

What:

- The native species that live in our rivers leave eDNA, which can be detected to help communities understand the health of the water and the taonga species it supports.
- Identification of fish, bird and plant species via eDNA includes taonga species and aligns with the key indicators currently used by regional councils.
- Among the taonga species identified using eDNA in the case study were whio/blue duck (not previously recorded in the area), ruru/morepork, kōtare/kingfisher, tuna/longfin and shortfin eels, kaharore bully, dwarf galaxias and kōura.
- The number of individuals of each species cannot be identified via eDNA.
- The results provided an opportunity to have honest conversations with farmers as it enabled them to see where wildlife and farmed animals are contributing eDNA.

More: ourlandandwater.nz/outputs/edna-taonga-species

Environmental DNA identified native and exotic species of fauna and flora in a culturally significant headwaters.

For generations, the Manawatū River was an important source of food and means of travel for local hapū who lived alongside its sacred headwaters.

"We have been collecting and re-telling stories of the awa as a way of reconnecting with it for a long time," says Arapera Paewai of Taiao Ora Contracting.

Now science, through environmental DNA, has provided yet another way to tell the stories of the awa and reveal its secrets.

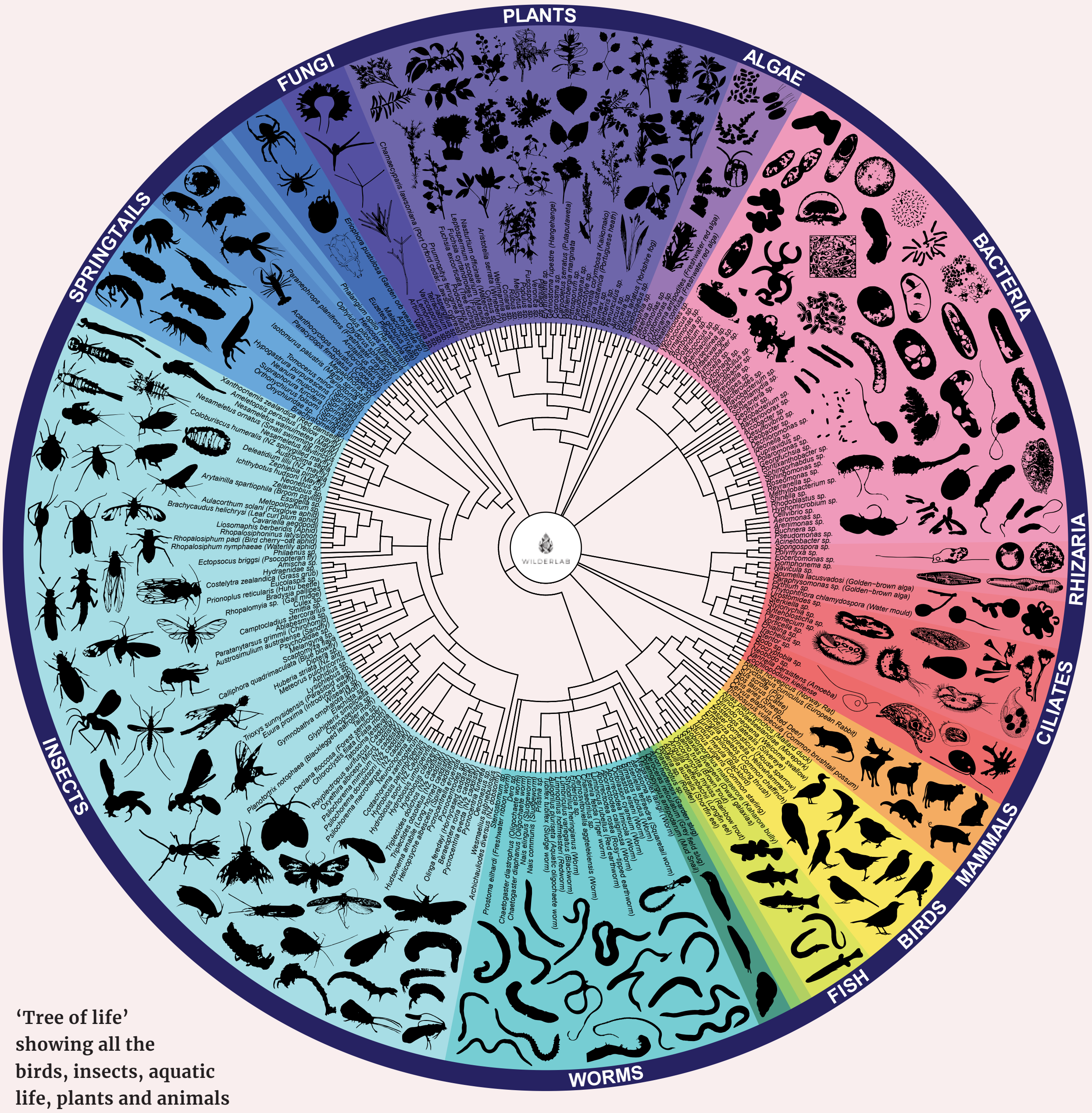
Funded through the Our Land and Water Rural Professionals Fund, the nine-month long project 'eDNA as a holistic measure of pastoral landscape effects on taonga species' involved collecting water samples and using eDNA to identify native and exotic species of fauna and flora that live in or near the river.

