INNOVATIVE IDEAS TESTED ON-FARM BY RURAL PROFESSIONALS FUND PROJECTS 2020–21

New Ground

ISSUE NUMBER 1

National SCIENCE Challenges

OUR LAND AND WATER

Toitū te Whenua, Toiora te Wai

Sign up to our newsletter

Sign up to the Our Land and Water newsletter for an update every two months about research news and funding opportunities – including the Rural Professionals Fund. **www.ourlandandwater.nz/enews**

New Ground

Volume 1 (December 2021)
ISSN 2744-7936 (Print) ISSN 2744-7944 (Online)
Publisher: Our Land and Water National Science Challenge
ourlandandwater@agresearch.co.nz

Contents

Horticulture/arable

Dairy

Sheep and beef

Cross-system

Cover: Sunflower crop established with strip-till method (see page 3). Photographer: Wadia Kandula

Exploring new ground

Richard McDowell

Kiwi farmers are creative and resourceful, often trying out new ideas and practices because they are curious to see what will happen.

As a science funder, we're used to hearing big ideas from scientists seeking research funding. But we wondered, how many promising ideas are stuck on one farm – or inside a farmer or rural professional's head? Loads, it turns out.

In May 2020, we launched the Rural Professionals Fund, with strong encouragement from the New Zealand Institute of Primary Industry Management. Its aim is to fund the rapid testing of innovative ideas that could create change for Kiwi farmers.

The Fund connects farmer innovations with the scientists who can assess them, and with rural professionals who can share them with other farmers.

The Rural Professionals Fund received 31 applications for its first funding round. The 15 projects selected encompassed a wide variety of farm systems, industries and ideas, tackling questions including:

- Does pure, clean drinking water improve milk production in cows?
- What horticulture and arable options are suitable for hill country?
- Does regenerative-style farming produce higher-quality meat?
- Should we grow more trees in pastures?
- How do farmers make land-use change decisions?
- Can we make it easier for farmers to prioritise mitigations?
- What are the pros and cons of using drones for environmental monitoring?

The projects all have one thing in common: if the concept was proved, it could create benefit for New Zealand farming communities, our land, or our water.

Communicating the results of both successful and unsuccessful projects to the wider rural profession and farming community is a crucial part of the process. In the pages that follow, you'll read about projects with promising results, and others that didn't prove their concept.

The projects in the pages in this magazine were each completed with $50,000 of funding from the Rural Professionals Fund; some received co-funding from other organisations, and all were boosted by the time freely donated by participants. Almost all the projects were completed within six months.

These were challenging limits, and we commend the project teams for doing so much, so quickly, within tight limitations.

A second round of the Rural Professionals Fund projects closed in August 2021, with 12 projects funded from 47 applications. This time, investment has been bumped up to $75,000 per project over a longer timeframe.

Two more funding rounds are planned, for late 2022 and 2023. Projects must align with the Our Land and Water objective: to improve Aotearoa's land and water quality for future generations, while enhancing the value of the primary sector to New Zealand.

From the Rural Professionals Fund, we hope to see concepts emerge that generate evidence and move into action quickly. We are particularly interested in projects that will help to diversify land use and practices, effect behavioural change and create new ways of doing things across the agri-food and fibre system.

The Rural Professionals Fund allows us to quickly explore a lot of options, and encourage and resource more innovators and entrepreneurs to test their good ideas. We encourage you to submit your smart idea and explore new ground in the next funding round.

Richard McDowell is chief scientist, Our Land and Water.

Sign up for email notification when the next Rural Professionals Fund round opens at: ourlandandwater.nz/news-events/

Seeds of change

The benefits of reduced tillage to combat soil degradation are well known internationally. Strip-till is widely used in New Zealand for commercial maize crops, but little is known about how effective it could be for hybrid vegetable seed crops

Novel crop establishment for high-value hybrid seed crops in Canterbury

Participants: Canterbury cropping farm above Lake Ellesmere

Project team: Richard Chynoweth (Foundation for Arable Research), David Birkett (farmer) and Prof John Hampton (Lincoln University)

Report: Report on strip-till trial (ourlandandwater.nz/RPF2020)

Technical information

Project aim: To see if strip-till would be suitable to produce hybrid vegetable seed crops.

- The trial area was prepared using conventional cultivation, utilising discs, a Maxi-till and a Cambridge roller, and strip-tillage using a Kverneland Kultistrip, cultivating a strip at 50 cm row spacings. The cultivation techniques were repeated four times across the paddock in which eight drill rows of radish were subsequently established.
- Drilling used the same precision planter for both treatments targeting nine radish seeds/m of drill row with standard crop management over all the rows for the growing season.
- Seedling counts, weed counts and types, along with canopy height and numbers of flowering branches were undertaken at various times, and soil moisture monitored.
- Seedling establishment did not differ. There was no difference in the spectrum of weeds between the strip and the conventional cultivation. Using strip-till could cause less damage to soil structure and produce fewer emissions.
- As fertiliser was broadcast across the paddock before the strip-till went across it and radish plants don't have wide spreading roots, a lot of fertiliser was then left sitting between the rows where the plants could not pick it up. Placing fertiliser down underneath the plants with the first strip-till could save 30–40 percent on fertiliser costs.

It is common to see stock grazing on cropping paddocks over the colder months around Canterbury.

Generally, it's dairy farmers making the most of the pasture or other cover crops like oats, prior to calving. Sheep are also common, coming off the dry hills, particularly around Banks Peninsula when there's not much feed for them, and over-wintering on the flats. It is a system that benefits everyone.

On David Birkett's cropping farm near Leeston you'll only see sheep. Cattle are heavy and more likely to damage the soil structure, David says. This is part of his overall farming strategy of low soil impacts and low inputs on his cropping land.

David is the third generation to grow crops on this family farm above Lake Ellesmere. He was one of the first farmers to get into vegetable seed production 20 years ago, and now grows around 10 different crops in rotation (mostly for seed) each year including wheat, barley, ryegrasses, clovers, beans, peas and radish.

David's family has owned this farm for 90 years, and it was previously cropped by its original European settlers in the 1880s. This amounts to 140 years of routinely disturbed earth.

His interest in growing vegetables like radish using lower soil impact strip-till led him to join in research with Richard Chynoweth of the Foundation for Arable Research (FAR) and John Hampton from Lincoln University for this Our Land and Water Rural Professionals Fund project.

Cultivation in Canterbury

Canterbury is one of the biggest seed multiplying areas globally, with about one-third of the world's white clover seed, one-third of all ryegrass seed, and about one-third of all radish and carrot seed coming off the plains, says Richard.

"Most of the seed comes from the Northern Hemisphere in their off-season and is sown in Canterbury. When the resulting seed crop is harvested, it is sent back again. This can see 1 kg of grass seed sown produce 2,000 kg of new seed," says Richard. "Around 200 different cultivars of ryegrass are grown here, far more than the number available for our own pasture. New Zealand growers also produce vegetable seed from about 100 different species."

Full cultivation is still common. This prepares the soil for the fine seed bed that many arable crops need, but it can be very aggressive. The top 15 cm of soil can be torn and turned using a plough, discs and rippers. Not only does it

Strip-till was used by farmer Stu Macaulay for his high oleic oil sunflower crop

Strip-tilling creates a narrow, cultivated strip into which the seed is sown, leaving the rest of the area uncultivated.

damage soil structure, but the soil is also more prone to erosion from wind and water run-off.

Less invasive strip-till is still relatively new on the cropping scene in New Zealand, with adoption in Canterbury beginning over the last few years. Strip-tilling creates a narrow, cultivated strip into which the seed is sown, leaving the rest of the area uncultivated. The aim is to create a favourable seed-bed within the strip only, similar to that achieved by conventional cultivation. It is widely used for crops like maize but there is little research on how useful such cultivation could be for vegetable seed crops.

There are some real benefits to moving away from full cultivation where possible, Richard says. Organic matter breaks down quickly when exposed to oxygen and water, and the microbes get going. Direct drilling and strip-tilling delays breakdown and nutrient release, and delays breakdown of material between the rows, giving a steady stream of nutrients over time.

The strip-till vs conventional till process

Sheep had been grazing on one of David's paddocks planted up with oats over winter, leaving a layer of plant material covering the soil. After spraying off the oats with glyphosate in mid-August, fertiliser was then broadcast and worked in by cultivation on the main paddock, and strip-tilled in the trial rows.

The seed being used was to produce a hybrid European round radish, which sees pollen produced by the male parent plants (SPS11030M) received by the female parent plants (PS11030FM). Across the paddock are sets of six female rows separated by two male rows with 50 cm between the rows.

One set of eight rows used conventional tillage, while the other set of eight rows used strip-till. This was repeated four times in the paddock.

The cultivated rows got the full treatment: disced, Maxi-tilled for pre-emergence herbicide Treflan, then base fertiliser applied and disced in, and 'Cambridge rolled' before planting.

The strip-tillage rows had a specialised Kverneland Kultistrip machine, which has changeable row spacing of 45–80 cm with cultivation depth able to be altered between 10–30 cm, and is a popular choice. So too is the multi-role tillage and Mzuri seed drill. The first strip-till pass was in early September, and another pass 10 days

Table 1: Seedling numbers 5.5 weeks after sowing, plant height, weed density, number of flowering branches per plant, white blister lesions and seed yield for full cultivated and strip-till radish seed crop at Leeston

	Seedling (m^2)	Height (cm)	Weeds (m^2)	Flower branches (per plant)	White blister lesions (m^2)	Seed yield (kg/ha)
Treatments	23-Oct	24-Dec	24-Dec	24-Dec	26-Feb	9-May
Full	17.2	976	3.9	11.1	9.8	910
Strip-till	16.5	835	2.9	8.7	7.4	960
LSD 5%	3.3	136	4.5	2.3	1.4	118
F.prob	0.52	0.046	0.53	0.048	0.011	0.184
Significance	NS	*	NS	*	**	NS
% IMF	17	12	NS			

Table 2: Maximum and average soil moisture deficit 25 November – 16 February 2021 for full cultivation vs strip-till radish seed production grown with irrigation at Leeston 2020/21

	Max deficit (mm)	Avg deficit (mm)
Full	25.4	12.6
Strip-till	28.4	15.6
LSD 5%	8.0	1.4
F.prob	0.32	0.006

later before being 'Cambridge rolled' before drilling. Treflan was applied at the same time as the full cultivation rows but not incorporated.

Drilling used the same precision planter for both treatments, targeting nine seeds/m of drill row with standard crop management over all the rows for the growing season.

A count was taken of the numbers of radish seedlings that had established after about five weeks, along with weed counts, the height of the canopy and number of flowering branches per plant at Christmas time (see Table 1).

Neutron probes were put in each row measuring soil moisture at depths down to 60 cm in late November for weekly readings from five depths (see Table 2).

The amount of white blister disease (*Albugo candida*) in the crop was also assessed in late February before the crop was desiccated in early April, with the seed harvested a month later with a Case IH, 'Axial Flow' combine.

How it went

Seedling establishment did not differ, although the strip-till radish got off to a slower start. This was likely due to the soil being slightly cooler to start with, from crop residue covering much of it. The maximum moisture deficits between the two establishment practices were not significantly different. There was no difference in the spectrum of weeds between the strip and the conventional cultivation. White blister disease was lower in the strip-till rows.

There was no difference in radish seed yield.

Along with a thumbs up from David, Owen Gibson of FAR also surveyed other Canterbury farmers who had previously used strip-till. They highlighted the following benefits:

- provides a fine seed bed tilth within the rows without disturbing the entire paddock
- soil erosion is greatly reduced
- soil strength and health are improved, and more soil moisture retained
- increased ability to graze livestock in the winter increases profitability of the system
- can cultivate into existing grass/forage crop without the more invasive cultivation techniques needed to prepare a conventional seed bed.

Next steps

The trial has confirmed a change for the future for David. Not only can he protect his soil structure more with lower impact strip-till, but he will also produce fewer emissions and save money.

The tractor the contractor had used for the strip-till rows has a 100 hp engine compared to David's usual 180 hp tractor, so less eCO_2 emissions. With just two passes for the strip-till he also saved on another pass needed for the conventional crop.

On top of that there would likely be less of a weed burden in the non-cultivated parts of the paddock, so this means less additional passes with herbicide applications on a strip-tilled paddock.

Fertiliser costs could also be conservatively reduced by 30-40 percent, David reckons.

In the trial the fertiliser was broadcast across the paddock before the strip-till went across it. Radish plants don't have wide spreading roots so a lot of fertiliser was then left sitting between the rows where the plants could not pick it up. In the future, David says he would put the fertiliser down underneath the plants with the first strip-till.

– Delwyn Dickey for Our Land and Water National Science Challenge (CC BY-4.0)

Finding the key to perfect apples

Differences to fruit yield and quality among apple trees within an orchard is one of the biggest challenges for growers. Could more targeted water and nutrient application for trees on lighter soils reduce this variation?

Reducing variation in apple tree yield through targeted water and nutrient application

Participants: 23 ha apple orchard, Kono Horticulture, Motueka

Project team: Greg Dryden (Fruition Horticulture), Mike Nelson (Fruition Horticulture) and Dr Ken Breen (Plant & Food Research)

Report: What are the opportunities to reduce variability in apple tree productivity through targeted (sub-block) water and nutrient application? (ourlandandwater/RPF2020)

Technical information

Project aim: To see if trees on different soil types on the same apple orchard blocks would benefit from a more targeted water and nutrient supply and reduce the difference in yield and fruit quality.

- Sand made up about half of the Hau stony sandy loam, slightly less in Riwaka medium sandy loam, and with Riwaka silt loam having between 35-45 percent.
- Electromagnetic (EM) soil survey results showed differences in soil composition.
- Chemical analysis found little difference in nutrient supply among the soil types and all samples.
- Too much water and nutrients were being added to show any benefit from soil type variation, but benefits may arise if inputs are reduced.

The vineyards and orchards that make up the horticultural food basket of the Nelson and Marlborough areas create a patchwork across what are the remains of huge river deltas. The rivers have meandered here over millennia on their way to the sea, distributing silt and clay, sand and gravel.

This makes for a complicated soil map in the area, with sweeping variations of soils found, often within the same orchard, hop or vineyard block.

For horticultural consultant and Fruition managing director Greg Dryden this can be challenging, as it leads to differences of yield and fruit quality in the various crops grown across the region. “Variation is probably one of the biggest limiting things in orcharding,” he says.

Greg could see the potential when fellow consultant Mike Nelson and plant physiologist Dr Ken Breen of Plant & Food Research were keen to run a research project through Our Land and Water with funding from the Rural Professionals Fund.

They wanted to look at the potential for reducing tree variability within an apple orchard using targeted water and nutrient application. Any insights from the project could be applied across the region.

New Zealand already has an enviable international reputation for apple production, with the highest productivity per hectare in the world. Averaging around 85 tonnes of fruit per hectare annually, 400,000 tonnes of these apples are exported fresh each year with a value of $876 million.

Having more fruit across the orchard reach maturity at the same time, along with reducing the amount of low-quality fruit which attracts a lower value and often ends up processed, could mean significant gains for the industry.

Does one size fit all?

Current orchard management sees a one-size-fits-all approach to irrigating the fruit trees without considering the different water- and nutrient-holding properties of the various soils across a block.

Smaller trees growing in Hau stony sandy loam produced more than larger trees growing in Riwaka silt loam

Current orchard management sees a one-size-fits-all approach to irrigating the fruit trees without considering the different water- and nutrient-holding properties of the various soils across a block.

Was there a relationship between the various soil types and the health and productivity of trees growing across a block? If there was, could putting in an additional water/nutrient line through the orchard, to give more targeted supply, reduce the variability in fruit and justify the installation cost?

The more sand the less water the soil can hold, and the more frequently you should be irrigating, says Mike Nelson. He wondered if trees growing in an area of soil with a lighter texture could have suffered a wee bit every month, affecting their health and productivity compared to trees on more silt and clay soils which hold moisture better.

Kono Horticulture gave the team access to one of their apple orchards in the Motueka area and its production data. The 23 ha block, planted up with 10-year-old ‘Scilate’ (Envy™) on ‘M9’ rootstock, had four soil types running through it. The lighter soils – Hau stony sandy loam, Riwaka medium sandy loam and a heavier Riwaka silt loam – were chosen to give a range of soil textures.

There were 20 plots within each soil type with about 21 trees per plot. The circumference of the trees’ trunks in each plot was measured 20 cm above the graft union to find the trunk’s cross-sectional area (TCA) to give an idea of the historical vigour of the trees.

Soil moisture levels were monitored using Sentek continuous monitoring probes to 90 cm on one site on each soil type.

Soil composition (texture) for each plot was found by mixing multiple samples taken in the top 15 cm of soil, breaking particle bonds by vigorously shaking powdered detergent with water and letting the soil settle into its constituent particles of sand, silt and clay. Soil samples were also sent to Hill Laboratories for chemical analysis.

Next, an (EM) soil survey was undertaken (see Figure 1). Coarse soil texture like sand has low electrical conductivity, clay soils high, and silt soils medium conductivity. Measurements were taken at two depths (0.4 m, 1.2-1.4 m), with mean values for each plot derived from a 3 m radius from the plot centre.

Plans to take yield data from the trees in the various plots were dashed after the area was pelted with hail in late December and management changed to help the trees recover. Fruit load was then estimated on 7-10 trees within each plot.

In February, when the trees were most likely to be struggling in the heat and dry of summer, a snapshot of the orchard block was taken by satellite using normalised difference vegetation index (NDVI) imaging (see Figure 2).

When plants are growing vigorously with lots of photosynthesis going on, they absorb visible light (especially red light) and reflect large amounts of near-infrared light. Stressed plants absorb very little red light.

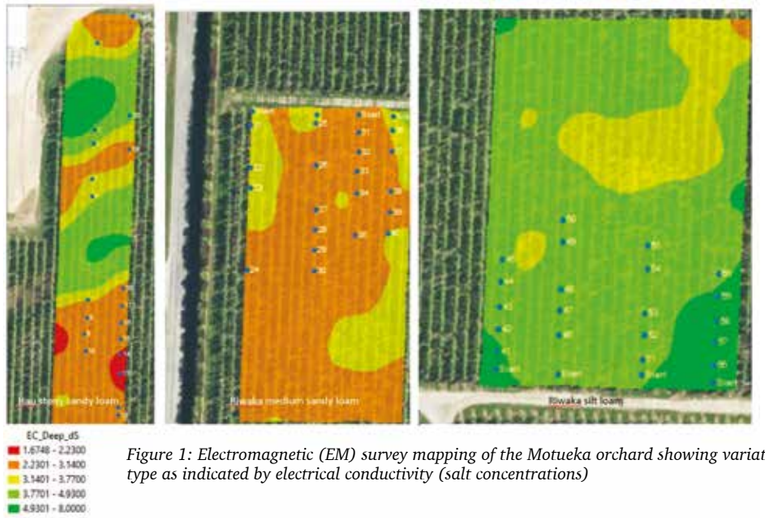


Figure 1: Electromagnetic (EM) survey mapping of the Motueka orchard showing variation in soil type as indicated by electrical conductivity (salt concentrations)

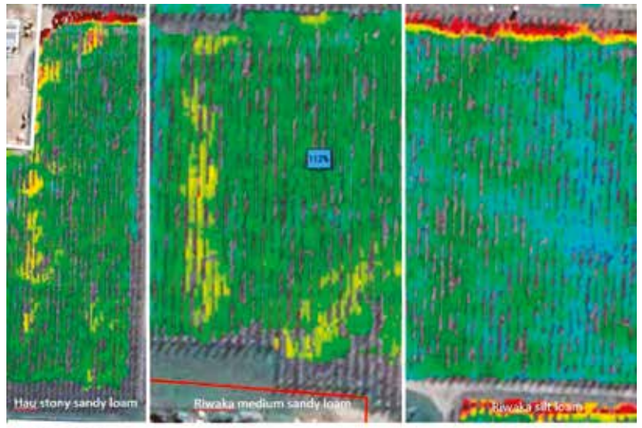


Figure 2: NDVI satellite mapping measures near-infrared light reflectance on the Motueka orchard

In the images, lots of blue and green equates to vigorous growth while yellow, orange and red represent reduced photosynthesis, stressed trees and less vigorous growth.

Vigour isn't better

The NDVI threw a bit of a curve ball. Instead of showing trees in stress on the sandier parts of the block, it actually showed little stress anywhere and a lot of unwelcome growth. There was likely an oversupply of water and nutrients to virtually the whole block, with management practices probably behind this. There is a tendency to oversupply to ensure there is no undersupply of water and nutrients.

The trees showing most vigour (blue) were those with the biggest trunks, indicating this oversupply had been going on for some time.

While big vigorous trees might sound ideal, they don't produce the most fruit. Big trees put more energy into shoots, leaves and branches, diverting nutrients away from the fruit, which has a negative impact on its colour, flavour and looks. Only the leaves around the fruit do the work to size that fruit up.

Bulkier trees also shade their lower buds. Orchardists are after fruit over the entire height and breadth of the tree.

Over a three-year period, the smaller stony Hau trees produced about 33 percent more fruit than the bigger silt loam trees, but had about half the biomass.

Next steps

While the trial did not show a need for targeted watering, it did point to a need to investigate reducing inputs of water and nutrients.

Horticulture/
arable

Measuring real-time nitrate loss from cropping leachate

Farmers want to look under the bonnet to see how something works. With more pressure to measure and reduce nitrate loss in leachate from vegetable production, real-time measurement may help link better management to lower nitrate losses.

Measuring real-time nitrogen losses in vegetable production

Participants: 16 ha cropping paddock near Clive, Hawke's Bay

Project team: Jamie Thompson (consultant, Ravensdown Fertiliser), Chris Zuierwijk (grower, Bostock New Zealand) and Bruce Searle (crop physiologist, Plant & Food Research)

Report: RPF4 Project Report 2020/21 Q4 (ourlandandwater.nz/RPF2020)

Tech note: Nitrate-nitrogen leaching in horticulture (ourlandandwater.nz/RPF2020)

Technical information

Project aim: To find an accurate way to measure the amount of nitrate leaching from a cropping paddock in real time, giving growers the chance to alter management practices for more control.

- A TriOS Nico nitrate sensor (TriOS Optical Sensors, Denmark) fitted into the Bostock paddock drainage sump detected 8 percent more nitrate than grab samples. This difference is not material.
- Nitrate leaching losses largely followed the pattern of drainage losses, with spikes during heavy rain and irrigation events.
- Coupled with forecasting rainfall, this data could help management to reduce nitrate leaching losses.

Intensive export and process vegetable growing is the name of the game on the Heretaunga Plains in the Hawke's Bay. Around 5,800 ha of vegetables are planted annually, with a combination of conventional and organic horticulture soaking up both the sun and plentiful rain.

It is a busy and dynamic landscape. Gulls flock to soil behind tractors turning paddocks for new crops in spring. The back and forward of tractors applying fertiliser. Irrigation guns shooting water streams on hot summer days.

But regulations are tightening up around crop cultivation under the Hawke's Bay Regional Council's proposed Plan Change 9 (TANK). Hundreds of horticultural growers would need to develop a management plan, including identifying and addressing risks to waterways from nutrient (nitrogen and phosphorus) loss. Nitrate is the main form of nitrogen being lost in these systems.

Measuring the amount of nitrate being lost through leaching and drainage in real time presents growers with a serious challenge. There is a big knowledge gap around nitrate losses from vegetable systems, especially in how crops respond to daily management decisions – let alone cropping cycles.

"We know there are nitrate losses, but there was no tangible way of knowing what those losses were," says Ravensdown consultant Jamie Thompson.

Jamie developed a project, funded by the Our Land and Water Rural Professionals Fund, to help fill that gap. The project aimed to provide data to improve existing modelling, or develop new models that better reflect those changing conditions.