The small research project brought together rural professionals, scientists, farmers and mana whenua from three hapū environmental groups, as well as students to sample the river's water and record the results from five sites.

Paewai says the eDNA research is an exciting extension of work begun four years ago by Te Kāuru Eastern Manawatū River Hapū Collective and Penelope and Blair Drysdale of Te Miro dairy farm at the headwaters of the Manawatū River in the Ruahine Ranges (see **Figure 1**). The focus of the work has been to restore 18 ha of retired land along the river.

"Ultimately, we are all trying to improve the awa and build relationships, showing other areas how much can be achieved by working together," says Paewai.

The project compared eDNA from farmland and the culturally significant headwater site, to understand the ecosystem changes as the awa travels through different landscapes. As well as eDNA sampling, conventional water quality assessment of *E. coli*, total nitrogen, nitrate, phosphorus and turbidity were also measured.



'Tree of life' showing all the birds, insects, aquatic life, plants and animals that left their eDNA signatures at the sample sites, produced by Wilderlab

What was found in the water?

Sampling began in December 2022 and was repeated in January, March and May 2023. Those samples were sent to Wilderlab for DNA sequencing where the tiny traces of genetic material, or eDNA, they contained revealed the myriad of life the awa supports. The results provide a living context for understanding the ecological health of waterways.

Among the taonga species identified using eDNA were whio/blue duck (not previously recorded in the area), ruru/morepork, kōtare/kingfisher, tuna/longfin and shortfin eels, kaharore bully, dwarf galaxias and kōura.

The results of the eDNA sampling enabled farmers to see where wildlife and farm animals are contributing to eDNA, provided a method to detect positive change, and give communities a way to connect more deeply with their awa and its ecosystem.

"The eDNA data links what a community can see themselves with what can be detected from the freshwater samples," says Adrian Cookson of AgResearch. "While there were a few instances where detections were made of species not noted in the catchment, it was encouraging that many species known to be in the area were detected by eDNA analysis, including tree fuchsia, native beech trees, longfin eel, dwarf galaxias and kererū.

The nine-month long project involved collecting water samples and using eDNA to identify native and exotic species of fauna and flora that live in or near the river.

"This generates confidence that the eDNA results can give genuine insights into what might be lurking unseen.

"The eDNA results and species identified have been a great way to promote storytelling, and a shared ownership of potential mitigations and intervention for the improved ecosystem health of the catchment," says Cookson.

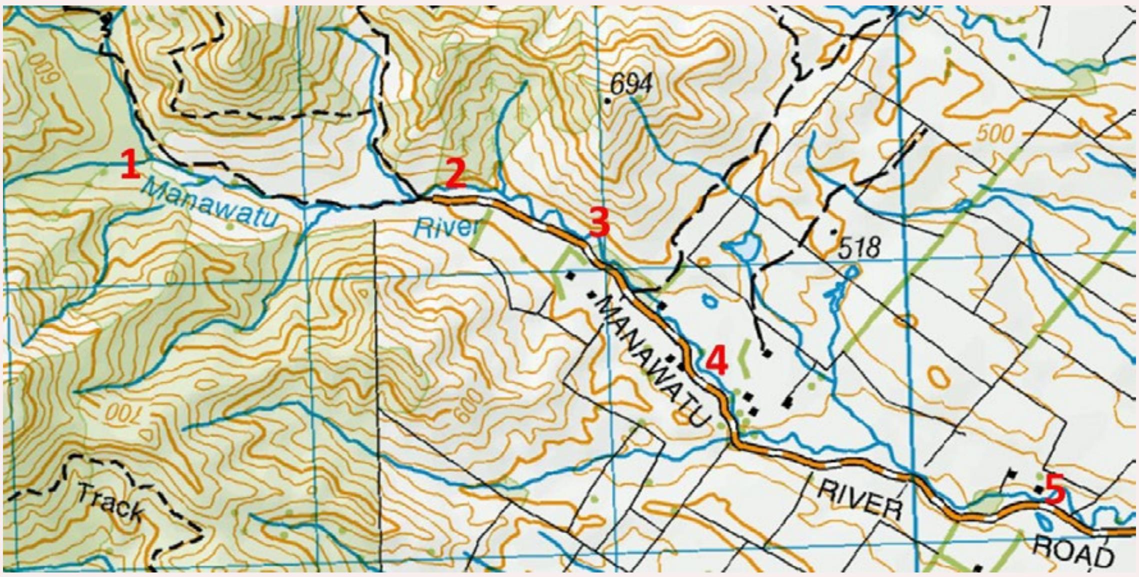
Penelope Drysdale says the research has highlighted that Te Miro Farm ecosystems have the ability to filter out pathogens and create habitats for taonga species to thrive. "Our ability to filter *E. coli* is evident. The last testing showed that there was significantly less *E. coli* leaving the farm than was coming in."

AgResearch's Cookson says that while *E. coli* counts from water are notoriously variable, "it is clear from the results that the retirement from grazing and planting of riparian margins is having a beneficial impact on reducing contaminants from the Te Miro Farm dairy platform reaching the waterway. Importantly, we were able to see when elevated *E. coli* counts did rarely occur, a specific farm practice could be pinpointed as being the potential cause.

"The striking thing for me was the range of species identified using the eDNA analysis and the way in which it facilitated community engagement. I was also excited by the apparent changes in ecosystem health as we moved downstream from the reserve site and the apparent resilience of the ecosystems to the recent heavy rainfall events, including the dump from Cyclone Gabrielle."

Growing community understanding

Involving the wider community was an important focus for the project from the beginning, with eDNA sampling kits that children were able to use.



1. Native bush reserve
2. Ngāmoko whare/information kiosk within hill-country sheep and beef farm
3. Site where Manawatū River enters Te Miro Farm
4. School's freshwater quality wānanga site
5. Site where Manawatū River exits Te Miro Farm

Figure 1. Spatial representation of Manawatū River sample sites for eDNA investigation.

Study site in full flood associated with Cyclone Gabrielle heavy rainfall event, 14 February 2023

eDNA results can give genuine insights into what might be lurking unseen.

The water sampling provided an opportunity for kaihautū and rangatahi from Pūhoro STEMM Academy to participate in the kaupapa and experience new technologies that align with mātauranga Māori and cultural health measurements of ecosystem health.

From the data collected, Wilderlab produced a 'tree of life' graphic showing all the birds, insects, aquatic life, plants and animals that left their eDNA signatures at the sample sites.

However, there isn't currently a way to determine how many individuals of each species are identified by the sample. Susan Welsh, data scientist and developer with Wilderlab, explains: "Different species shed DNA at different rates and interact with the water differently. For example, the 413 sequence reads for kererū [at Reserve, Site 1, February 2023] could come from one large deposit of DNA from one individual emptying their bowels in the water as they fly over, or it could come from numerous smaller deposits of DNA such as from multiple birds drinking from the water."