Organic conversion

Jamie connected with Bostock New Zealand grower Chris Zuierwijk. Bostock is the biggest organic apple grower in

Figure 1: Changes in sump nitrate-nitrogen concentration over the cropping period. Both sensor and grab sample nitrate-nitrogen concentrations are shown along with rainfall, irrigation and fertiliser applications

the southern hemisphere and is currently moving their cropping operations to organic production. This will see 1,500 ha of organic cropping added to 680 ha of organic apple orchards, with most of these crops exported.

Having been a grower with Bostock using both conventional and organic production methods for 12 years, and as a nurseryman growing seedlings for other growers before that, Chris has a broad understanding of cropping in the area.

A year ago, Bostock began looking at bringing a 16 ha cropping paddock near Clive into organic production. The conversion process would end the use of any conventional inputs and synthetic fertilisers. After the land had been lying fallow over winter, one last conventional crop of onions would be grown by Chris before he changed over to organic management.

Although not officially part of the original Our Land and Water project, which would cover the last onion crop, this changeover would give Jamie and Chris a fascinating opportunity to not only measure the levels of nitrate coming off a standard vegetable block, but also compare the difference organic management might have on losses on the same piece of land.

The soil in the area is naturally poorly drained, with a dense clay-rich subsoil about 50 cm below the soil surface, and with a high water table in winter adding to the problem. This sees paddocks in the area growing high-value crops increasingly being artificially drained.

The Bostock-managed paddock has tile-and-mole drainage. All the drains in the paddock lead to a single sump. Jamie installed a TriOS Nico nitrate sensor, one of the sensors used internationally to measure nitrate-nitrogen concentrations in wells and sumps. Comparing this data with that of regularly collected water samples analysed in a lab would show how accurate regular sampling was and whether events were being missed, as well as the effects of irrigation and wet weather events on nitrogen leaching.

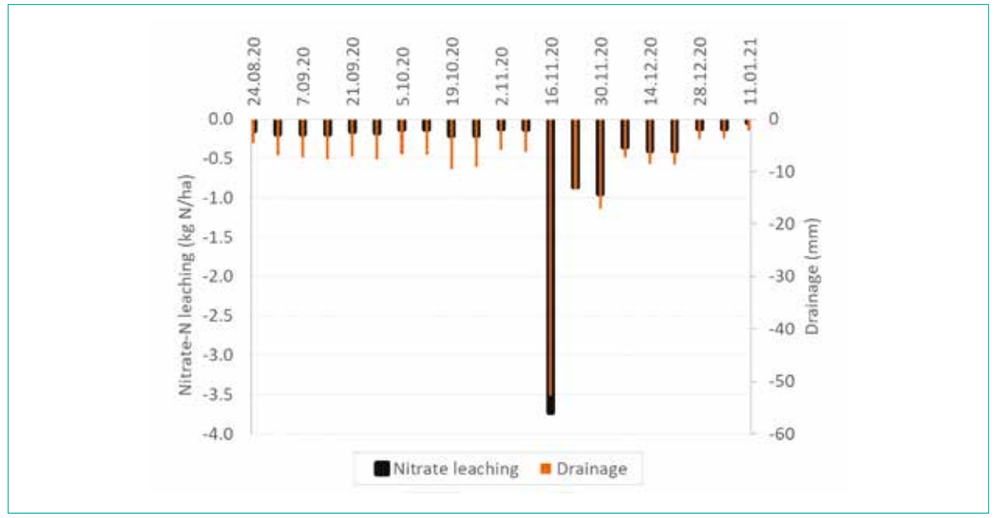


Figure 2: Drainage and nitrate-nitrogen leaching losses over the cropping period – plotted as negative numbers to represent system losses

We know there are nitrate losses, but there was no tangible way of knowing what those losses were.

In real time

Soil samples were collected when the crop was planted and when the crop had finished in January. Samples were sent to Analytical Research Laboratories (ARL) in Napier to measure mineral nitrogen.

After the onions were planted in early August, fertiliser was applied four times, about a month apart, from early September, with a total of 153 kg of nitrogen applied per hectare.

Soil moisture was gauged every couple of hours at 15, 30 and 60 cm depths at the front and back of the field by Decagon sensors, with weekly drainage recorded by two flow meters.

The TriOS Nico nitrate sensor Jamie had installed in the sump measured the nitrate in the water every hour, and every week a sample of the same water in the sump was collected, immediately taken to ARL and the nitrate concentration measured.

Chris took note of the eventual onion crop yield, with 20 onions also going to ARL to measure their nitrogen content.

Outcomes

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

The sump sensor and weekly sampling showed nitrate leaching whenever it rained, with losses of about 0.16 kg/ha each week. A big downpour in November, within a week of fertiliser going on, saw a huge spike with 3.7 kg/ha of nitrate lost in a week (see Figure 1).

With the soil now saturated, nitrate leaching stayed high, gradually decreasing through to the end of cropping, with a couple of more spikes from irrigation, and 9 kgN/ha was lost in total from the paddock (see Figure 2).

The TriOS Nico nitrate sensor and the grab samples showed similar results. Summing up losses, the sensor measured 8 percent more nitrate loss than lab results. This difference is not material and means that in this artificially drained field, weekly grab samples are not underestimating nitrate losses.

This was a positive result, says Jamie, showing a clear link between management practices, rain events and nitrate-leaching. If no time was available to take grab samples, the sensor would give farmers confidence they could measure total losses, but also see real-time nitrate losses.

From this, farmers could decide if they wanted to reduce the depth of each irrigation, use less fertiliser each application, and increase the number of applications through the growing season. However, they would need to consider any potential increase in CO_2e from running machinery.

With the onion crop off the ground, Chris's organic conversion began with a cover crop of oats planted, along with using compost and chicken manure from Bostock's organic chicken operation.

Jamie has continued with the sensor and grab samples, with indications the cover crop was soaking up surplus nitrogen and reducing nitrate losses.

Next steps

Extension funding has been granted through the Rural Professionals Fund to enable a full year of data capture through the catch crops and export squash crop cycle, and comparison of 'actual vs modelled' data.

– Delwyn Dickey for Our Land and Water National Science Challenge (CC BY-4.0)

Digging for avocado gold

Finding what common soil characteristics define a high-yielding avocado orchard could help increase production by creating a benchmark for growers.

High-performance soils for avocados

Participants: 29 avocado orchards in the Bay of Plenty, Mid-North and the Far North

Project team: Tony Bradley (Aongatete Avocado), Sarah Sorensen and Miguel Tapia (NZ Avocado) and Declan Graham (Plant & Food Research)

Report: Orchard soil characterisation (ourlandandwater.nz/RPF2020)

Technical information

Project aim: To collect leaf, fruit and soil samples from 29 different avocado orchards across the north, with various soil types, and assess their chemical, physical and biological soil characteristics to find a correlation between these characteristics and high yields.

- Soil testing results from three laboratories, which use different methodologies, were compared:
  - Hills Laboratory – Hot Water Extractable Carbon
  - Linnaeus – Microbe Wise
  - Soil Foodweb – Advanced Biological Package
- None of the biological parameters that were tested correlated well to avocado yield.

The avocado industry is one of New Zealand's horticultural success stories. In 1939, fruit from nine avocado trees, raised from seed, were sold in Auckland. Sixty years later there are 4,000 ha of avocado trees bringing $234 million into the country each year.

Around half of the orchards are in the Bay of Plenty area, with large pockets around Whangarei and in the Far North, including 500 ha of new plantings in the last five years in the Far North and 400 ha at Tapora, west of Wellsford in north Auckland.

Growers have become very good at managing their orchards to produce good quality fruit and bigger yields. "Increasingly, growers are becoming interested in their soil biology as a potential avenue for productivity," says Phillip West, research director with NZ Avocado's Research Programme, "but they don't yet have a benchmark for what an avocado soil should look like."

Setting that benchmark was the intention of the High-Performance Soils for Avocado project funded by Our Land and Water's Rural Professionals Fund.

Yields vary greatly

A typical orchard might produce around 10 t/ha of fruit each year. But some regularly produce more than 15 t/ha, and some nearly double that, regardless of which area they're in and general soil make-up. There are high organic matter soils in the Bay of Plenty, more clay in the Mid-North and sandy soil in the Far North.

Tony Bradley, NZIPIM-registered consultant and head of orchard management company Aongatete Avocados, consults with 65 orchards in the Katikati/Tauranga area and some participated in the trial. He believes the industry needs to be heading toward more sustainable practices to enhance their image in the market.

"We all have slightly different recipes," says Tony, "so creating the benchmark of what a good high-yielding orchard soil looks like is an important start. From there, they can look at nutrient loss and nutrient performance within those high-yield orchards and how it affects fruit quality."

Sampling from 29 orchards saw Miguel Tapia, a research engineer with NZ Avocado, travelling from the Bay of Plenty to the Far North

For former grower and now NZ Avocado project and sustainability manager Sarah Sorensen, who oversaw the project, issues like compaction and nutrient manipulation were of most interest during her orcharding days. "The current interest in soil biology is showing how quickly the industry is evolving," she says.

Seeking balance

Heather and Gavin Chapman have a low-yielding 4.2 ha orchard with good quality fruit at Bethlehem near Tauranga. They have trees planted on raised humped rows to help drainage. They only mow the orchard four times a year to reduce compaction and allow grasses and weeds to flower for the bees, as well to retain soil moisture in the orchard overall in summer. Aside from these things, they generally follow industry guidelines for orchard management and input regimes.

Heather and Gavin were keen to find out what makes the higher-yielding orchards tick.

"We need to understand the relationship between the quality of our soils and our productivity and impacts of the inputs that we make. We might be benefiting our crop, but if you're actually causing the soil to deteriorate that's not a sustainable situation either," Heather says.

Research conundrum

Twenty-nine orchards were investigated in the project (16 were high-yield producing over 15 t/ha average over four years and 13 were low-yield at under 15 t/ha). There was good data already for 17 of the Bay of Plenty orchards, gleaned from being part of an earlier 'Avovantage' project. Two additional high-yielding orchards in the area were trialing new cultivars. Five high-yield orchards from both the Mid-North and the Far North were also included.

This saw Miguel Tapia, a research engineer with NZ Avocado, set out on a research odyssey of visual soil assessments and collection of soil, leaf and fruit samples from 10 trees on each of the orchards for analysis. Leaf and fruit samples showed no correlation to yield. Nor did the visual soil assessment relate to yield.

The methods used by Soil Foodweb, Linnaeus and Hill Laboratories to measure the soil biology were different and provided different results. The Hills Hot Water Extractible Carbon method gave a measure of total microbial biomass. Soil Foodweb measured various microbial populations using microscope and counting. Linnaeus used molecular markers to quantify the amounts of different microbial populations. None of the parameters tested correlated well to avocado yield.

Including all data in a machine learning algorithm showed that no single biological or nutrient variable could be used as a statistically significant identifier of crop performance.

While orchard management practices were not part of the project, the results suggest some correlations may be a result of management on high-yield orchards, rather than from soil characteristics.

Next steps

Although the data did not show any significant results, they can be used to refine future studies. Data from the 17 orchards that participated in this project will be incorporated into the Avovantage project to understand how soil variables, as well as leaf and fruit nutrient concentrations, influence fruit rot.

– Delwyn Dickey for Our Land and Water National Science Challenge (CC BY-4.0)

Cows prefer bore water over town supply

A recent trial did not confirm anecdotal evidence that cows will produce more milk when they drink high-quality town supply water.

Increase milk production with improved water quality

Participants: DairyNZ's Lye research farm in Hamilton (and 200 cows)

Project team: Edward Hardie (LIC FarmWise), Karin Schütz (AgResearch), Shen He and Frances Huddart

Report: Does the quality of drinking water (bore vs town supply) influence water intake, milk production and animal preferences in dairy cattle? (ourlandandwater.nz/RPF2020)

Technical information

Project aim: To investigate if providing high-quality (town supply) water compared with unfiltered bore water, which is high in iron and manganese, would increase water intake and milk production in dairy cattle.

- There was anecdotal evidence from a Northland farmer that changing drinking water from unfiltered to filtered bore water increases production, but this was not demonstrated scientifically by this study.
- Four groups of cows (50 cows/group) managed on pasture were offered either town supply water or unfiltered bore water for two weeks, before changing the water treatment for another two weeks in a cross-over design.
- Drinking water treatment did not influence water intake or milk production, but cows preferred to drink the unfiltered bore water compared to town supply in a subsequent preference study.

When LIC national FarmWise manager Edward Hardie heard about a Northland farmer who reported he'd increased milk production simply by upgrading his stock water, he was interested and believed it would be worth doing a scientific trial to test the concept.

"They filtered the water and used some chlorine tablets to get rid of the pathogens, and they understood they had an increase in production as a result," says Edward.

He researched the scientific literature, and although there were some indications that better quality water would increase production with meat breeds, there was little research to indicate the same was true for milk production.

With support from the Our Land and Water Rural Professional Fund, he set up a trial on DairyNZ's Lye research farm in Hamilton with research support from AgResearch, led by Karin Schutz. The aim of the project was to investigate if providing chlorinated town supply water would improve the milk yield of cows, compared to drinking unfiltered bore water that contained high concentrations of iron and manganese.

Four groups of cows (50 cows/group), managed on pasture, were offered either town supply water or unfiltered bore water for two weeks, before changing the water treatment for another two weeks in a cross-over design.

Two water treatments

The water from the research farm's bore is discoloured and, to human beings at least, is far less attractive than the sparkling clean town supply.

"We thought, physically, this is fantastic, you can see the difference here," says Edward. "The bore water was high in iron and manganese and you could smell it, it was pretty strong. I wouldn't be keen on the bore water, it can taste a bit irony, whereas the town water is clear and looks and tastes good." (See photos next page)

Milk production for each cow was recorded daily and milk composition was analysed at the start and end of each treatment period. At the end of the four-week trial, there was virtually no difference in milk production between cows drinking bore water or clean town supply water (see Figure 1).

The two water treatments used in the experiment: (left) unfiltered bore water and (right) town supply

A small preference study undertaken after the four-week initial trial, where two groups of 20 cows were offered both water sources simultaneously, showed they preferred the unfiltered water over the town supply. It is thought that the cows' familiarity with drinking the unfiltered bore water influenced the results, as this was the main source of drinking water on the farm.

It is also possible that the cows' perceptions of palatability differed between the two water sources. The town supply was chlorinated, so they may have found this taste or smell aversive compared to the bore water to which they were accustomed.

Edward says it's known that cows will refuse to drink water dosed with zinc to prevent eczema unless it's added gradually over time to get them used to it. Studies have also shown that cows are extremely sensitive to manure contamination in their drinking water and can detect and avoid concentrations as low as 0.005 percent.

Next steps

Although the trial results did not show that milk production will increase if cows drink better quality water, Edward believes it would be worth doing another trial, this time finding a way to overcome their distaste for the chlorinated town supply water.

A different experimental design could be to get the cows accustomed to the town water before the trial or, alternatively, to use non-chlorinated filtered water. "We had considered just using filtered water in setting up the trial, but the cost was too much," says Edward.

– Tony Benny for Our Land and Water National Science Challenge (CC BY-4.0)

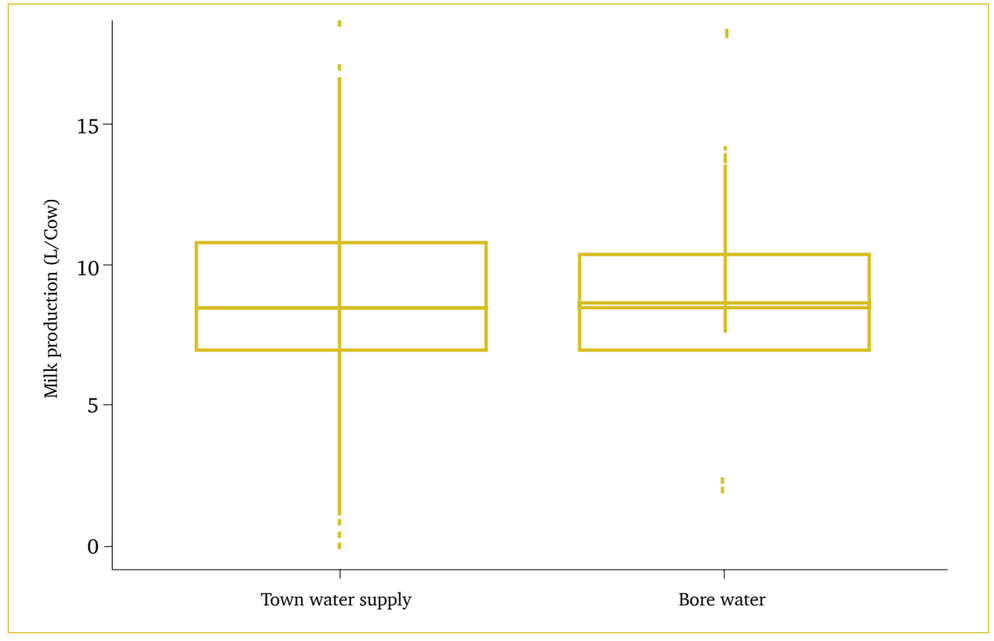


Figure 1: Effect of drinking water source on milk production of dairy cattle (n=4 groups/treatment, 50 cows/group) over a two-week period in a cross-over design

Going bananas

As the north warms up, one dairy farmer is looking for expertise to turn bananas into a future forage crop and a more sustainable effluent cycling system.

Bananas on Northland dairy farms – a new option for forage and effluent cycling

Participants: Northland dairy farm with a small herd

Project team: Warren King, Robyn Dynes and Grant Rennie (AgResearch) and Graeme Edwards (Kahurangi Farm)

Report: Bananas on Northland dairy farms (ourlandandwater.nz/RPF2020)

Technical information

Project aim: To investigate whether growing bananas on Northland dairy farms has the potential to increase the economic and environmental sustainability of the dairy enterprise by measuring plant growth, uptake of nutrients from effluent, and the nutritional content of banana stems as forage for cattle.

- Growth surveys on an established banana plot over nine months to determine the timing, growth rate and dry matter (DM) content of leaves and stem.
- At 1,600 plants/ha, regrowth of cut plants produced 14.6-18.4 t DM/ha.
- Neutral detergent fibre content was low in the leaves (like spring pasture) and low in the stem (like turnip bulbs). Soluble sugars were moderate in the leaves and high in the stem.
- Further work could look to see if these data stack up if stems and leaves are used for forage.

Northland and northern Waikato are getting warmer and drier. Farmers need sustainable changes to farm systems, so they are fit for the future, says dairy farmer Graeme Edwards.

Back in 2018 after a suggestion from their son Paul, a farm systems scientist with DairyNZ, Graeme and Carol Edwards planted up a plot of banana plants adjacent to their dairy effluent pond. They ran trickle irrigation lines through the rows of 65 stems so they could be fed with effluent from the pond.

Graeme was hopeful the plot of Misi Luki bananas could be used to evaluate the possibility of growing bananas as a new summer-autumn forage crop for northern dairy farms, and potentially become a more sustainable option for the recycling of dairy effluent.

His efforts to kickstart the conversation around bananas in a dairy system left him frustrated. While there was strong interest from media, there was little practical research help or guidance from industry or otherwise. Funding was eventually sourced from the Our Land and Water Rural Professionals Fund, and Dr Warren King and Grant Rennie from AgResearch were able to get some research underway.

Now well into his sixties and currently running three farms, Graeme feels bananas have the potential to provide significant benefit to farming in the north. He is hopeful the results of the study, showing the project has merit, will act as a catalyst for action.

Maximising dry matter

When Warren King and Grant Rennie had a look at the mini-plantation, the banana plants were nearly two years old and towered over Graeme and Carol. Some were sending up the first stems that would flower and produce fruit.

Although there is potential for the plants to produce saleable fruit, the focus of this research was on measuring growth, uptake of nutrients from effluent, and the nutritional content of banana stems as forage for cattle.

Cutting off the main stem of a young plant to make the plant bulk out is an old gardening technique, used in this research to push smaller and outlying stems to grow faster and encourage more new stems to grow. It was meant to approximate what might be left behind after a previous season's harvest or grazing.

The bananas proved to be more than up to the challenge of some serious hacking. In September 2020, 15 palms had their main stem cut out, some with a forming spike that would have eventually become a flowerhead, along with some other stems of varying heights before being left to regrow.

Compared to 15 other plants that had been left uncut, by January there wasn't a lot of difference in the final number of stems. All had grown more stems. The cut bananas hadn't produced greater numbers, although they did grow faster and had regrown to their original height.

The fastest growth came from stems cut that hadn't yet started to produce what would eventually be a flower spike, and these shot up to over 2 m high by January. Two plants were also cut down completely on Graeme's suggestion in January, as if they had been fully grazed. By the end of June these had also grown back to 1.5 m.

Estimates of dry matter (DM) from the stems and foliage were taken for cut and uncut plants in September, December, January and June. This saw the uncut plants go from an estimated 6.8 kg DM/plant in September 2020 to an estimated 15.9 kg DM/plant by June 2021.

A typical banana plantation such as those grown for fruit rather than foliage in Queensland, Australia, has 1,600 plants/ha. For Graeme and Carol's plantation this equates to 14.6 t DM/ha. At 2,000 plants/ha, also common for some varieties, this could be substantially higher, especially as their palms are still quite young (see Table 1).

The cut plants bulked out from 3.2 kg DM/plant to 14.6 kg DM/plant in the same timeframe, giving an impressive 18.4 t DM/ha with the strongest regrowth from the middle stem. The biggest growth spurt happened between December and January when the cut plants increased their DM by 75 percent, leaving the uncut palms behind with around 40 percent increase.

The regrowth is impressive, especially as it came in the heat of summer when soil was dry and pasture might be starting to struggle. But how much of a toll the rapid regrowth has on the plant's future health and longevity, if it is subject to this onslaught every summer, remains to be seen.

Bananas thrive in the heat and dry of summer and autumn

Table 1: DM estimate of all stems following each survey

Treatment	Sep	Sep Post-cut	Dec	Jan	Jun
Not cut					
DM/plant (kg)	6.8t	6.8	9.9	14	15.9
DM/ha @ 1,600 plants per ha (t/ha)	10.8	10.8	15.9	22.4	25.5
Cut					
DM/plant (kg)	6.6	3.2	6.3	10.9	14.6
DM/ha @ 1,600 plants per ha (t/ha)	10.6	5.0	10.1	17.5	23.3

Table 2: DM production at 1600 plants per ha-(t DM/ha), enabling an estimate of growth to be calculated

Treatment	Sep-Dec	Dec-Jan	Jan-Jun	Growing season
Not cut @ 1,600	4.9	6.6	3.1	14.6 t DM/ha
Cut @ 1,600	5.2	7.4	5.8	18.4 t DM/ha

A summer treat

Graeme had heard of banana plants being fed to cattle in Queensland. Although not part of this research, he had been throwing the cut plant scraps over the fence to his cows. Initially they seemed a bit uncertain but were soon happily devouring, leaf, smaller stems and fruit.

While they may have been tasty, did the plants have any food value as a forage? Overall, the bananas showed potential as a suitable feed crop for cows, with digestibility similar to various silages.

Using near-infrared spectroscopy (NIR) on the cuttings along with some 'wet' testing showed crude protein was low (like summer pasture in the leaves), with the stalk even lower (like maize silage).

Neutral detergent fibre content was low in the leaves (like spring pasture), with the stem also low (like turnip bulbs) – low fibre is good for dairy cows.

Finally soluble sugars were looked at. They were moderate in the leaves (like pasture) and high in the stem (like maize silage).

With a couple of boxes ticked as a forage, then came testing the nutrient uptake from effluent.

Graeme ran dairy effluent to the banana plot regularly over summer, although volume applied was not measured. In June, soil samples were taken at four depths to see how minerals were moving through the soil profile. This showed no unexpectedly high levels of nitrogen or potassium.