Wilderlab hosted a workshop for Māori environmental groups, the Drysdale whānau and Pūhoro STEMM Academy, to go through the results in more detail and provide further information about the technical aspects of the eDNA analysis. Results from this analysis have also been widely socialised during community events at Te Miro Farm and a riparian community planting day attended by farmers, teachers, school children, Horizons Regional Council staff and local conservation workers.

The project report links to the eDNA results and Wilderlab website have been made available to the local community through Facebook posts. Permanent posterboards highlighting the 'tree of life' associated with different sample sites have also been installed at the Te Miro Farm Wānanga nursery.

Insights and next steps

The project team is hoping to carry the project on for a further six to 12 months. They identify several opportunities created and demonstrated by their project: the progression of science; hapū reconnection and engagement; education; awareness of a new tool as a holistic measure of the health of waterways on-farm; and helping conservation by identifying species that need extra protection and those that require extra pest management.

The Drysdales plan to hold an event at Te Miro Farm to release the project's findings and celebrate its achievements. "We will also promote the use of eDNA as a holistic measure of the health of ecosystems in and around our waterways on-farm," says Penelope Drysdale.

Drysdale says collaboration is why the project worked so well. "We all have different strengths and different things we are wanting out of the project, but ultimately we all want the same thing – the health of our awa."

Elaine Fisher for the Our Land and Water National Science Challenge

"We will also promote the use of eDNA as a holistic measure of the health of ecosystems in and around our waterways on-farm," says Penelope Drysdale.

Nurse pines could support native regeneration

Pines as a nurse crop to establish natives

Why: To investigate the practicality of using pine forest as a nursery crop for the regeneration of native trees and shrubs, and to outline the required management and economics of leveraging Emissions Trading Scheme (ETS) payments.

Where: Waikato.

Who: Steve Howarth (AgFirst) and Adam Forbes (Forbes Ecology).

What:

- Natives do naturally regenerate as an understorey in pine plantations, but are generally too small to be effective for long-term forest development.
- Enrichment planting of canopy species would be required to regenerate a native forest, with selective poisoning of pines to create spaces.
- Carbon storage of native understorey in a pine plantation was calculated to be 1.5 tonnes of carbon/ha (compared with 88 tonnes carbon/ha for a *Pinus radiata* stand).
- Control of mammalian browsers, including deer and goats, is essential to ensure the success of transitional forestry.
- Planting natives carries a large upfront cost and may be putting farmers off. Using pines as a nurse crop reduces upfront costs, and enables a higher income stream through the ETS for the first 16 years (claimed under averaging accounting at $70/t CO_2e). By year 50 the cumulative total cashflow is +$3,181/ha, but due to ongoing weed and pest control costs by year 69 cashflow has reached $0.

Research shows taking advantage of ETS payments for pine forestry could effectively subsidise the costs of planting native trees – but it requires a long-term intergenerational approach.

Native forest can be established using pine trees as a nurse crop and Emissions Trading Scheme (ETS) payments to help pay for initial costs – but it is not a money-making exercise, a research project shows.

"For farmers looking to establish natives on marginal land, using pine trees as a nurse crop is a less costly option than planting natives in year 1," says Waikato consultant Steve Howarth.

The research started following a conversation between Howarth and farming leader Martin Coup, wondering whether there was a way to leverage ETS credits to make planting native trees and shrubs on marginal hill country more affordable for farmers.

"Say you have a steep paddock out the back of the farm that could be retired and planted in natives but there are high upfront costs – you could be talking $20,000 to $30,000/ha to plant the natives, and then you need to actively manage pests and control weeds as well," Howarth says.

"We saw pine blocks where some of the understorey appeared to be natives and we wondered, 'Why is that, and is there an opportunity for a lower entry point into natives using pines as a nurse crop?'," he says.

They contacted ecologist Adam Forbes, an expert in forest regeneration, to assess whether pines could be a suitable nurse crop. Funding was provided by Our Land and Water's Rural Professionals Fund.

"There is some uncertainty over the potential of regeneration in the understorey and the long-term

Participants on a field day visit a 33-year-old radiata pine plantation located in the King Country to discuss levels of native regeneration and management requirements

forest outcomes. That's partly because we haven't been doing this long enough to know, and there are not many empirical examples," says Forbes.