Next steps

AgResearch's Warren King and Grant Rennie see the banana forage and effluent uptake concept as having merit and being worthy of more research.

There also appear to be some valuable opportunities. While there is some literature on feeding banana fruit to animals, there are very few places in the world where banana stem and leaf is fed to livestock and very little published work.

"The only work we could find was a tiny little study in the Canary Islands where someone was feeding banana stems to goats. So this is not a common thing to feed stem and leaf to ruminants let alone dairy cows," Warren says.

The next step would be to do more research with animals and take a closer look at the nutrient uptake and cycling.

While Graeme was happy to feed his cows with the plant offcuts and scraps, and the animals seeming to enjoy them, Warren emphasises that this was not part of the trial.

He says this trial has been useful to check for 'red flags' before testing on animals, which requires significant research funding. "We discovered none," he says.

– Delwyn Dickey for Our Land and Water National Science Challenge (CC BY-4.0)

Online tool aids freshwater action

A new online tool will make it easier for farmers and rural professionals to find the right mitigation options for freshwater farm plans that will contribute to improved freshwater outcomes.

A risk assessment approach for prioritising actions in farm environment plans with mahinga kai values

Participants: The beta tool was tested with rural professionals including some regional councils, Dairy Environment Leaders and farmers

Project team: Katrina Macintosh (DairyNZ), Christophe Thiange (DairyNZ), Craig Depree (DairyNZ) and Ross Monaghan (AgResearch)

Report: A risk assessment approach for prioritising actions in farm environment plans with mahinga kai values (ourlandandwater.nz/RPF2020)

Technical information

Project aim: To produce a prototype geospatial tool to identify and prioritise management practices and mitigation options for water quality.

- The tool locates and presents the nearest water quality dataset, so users understand their catchment context and the main issues to further prioritise the selection of on-farm actions.
- The tool prioritises on-farm actions based on contaminant reduction effectiveness and provides farm-specific prioritisation of actions based on each farm's location.
- A final version of the tool will be freely available on the DairyNZ website. The online beta version is going through user-interface development.

When farmers and their advisors begin formulating the freshwater farm plans that will soon be compulsory for all pastoral farms larger than 20 ha, they first must bring together data about their property (including climate, soil and slope), as well as water quality data. Sometimes finding that information is not straightforward.

A project led by DairyNZ senior water quality scientist Katrina Macintosh has built an online tool that not only makes gathering that data easier, but also provides farm-specific prioritisation of actions to help meet freshwater outcomes.

"It's basically a one-stop-shop to pull available data and resources together," says Katrina. "Given the number of farm plans which are going to need to be done over the next while, if you can streamline access to that information to make it easily accessible, I think it's a win-win for the dairy sector."

The tool, now a prototype version (see Figure 1), allows users to identify and prioritise catchment-specific management practices and mitigation options for water quality that are optimised to their farm.

The project was developed to support the dairy sector's response to the Action for Healthy Waterways reforms that will require freshwater farm plans as part of wider farm environment plans (FEPs). It was funded by DairyNZ and the Our Land and Water National Science Challenge Rural Professionals Fund. The intended users are dairy farmers and their advisors, but there is potential for the tool to be adapted to non-dairy pastoral farms.

Up-to-date science

The prototype tool links users to the most up-to-date science and resources, physical parameters of a farm, and helps prioritise mitigation actions based on the key water quality contaminants.

"Ecosystem health is affected by a multiplicity of drivers such as fine sediment, nutrients, water quantity (flow), light, shading, riparian vegetation and habitat quality," says Katrina. "If you're doing an action on-farm to improve water quality or stream habitat, like stream fencing and riparian planting, using cover crops and good land management practices, you'll reduce your sediment

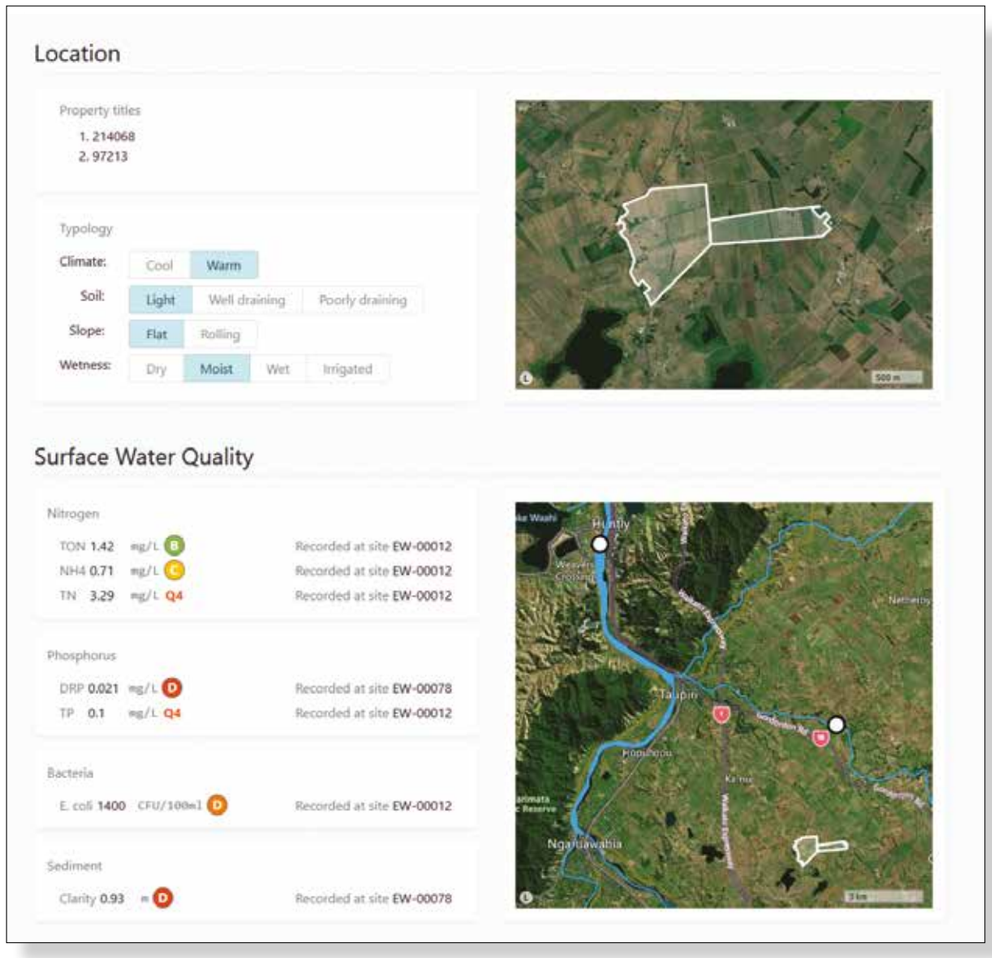


Figure 1: Interactive map to selected farm property title (screen-capture from prototype tool)

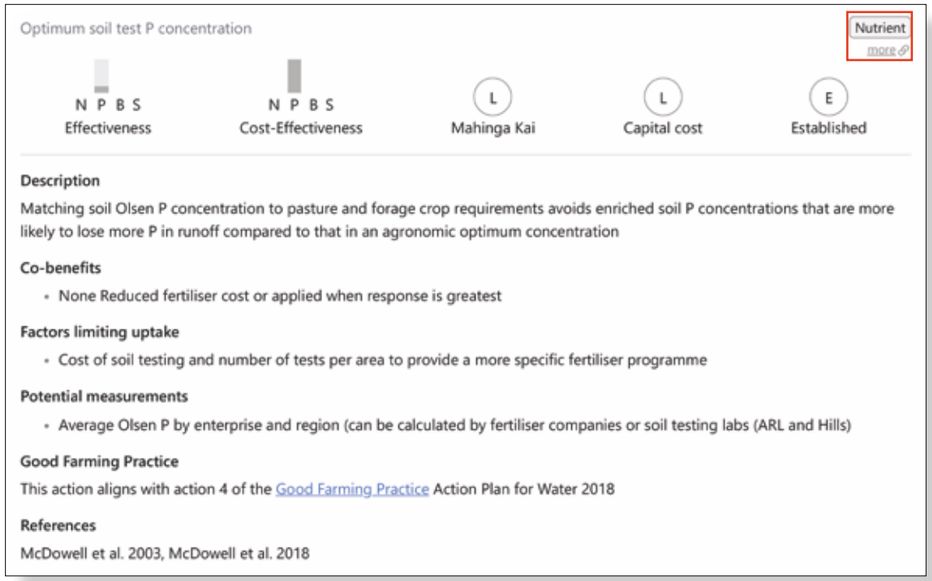


Figure 2: Example mitigation action and associated text. Red box highlights interactive link to more information and DairyNZ resources. N is nitrogen, P is phosphorus, B is bacteria and S is sediment (screen-capture from prototype tool)

The tool acknowledges that no two farms are the same, so each farm will have a tailored solution for the health of the freshwater in its catchment.

and particulate phosphorus losses. Other actions might be more nitrogen-centric, but with most actions there are co-benefits for other key contaminants, and they're all having a cumulative positive effect for in-stream health."

Using the tool

The prototype version of the tool is having its interface further developed to make it more user-friendly, but already it's possible to find your farm on the displayed map and click on it to select it (see Figure 1). This triggers a display of the property's typology (as determined by key characteristics like slope and climate), up-to-date surface water quality information, and a list of mitigations.

The information underpinning the tool is already freely available, but can take time to find and access.

Beneath the clearly laid out farm information are all the potential mitigations that can be ranked by their effectiveness in reducing contaminant loss, their cost-effectiveness and capital cost (see Figure 2). The mitigations are underpinned by a comprehensive body of knowledge built up over 20 years of work by scientists and researchers throughout New Zealand.

The tool acknowledges that no two farms are the same, so each farm will have a tailored solution for the health of the freshwater in its catchment. The tool has been designed to be used in conjunction with expert knowledge and on-farm visits to ascertain site-specific actions in relation to farmer goals.

The prototype version has been user-tested by rural professionals and dairy farmers, including a select group of environmentally leading dairy farmers. They generally found the tool easy to use and said they would recommend it to others.

"It makes it so much easier to get access to all the relevant information, particularly as people prepare to create or update a freshwater farm plan, whether that's a rural professional or a farmer. Previously you could spend a lot of time on the web hunting for information and useful resources," says Katrina.

Next steps

In the future, Katrina and the project team aim to develop the tool's functionality so users can select mitigations for their property and then export them as a document to feed into farm plans.

Planning is underway to take the tool from a working prototype to a fully functional 'bells and whistles version' to support the continued uptake of environmentally driven actions on dairy farms.

A technology company will help DairyNZ develop the final version of the tool and make the interface slicker and easier to use.

The DairyNZ-developed tool is configured for dairy farms, but could, in principle, be developed for other farming types.

– Tony Benny for Our Land and Water National Science Challenge (CC BY-4.0)

Shade from trees inhibits pasture growth

A trial designed to test whether pasture production would increase in a shaded environment showed the opposite.

Creating a diverse and sustainable dairy farming and forestry landscape

Participants: Waikato dairy farm planted with Paulownia trees

Project team: Regan McCorquindale (LIC FarmWise), Graham Smith (Miraka Farm) and Gina Lucci (AgResearch)

Report: Creating a diverse and sustainable dairy farming and forestry landscape (ourlandandwater.nz/RPF2020)

Technical information

Project aim: To assess the impact of trees in dairy paddocks on pasture production and cow behaviour.

- Pasture production was measured using a rising plate meter in December 2020 and March 2021.
- The hypothesis that pasture production would increase in shaded areas was not proved.
- Cows spent more time under shade, where available, in the afternoon.

Waikato dairy farmer Graham Smith has been growing Paulownia trees on his farm for 30 years. He reckons he could just about survive on the income from timber alone now without relying on the returns from his 80 cows.

"My son is coming back here soon to take over the farm. I'm going to live off the timber and he's going to live off the dairying," Graham says.

While Graham was planting trees, Regan McCorquindale, LIC FarmWise consultant, was growing up on a neighbouring farm and saw what was happening on the Smith family property, called Miraka Farm.

"I'd always known he'd been growing these funny looking trees. I started to learn more about them when I had a pasture measuring business and Graham was one of my clients," Regan recalls.

He really started to take notice during the drought of summer 2019 when about the only grass growing in the district seemed to be under the trees in Graham's paddocks. "All the pasture under the trees was still growing, whereas everything else was more like cardboard, just absolutely dead."

It occurred to him that growing more trees on farms could help make them summer-safe, so with Our Land and Water Rural Professionals Fund support, Regan set up a trial to put some real numbers behind that theory. He also wanted to compare cow behaviour under shade and away from shade.

However, the trial in fact showed unshaded pasture grew better than shaded. Pasture monitoring was done in December 2020 and then again in March 2021. The December pasture samples showed a greater percentage of ryegrass in the 'no shade' trial site (see Figure 1) and that pattern continued in March (see Figure 2).

The data collected shows the clover percentage was higher in December in the shade. Crude protein level is the only valuable metric under a 'shade' paddock that has more advantageous results compared to the 'no shade' paddocks. All the other metrics were similar, or in favour of the 'no shade' paddocks.

Dense planting

Graham says the trial results confirmed what experience had already told him – that trees in the trial block were planted too densely to allow pasture to thrive.

"I could see it myself before they did the trial that I was having trouble with the pasture, so my plans for this summer are to thin the trees down from about 100 trees/ha to 50 and let more sunlight in to rectify the problem," he says.

Farmer Graham Smith prunes a Paulownia tree. Although not part of this research, he says his small dairy herd enjoys eating the leaves. The trees will eventually be coppiced and the timber milled and sold

Regan agrees that thinning the trees to let in more light will be helpful. Graham is sure of the value of trees, but is still working out exactly where the sweet spot is for the ratio of trees to pasture. "You've got to stay flexible and roll with the punches. I'm still learning and so is everybody else," he says.

"You get to the stage where you say, 'Am I in trees or dairy?', but I want to keep the blend because I think diversification is the name of the game," says Graham. "You don't want to have everything tied up down one track. I think that's a smarter move than being tied into one form of farming."

Cow behaviour

The second part of the project assessed cow behaviour in shaded vs unshaded environments.

The cows were split into two herds and fitted with Cow Manager ear tags, HOBO cow collars and GPS pedometers.

The cows with access to shade moved faster than those who were more protected by shade from the trees during the afternoon (see Figure 3). The activity collars also showed that the cows in the no shade paddocks spent more time lying down than those in the shaded trial area.

Next steps

The summer and autumn of 2021 received a lot more rain than has been typical in recent years. A trial over multiple years would capture greater variation in weather conditions and give more reliable results. The optimal number of stems per hectare that offer shade to cows and allow an increase in pasture production through drier summers is still to be found.

– Tony Benny for Our Land and Water National Science Challenge (CC BY-4.0)

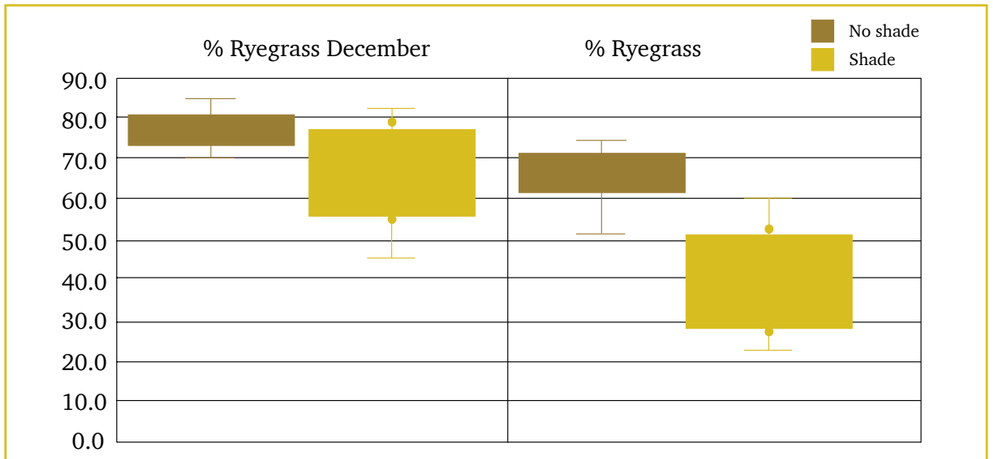


Figure 1:Percentage of ryegrass in pasture samples, December 2020

Figure 2: Percentage of ryegrass in pasture samples, March 2021

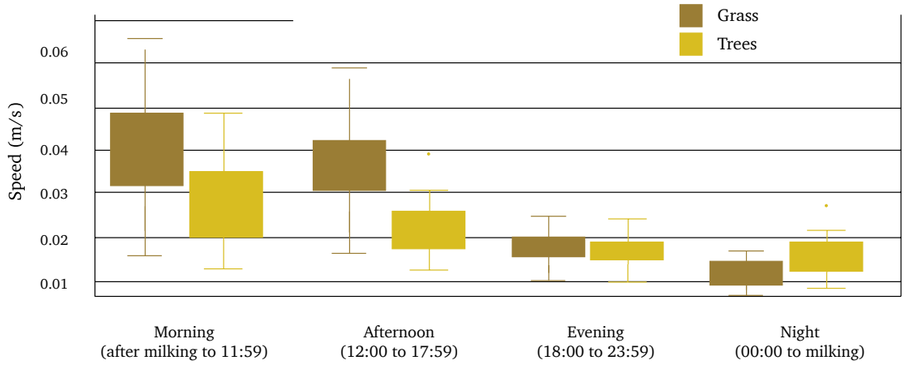


Figure 3: Dairy cow speed while grazing

Future-proofing the hill country

Farming the hill country can be hard. Getting hold of free open-access software tools and data to evaluate crop and market options for added horticulture ventures can help simplify options.

Integrating horticultural and arable land use options into hill country farm systems

Participants: Eight sheep and beef farmers, Taihape

Project team: Dr Liz Dooley (PerrinAg Consultants), DJ Apparao (G&D Consulting), Rita Batley (farmer), Iona McCarthy (Massey University) and Carol Mowat (Thought Strategy)

Reports:

- Integrating horticultural and arable land use options into hill country farming systems: The multi-criteria decision-making process (ourlandandwater.nz/RPF2020)
- Integrating horticultural and arable land use options into hill country farming systems: Site-specific crop options and value chain-based business case (ourlandandwater.nz/RPF2020)

Farming in the rugged, but beautiful, central North Island hill country can be challenging at times. It's dry, the soils are poor, and snow in winter is common. But it is a lifestyle that many farmers cherish and want to preserve.

Concerned that the local farming community's way of life could be threatened with challenges to sheep and beef farming five or six years ago, Taihape farmer Rita Batley felt that change was needed. More recently, an aversion to seeing pines planted in the area has been behind growing interest in diversification from her community, with the aim of making farm businesses more financially sustainable.

To future-proof the rural community, they needed to inspire the young and look at what other income strands would suit their land. Rita teamed up with rural consultant and researcher Dr Liz Dooley, now working for PerrinAg Consultants based in Rotorua, and together they looked at options.

Rita and some like-minded farmers then formed a group under the Red Meat Profit Partnership Action Network (RMPP) looking to diversify into sustainable horticulture on some of their land.

Rita and friend Vanessa Witt planted up a plot with 20,000 garlic plants that are grown organically using permaculture principles on some of the precious, but relatively infertile, flat land on Rita and husband Peter's sheep and beef farm. Over the past three years they have gradually enriched the soil, developing a new plot each year as they rotated the garlic crop.

Looking at the possibility of organic certification they learned they needed three other successful crops to come in behind the garlic to make up a four-year rotation. "It's hard work, and while the garlic sells well it isn't viable on its own," Rita says.

The diversification challenge

Rita and others in her group are actively seeking diversification, but encouraging less interested farmers is not straightforward. Farmers take pride in their own resourcefulness to get things done without a big cash outlay, so forking out a lot of money right from the start to find a site-specific crop may be a hard ask for many dabbling with the idea of diversification.

Getting hold of information about crops that suited their lifestyle and aspirations, along with market options, and that didn't also cost an arm or a leg could be key.

Once the basic groundwork was done the landowner could then decide if they wanted to seriously move forward with a more detailed analysis of a venture, with the associated costs of that analysis made available. Coming up with tools that could do all of that was the challenge funded by the Our Land and Water Rural Professionals Fund led by the project team of Liz Dooley, DJ Apparao, Iona McCarthy and Carol Mowat.

Any crop data used and other information sources across the project needed to be free and open-source, without proprietary software packages or licensing required. Any tools developed by the team will be free for others to use.

The process also needed to consider the challenges that farmers often had with internet access. However, with high-speed satellite internet connection provider Starlink now on the scene connectivity may improve, for South Islanders at least.

Technical information

Project aim: To develop a process and tools to help farmers select different crops to integrate into hill country farms.

- A set of crop alternatives suited to local farming areas were identified. EcoCrop, a United Nations Food and Agriculture Organisation tool, provided climatic suitability parameters for 2,568 crop plants alongside global climate data.
- Based on a crop suitability ranking for a given site, a total of 49 crop plant species were identified in three locations.
- Farmers used a multi-criteria decision-making approach to assess the performance of these crops against their selected decision-making criteria, weighted according to their preference.
- For hill country farms, higher-returning niche crops suited to smaller areas of flat land were of greater interest, e.g. fruits, nuts, medicinal crops.
- The proof of concept tool then enabled apricot, quinoa, arnica, hazelnut and garlic to be investigated for the most important step – finding a market and value chain.

Organic garlic is an alternative crop being looked at by farmer Rita Batley and friend Vanessa Witt

To future-proof the rural community, they needed to inspire the young and look at what other income strands would suit their land.

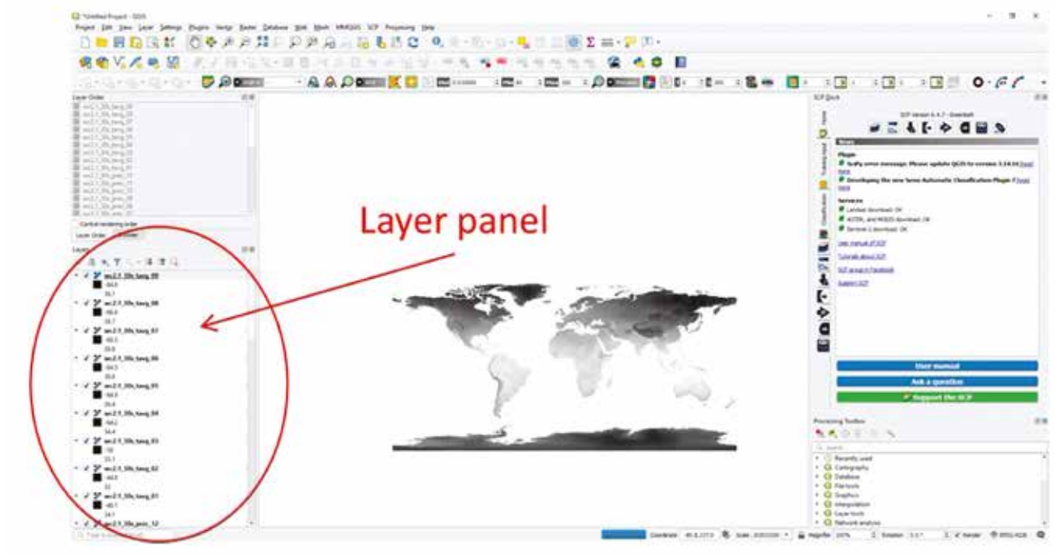


Figure 1: A protocol for determining crop suitability using GPS coordinates

Down to business

DJ Apparao put together a tool – a piece of code – that would allow a crop database to be explored using the geographic information system, QGIS, to find crops suited to a given area, with RStudio included to enable statistical analysis.

A protocol to install and run this suite of software was also collated so the process could be replicated by landowners and rural professionals on their own personal computers (see Figure 1).