Given he had eight months for the project, not the years or decades a full trial might take, Forbes undertook a vegetational survey in rotational *Pinus radiata* plantations in Waikato, using them as an analogue for non-harvest plantations.

"I surveyed stands that were greater than 20 years old because I know that not much happens before that time in terms of regeneration. It's important to note that these sites have had no specific management, they're just rotational forests," he says.

Counting native trees

Forbes surveyed 25 plots of 10 m x 10 m, working with forestry investment company Manulife in structuring the survey along elevation gradients. Sampling was taken usually at every 100 m elevation difference to explore variability in the understorey composition and structure caused by variability in climate.

The most abundant native woody species found was mahoe (*Melicytus ramiflorus*), on average about 1,100 stems/ha.

Every native tree and shrub in the plots were counted and multiplied by 100 to give a per hectare count. In some places there were large numbers of natives growing, but in others none or very few. The greatest number counted was 18,600 stems/ha, but overall the mean was 4,112 and most of those stems occurred as seedlings, not saplings or trees.

"Seedlings are anything up to 1.35 m, about breast height. Saplings are the next stage, taller than 1.35 m but not greater than 2 cm diameter. Trees are greater than 2 cm diameter and greater than breast height," Forbes explains.

Mature *Pinus radiata* plantation containing good regeneration of one readily dispersed species, *Brachyglottis repanda* (Rangiora), but low diversity and lacking tall old-growth species

High levels of mammalian browsing impacts native forest regeneration and reduces diversity and the prospect of successional development

The most abundant native woody species found was mahoe (*Melicytus ramiflorus*), on average about 1,100 stems/ha. There were four native trees appearing in greater than 200 stems/ha and there were a further 32 native species occurring at stem densities less than 200/ha.

"The point is that these species are quite short-statured, short-lived trees so that's not particularly great for long-term forest development," he says.

What was missing were significant numbers of taller canopy trees. Tawa, an important North Island canopy tree, was present at an average 48 stems/ha, totara and miro both at at 8 stems/ha, matai at 4 stems/ha and kamahi at 4 stems/ha.

Forbes calculated the average basal area of native trees and shrubs in the plots at 2.7 square metres/ha and determined this vegetation was holding about 1.5 tonnes of carbon/ha.

"This is probably the first time this has been calculated. A *Pinus radiata* stand would have about 88 tonnes/ha and here we're talking 1.5 tonnes in the native understorey, so it is a relatively small amount of carbon being stored," he says.

Another important finding that must be considered is the effect of mammalian browsing, mainly deer and goats that feast on palatable natives.

Although this is quite low, Forbes points out this is effectively a baseline and a mature native forest would hold more carbon. To achieve that, he says, plots would have to be actively managed to create conditions for taller canopy species to thrive.

Active management requirements

Forbes says another important finding that must be considered is the effect of mammalian browsing, mainly deer and goats that feast on palatable natives.

"There's a lot of damage being done by those animals," he says. "Browsing the vegetation is one thing, but the deer tend to rub their antlers and ringbark the trees, and can even pull small trees out of the ground or bend them over. It's quite devastating."

Unless those pests can be controlled, native revegetation projects will be severely impacted, he says.

While there are obstacles to overcome to make transition forestry work, Forbes does see positives. "When I was doing my data collection, at the end, I'd just stand and look at the plot and go, 'Is there actually a future forest here based on what I'm seeing?', and there were some sites where I said, 'Yep, if the browsers could be addressed, this has got potential'."