The main database used by the crop selection tool was EcoCrop, a United Nations Food and Agriculture Organisation database, which covers climatic suitability for over 2,500 crop plants alongside global climate data.

Monthly rainfall and temperature data can be searched for on the EcoCrop database to match a crop's acceptable temperature and total rainfall range, and the length of the crop cycle. The model simulates different possible growing seasons and selects the most suitable. From there, EcoCrop suggests the highest value crop and assumes the landowner would plant during the most ideal season.

World yield and export price were gleaned from publicly available data on the global crop yield and the freight-on-board (FOB) export price by crop and country, from online databases at Earthstat (www.earthstat.org) and UN Comtrade (comtrade.un.org), respectively. Published literature and an online database at Tridge (www.tridge.com) filled in some gaps.

Industry-scale data to calculate farmgate returns were a bit scarce, probably due to commercial sensitivity, so the proportion of farmgate returns from global market returns were estimated using industry-scale data for fresh kiwifruit exports. If individual farmers were privy to actual farmgate prices derived from market returns through other sources of information, they could use that data instead.

How the product would be used (fresh, processed, dried) and estimated time to production for trees were all compared between crops, along with world yield and export price and estimated farmgate returns per hectare, to give a rough estimate of their respective values.

Armed with the crop selection tool, a fairly computer competent landowner would also be able to navigate the process alone, Liz Dooley says. "Some farmers may find it easier to work with a consultant or get them to run the tool, especially if not computer savvy. And consultants may find the tool and process useful for working with clients who approach them to look at options."

Several hill country farms in two areas in the Taihape region were chosen as test sites, with the software put through its paces for cropping options. This resulted in 49 possible crops for each of the two sites looked at.

Two sets of crop suitability options were generated in this project – one with irrigation and one without. A need to irrigate on a site changed how suitable some crops were shown to be for those sites. Liz says that as many farms would not have irrigation, that option would be unnecessary for most.

Multi-criteria decision-making

A multi-criteria decision-making support tool was then used with the crops. This helped the farmers sort through the crops, as well as assisted in applying their personal and business priorities, aspirations and concerns to narrow the number of suitable crops.

Unsurprisingly, financial returns, labour needs, processing requirements and risk were seen as most important when considering each crop. Given the limited flat land on the farms, ventures that had the potential for high returns from a small area garnered the most weight, except if they needed to fit in with an existing crop rotation.

Surprised at the range of crops suited to their land, the greatest interest was in medicinal crops, fruit trees, fruit bushes and nut trees – of which there were nine medicinal crops, 10 fruit trees and five nut trees. Although there were 10 vegetables and 15 suitable grains, only garlic and horseradish (and arable crops quinoa and hemp) were earmarked for further investigation. The whittling down process resulted in five to 11 crop options for each farm.

Building value

Liz says that some of these crops were then used as case studies to demonstrate how to develop a value-chain based business case, looking at what questions farmers would need to ask and what they needed to understand in the evaluation of a new enterprise.

For this, a business case incorporating Porter's 'five forces model' was used on a potential crop. Porter's model looks at the barriers to entry on the market for a product, the threat of substitutes, the bargaining power of suppliers, the bargaining power of buyers and competition from existing companies. Alongside this, an analysis of business strengths, weaknesses, opportunities and threats in the market was undertaken.

Open-access research and science reports to support the business case came from Google Scholar (scholar.google.com), with other general information found through a Google search. This would help the farmer or their consultant to figure out if the crops were feasible and warranted a closer look.

Some take-aways from the process

Having the founders of Kiwi Quinoa in their RMPP group, along with another start-up, Hinterland Foods run by young farmers Sarah and Thomas Wells was a big influence on the willingness and confidence of some to look at diversification seriously, Rita says.

High-returning quinoa was already being grown in the area by entrepreneurial young local farmers, Jacqui and Dan Cottrell, and helped to raise the scoring for this uncommon

crop. Horseradish grew like a weed in the area, so there were no concerns about how it would perform.

For some, choosing a crop with little understanding of it locally, and having to research it from scratch, could be a hard ask. But with the tools developed on hand, these crops could present some unusual opportunities.

“Going through a business case format helps provide people with the tools to identify and explore these opportunities,” Liz says. “Some may take the opportunity and risk to give it a go.”

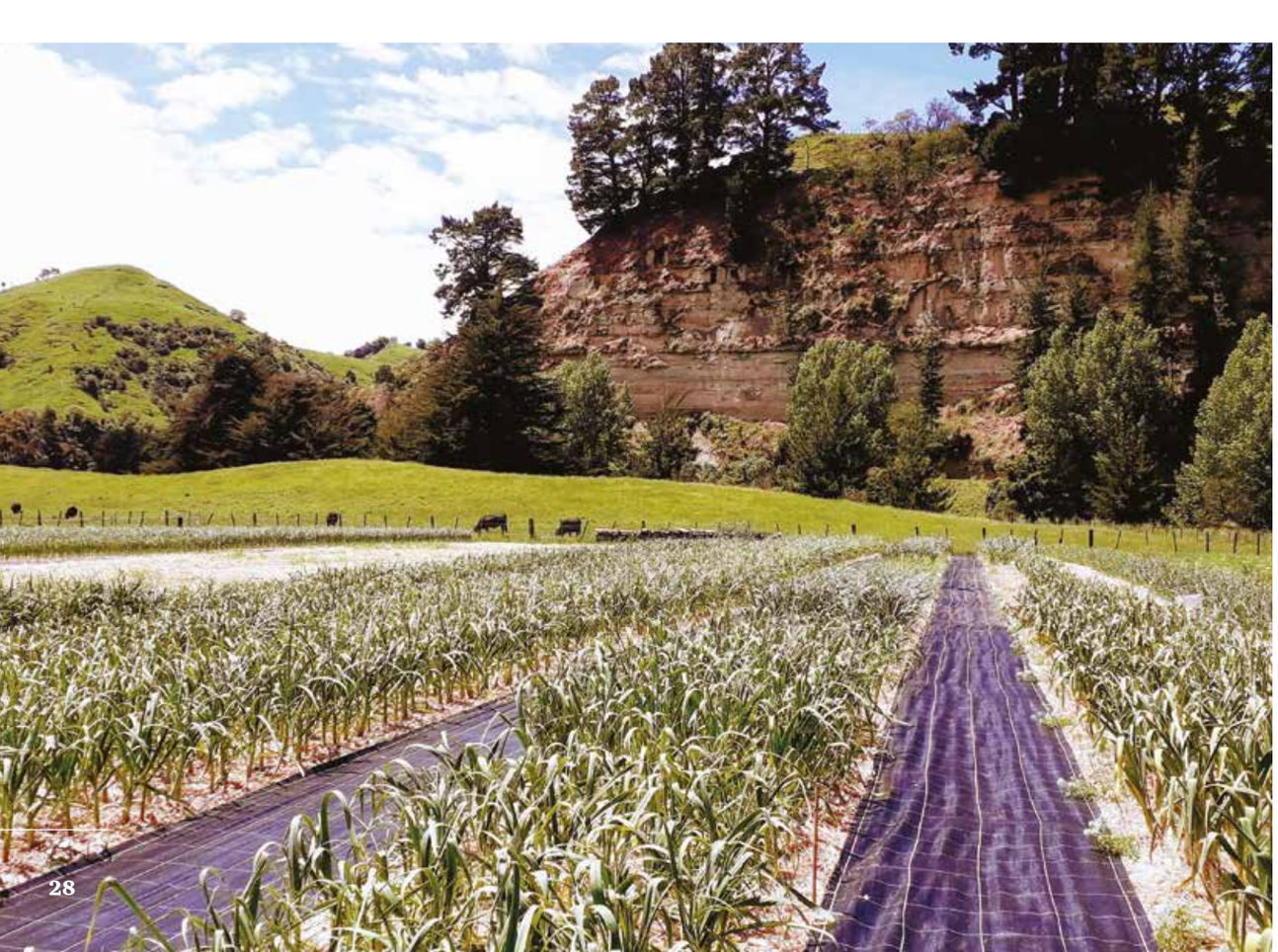
Clearly not needed for some ventures, banding together to grow the same crop for others may provide the scale for a value chain to form. Finding a market and value chain is often the hardest step, and growers should be confident they exist before embarking on change.

Rita Batley and Vanessa Witt are still weighing up their options for their three rotation crops. Echinacea and arnica are used in the organics industry and are strong contenders, with liquorice also under the microscope. Having sourced seeds for all three from Germany, they will do a germination trial this spring to see if they will grow in high country conditions. “If we establish that we can grow some or all of them, we will then have to find a market before we plant commercially,” Rita says.

Next steps

- Landowner tools to identify potential climate suitable crop options are needed for land use diversification. These need to be open-source, open-access and easy to use under poor internet connectivity.
- Concise, reliable and relevant information on crop options is required. There is a role for central and local government to build on existing open-data initiatives to improve the access and content of New Zealand-specific spatial datasets.
- An MCDM process and model that is straightforward, relatively quick to use and freely available to farmers and advisers could be developed.
- While a proof of concept was created, work needs to continue to make the process more accessible and understandable.
- This work needs to be connected to markets and value chains to make the prospect of farming different crops successful.

– Delwyn Dickey for Our Land and Water National Science Challenge (CC BY-4.0)



We are what we eat

If regenerative farming can improve meat quality, particularly intramuscular fat and flavour, this could open up more markets for premium meat products, including from dairy cross cattle.

Impact of regenerative farming on meat quality

Participants: Nine regenerative and nine conventional farms in the upper North Island of New Zealand

Project team: Steve Howarth (AgFirst), Tracey Bayliss (Grandads Beef), Dr Katherine Tozer (AgResearch), Mustafa Farouk (AgResearch) and Rose Greenfield (AgResearch)

Report: Impact of regenerative farming on quality (ourlandandwater.nz/RPF2020)

Technical information

Project aim: Compare the quality of meat from cattle of comparable age, sex and breed raised on regenerative farms and on conventional farms and see if any differences could be related to increased pasture diversity.

- Cattle finished on nine self-classified regenerative and nine conventional farms in the upper North Island of New Zealand were paired by breed, sex and age.
- Raw muscle pH, moisture, total iron (heme plus non-heme), intramuscular fat (IMF) fatty acid composition, microelements and colour were evaluated from meat samples.
- Most tests showed no significant difference between farm types in the concentration of fatty acids considered to be beneficial to human health.
- Pasture testing included pasture mass, botanical diversity and herbage mineral analysis.
- Legume content was higher in regenerative than conventional pastures. Overall, botanical diversity in pastures on both farm types was low (averaging less than nine species). It is unlikely that differences between pasture types in the number of species influenced meat quality.

‘You are what you eat’, the saying goes – and just as it is for people, the same it seems goes for stock.

Increased pasture botanical diversity, longer grazing rounds and higher residuals, along with reduced synthetic fertiliser use, are some of the key practices of regenerative farming.

Regenerative farming can be hard to define as it is outcomes-focused and more about principles than practices. It can also mean different things to different farmers in New Zealand and in different countries. Our pasture-based farm management systems already have more in common with these values than in countries where feedlot farming is common.

Because of this, Beef + Lamb New Zealand is interested in regenerative farming as a potential selling point for our meat overseas and says there is a need to act quickly to take full advantage of it. But they also emphasise any claims must not be ‘greenwashing’ and need to be able to be backed up by science.

Studies from overseas have shown cattle finished on diverse mountain pastures, with nearly 40 different species, have improved meat quality and taste compared to pastures on the flats with few species, says Steve Howarth, agricultural consultant with AgFirst.

Originally off a Hawke’s Bay sheep and beef farm, Steve has a strong interest in farm system management that includes sustainable nutrient management and environmental management. This drew him to look more closely at regenerative agriculture. “Regen is gaining a lot of traction but there has been little research done in New Zealand. We need to be able to show farmers what regen looks like, its pros and cons,” he says.

This saw him join forces with Tracey Bayliss, owner of regenerative meat supplier Grandads Beef, and scientists from AgResearch for a study on meat quality, with funding from Our Land and Water’s Rural Professionals Fund. Could the difference in pasture on regenerative farms be behind the positive comments around taste that Tracey’s meat products had garnered?