With that in mind, he worked with Steve Howarth to create a management plan for farmers considering planting pines with a view to transitioning to natives. To assist with the transition, the management plan includes selective poisoning of pine trees coupled with

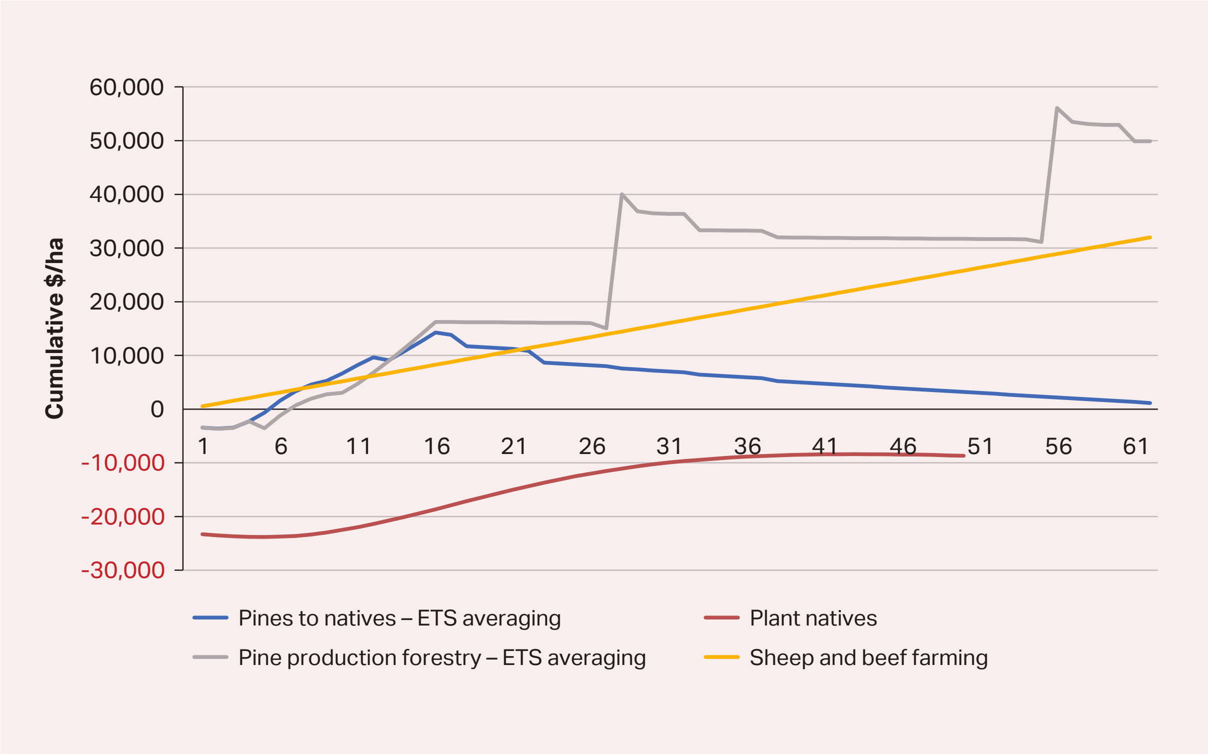


Figure 1: Cumulative cashflow

Field day participants discussing one of the project field survey sites

planting of native canopy species (such and totara and rewarewa). This is to ensure each gap contains species capable of taking up a position in the canopy, a practice called enrichment planting.

By year 38, it is assumed that established native trees will have become a seed source and natural recruitment will have been established.

Crunching the costs

Carbon credits are claimed under the ETS using averaging accounting for *Pinus radiata*. For the first 16 years, at a carbon price of $70/tonne, this provides a total income of $22,150/ha. Costs associated with establishing pines totals $3,000/ha, and to establish the natives costs $7,655/ha. Ongoing costs for weed and browser pest control are estimated at $6,934/ha for the first 50 years.

Including costs under the ETS, the cumulative total return at year 50 is $3,181/ha.

"These are all high-level indicative costs and anyone considering this should complete a site-specific management plan and costings," Howarth points out.

There is no further income after year 16 to offset ongoing costs. By year 69, the cumulative total return has reached $0 (see **Figure 1**).

"It's an exciting concept and it does provide a lower-cost entry into natives," says Howarth. He reasons that landowners who go down this track will do so not for the ETS income, but to fund establishment costs of a project with a multi-generational timeline.

"You would do it to enhance biodiversity and the aesthetics of the farm. The high upfront costs to plant natives I believe are putting many farmers off. Using pines as a nurse crop reduces costs and helps get some cash in the bank from the ETS straight-up, and that does pay those initial establishment costs," he says.

Tony Benny for the Our Land and Water National Science Challenge

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