Tracey also had a country upbringing on a beef farm, but like a lot of rural youngsters found country living too slow and says she couldn’t get off the family farm fast enough. As a beautician and salon owner she became interested in the relationship between diet and skin problems, which led to an interest in healthy diets for the animals

we eat. Eventually, she returned to the farm, running Friesian-Hereford dairy cross cattle – not as a farmer, but marketing its meat and that of other regenerative farmers as Grandads Beef.

Investigating premium potential

If there was a marked difference between the meat of regeneratively and conventionally raised dairy cross cattle, and the regeneratively raised cattle had improved meat quality, there may be an opportunity to market a premium meat product.

Dairy cross cattle make up around two-thirds of beef animals in the industry. As they have a big influence on the beef sector, there has been increased interest in recent years in finding ways to produce dairy cross animals that are more valuable for beef, including using easy calving, short gestation, high-growth beef breed sires.

Tracey and Steve's project covered a lot of different areas to see if anything really stood out in meat quality, and if that could be connected to pastoral biodiversity. From there, more scientifically robust studies could be conducted.

Nine conventional farms were paired by geographical location with nine farms their owners considered to be farmed regeneratively. The paired farms were in the same region – either Bay of Plenty, Waikato or Northland, and generally within 25 km of each other.

One of the cattle on each of these paired farms was also paired by breed, sex and age – nine animal pairs. Most were either Hereford-Friesian crosses or Angus-Friesian crosses.

The animals were sent to slaughter from each farm around late autumn 2021 to two Waikato processing plants. Pastures were assessed around the same time.

Meat testing

A striploin from each of the 18 animals in the nine pairs was sent to AgResearch, aged for two weeks, then frozen. Once all striploins were on hand they were thawed again, with samples taken at the same place on each strip.

A range of tests were performed to assess meat quality including pH, moisture content, elemental analyses, fat-soluble vitamins, intramuscular fatty acid profile and colour. Most tests showed no significant difference between farm types in the levels of fatty acids considered to be beneficial to human health (see Table 1).

Table 1: Fatty acid content of beef striploins from regenerative vs conventional farms. There were no significant differences between regenerative and conventional farms in Omega 3 or Omega 6 fatty acids

	mg FA/g dry meat		
Fatty acid profile	**Regenerative farms**	**Conventional farms**	***P*-value**
Omega 3	2.2	1.9	NS
Omega 6	3.6	3.3	NS
Omega 3: Omega 6	0.59	0.58	NS
% IMF	17	12	NS

NS: Not significantly different (P>0.05).

Dairy cross animals raised on regenerative farms have a different diet

Pasture testing

On each of the 18 farms a typical paddock was looked at that had not been used for cropping, hay or silage within the last five years, had less than 15 degrees slope, and was ready for grazing within two days. An additional paddock was selected for a post-grazing assessment.

Herbage mass, botanical composition, herbage mineral content and nutritive value, and soil nutrients were assessed in pastures prior to grazing, and the residual herbage mass of a pasture that had been grazed within two days.

Both farm types had similar amounts of herbage on their pasture before grazing. The amounts left after grazing were also similar. This suggests that while longer rounds and higher residuals may be an aspiration for regenerative farmers, this may be difficult to achieve in practice, says Steve.

There were low numbers of pasture species overall on both farm types – around nine on regenerative farms and eight conventional. Because of this, botanical biodiversity was unlikely to make a difference to meat quality, Steve says. Overseas, regenerative farms may have 40 different species in alpine pastures.

Ryegrass and clover were prevalent on both farm types, but with less ryegrass on regenerative farms. Pasture had three times the amount of legume (clover) on the regenerative farms, which may be related to soil fertility (see Table 2).

Farm management

Each farm was surveyed on livestock and pasture management and included area, number of livestock wintered, pasture renovation/cropping, fertiliser inputs, supplement use and herbicide/pesticide use. The purchase and rearing details of each animal in the trial was looked at along with their health. Grazing and sales details of the wider mob were also looked at.

The regenerative farms were generally smaller, averaging 164 ha, compared to the conventional average of 311 ha. The smaller size likely contributed to the stronger focus on

Table 2: The number of species present, herbage mass and content of perennial ryegrass and legumes in 13 paired regenerative and conventional farms in the Upper North Island

Three times the amount of legume was found in regenerative pasture				
Measurement		**Regenerative**	**Conventional**	***P value***
Number of species		9	8	*
Herbage mass (kg DM/ha)	Pre-grazing	3,230	2,980	NS
	Post-grazing	1,790	1,660	NS
Botanical composition (% of total DM)	Perennial ryegrass	27	39	**
	Legumes	13	4	**

**P<0.05 and **P<0.01 (statistically significant). NS: Not statistically significant (P>0.05).*

Steaks from regenerative and conventionally raised cattle were compared

beef on regenerative farms. Winter stocking rates were similar for both, as was average weight gain at 0.6 kg/hd/day.

Around half of each farm group did some form of re-grassing each year with direct drilling preferred. On conventional farms, re-seeding was with ryegrass and clover including plantain and/or chicory or cocksfoot. For the regenerative farms, four used a mix of grasses, legumes and herbs, with up to 20 species sown, while another used similar species to the conventional farms of ryegrass, clover, chicory and plantain.

Herbicides like glyphosate, MCPA and Brushkiller were used by both farm types, with pesticides uncommon for both, and only used for slug control with re-grassing. Anthelmintic products to treat internal parasites were also common for both.

Fertiliser differences

One of the biggest differences between the two farm types was around fertiliser use. Synthetic fertilisers focusing on the macro-nutrients N, P, K, S were widely used on the conventional farms using either DAP or superphosphate.

Synthetic fertilisers weren't used on the regenerative farms. Both macro- and micro-nutrients were used on the regenerative farmers (including phosphate, potassium, sulphur, boron, zinc, selenium, magnesium, copper and cobalt, plus soil conditioners) from a range of sources, including fish hydrolysate, RPR, lime, potassium sulphate and humates.

Differences in soil fertility may account for less ryegrass and the higher legume content on regenerative farms. Further work is required to find out if differences in legume content affect meat quality, Steve says.

Next steps

Steve emphasises that with the large number of variables considered, this trial was only designed to pick up major differences in meat quality or farming comparisons. It can only be considered a snapshot to show where more research would be useful, he says. This could include:

- The long-term effect of different fertiliser programmes on botanical composition, pasture performance, soil quality, environmental indicators and meat quality
- Studies with larger cattle numbers and tighter control over selection, pairing and management for meat quality comparison
- Testing if legume content is higher all year round on regenerative farms and if this leads to improved meat quality
- Further testing of the meat samples in this study for taste and consumer appeal.

"Knowing where the two farm types don't differ is just as important as where they do. This gives us an evidence-based approach to start defining, in a New Zealand context, what regenerative agriculture is," Steve says. "It's challenging, but something we need to do."

– Delwyn Dickey for Our Land and Water National Science Challenge (CC BY-4.0)

Traps catch sediment

A farmer-led study investigating the effectiveness of sediment traps to improve water quality has delivered some encouraging results.

Sediment traps in hill country

Participants: Three families farming near the Mokau River who belong to the King Country River Care catchment group

Project team: Peter Keeling (Perrin Ag), Blair Nelson (farmer), Ian Fuller and Lucy Burkitt (Massey University)

Report: ourlandandwater.nz/RPF2020

Technical information

Project aim: To evaluate the effectiveness of three different sediment traps within the same valley and provide a simple guidance document to help farmers develop their own sediment traps.

- There are a variety of sediment trap methodologies, but no guidelines on which ones are best in what circumstances.
- A typical farm dam can be constructed relatively simply and quickly with minimal cost and can act as a sediment trap if placed in the right location.
- The sites chosen by the three farmers considered aspects such as size of catchment, water flow, access, shape and contour, and existing structures in place.
- The most common on-farm 'sediment trap' is based on a stock water dam concept.

King Country farmer Blair 'Munta' Nelson knows sediment run-off is the number one environmental issue faced by farmers in his district. He's convinced farmers can go a long way to solving the problem by installing small, low-cost sediment traps on their properties.

Munta joined Perrin Ag consultant Peter Keeling to run a trial to test the effectiveness of the traps and come up with some recommendations on the best way to construct them, with funding from Our Land and Water's Rural Professionals Fund.

"There's a whole lot of pressure to make improvements on-farm and we need more tools in the toolbox," says Munta.

"In my opinion there's still not enough hands-on data to say, 'This is what you should be doing'. We're getting asked to fence off our waterways and plant trees, and there are mixed recommendations as to what you should and shouldn't be planting, so we were looking for another form of mitigation."

Peter Keeling says King Country hills are prone to sediment run-off thanks to the soil type and relatively high rainfall. "Those soils are either soft or softer. It doesn't really matter whether it's got bush on it or not, you'll get a lot of silt come down off the hill country. Initially it forms small water channels which then grow into something bigger."

One solution to sediment run-off investigated by a farmer group near Rotorua involved large detainment bunds. That approach won't work in the King Country hills, Peter says, because the landscape is steeper and the soil is different. "The detainment bunds are quite big and they're on quite a gentle slope. We can't do that on hill country."

Large bunds are also costly and may require resource consent, which Munta Nelson was keen to avoid. By keeping sediment traps small (with dam walls less than 1.5 m high) resource consent requirements aren't triggered and the cost is likely to be $2,000 to $3,000 – compared to perhaps 10 times as much for a large, engineered, consented detainment bund.

"I believe the solution is not building one massive bund or sediment trap that costs me $45,000. For me, the answer is spending a couple of thousand dollars on a sediment trap and doing one every year," Munta says.

Traps trialed on three farms

The project constructed three different ponds on three neighbouring farms: the Nelson's, the Foss' and the Proffit's.

The project aimed to measure the effectiveness of the three traps in reducing sediment concentrations leaving small-to-medium (3.5-20 ha) hill country sub-catchments. Through demonstration, the team hoped to create farmer discussion and increase awareness of the factors that need to be considered when installing sediment traps.

The effectiveness of the three sediment traps was measured by installing simple siphon samplers to monitor sediment concentrations entering and leaving the sediment trap, from approximately three different flow heights during six rainfall events. The hope was to get a picture of trap efficiency over a range of rainfall run-off events.

Sediment trap at Russell Proffit's farm

There's a whole lot of pressure to make improvements on-farm and we need more tools in the toolbox.

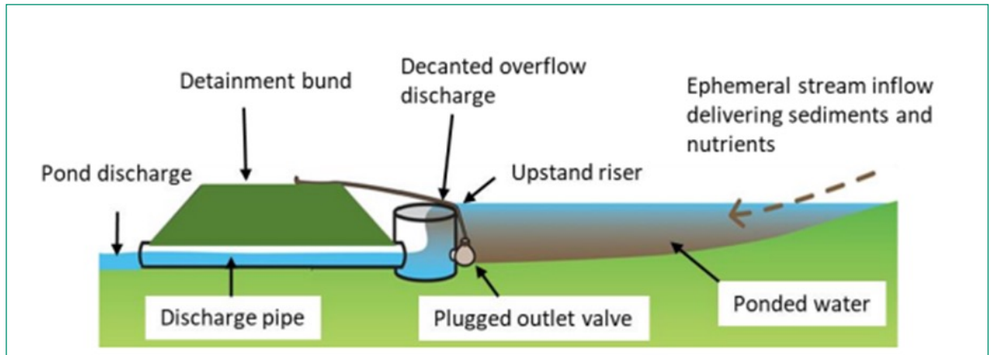


Figure 1: The detainment bund/sediment trap concept, Levine et al (2021)

The three traps trialed were constructed differently. All held water that was released via a riser connected to a pipe that drained through the front of the structure, sufficiently slowing the movement of water to allow suspended sediment to drop out (see Figure 1).

Sediment concentrations in the trial were highly variable, but generally outflow concentrations were less than inflow concentrations, suggesting that the sediment traps were working (see Figure 2). The farmers faced challenges adapting the riser design to their environment and more work is needed to find a design that works in this environment.

Next steps

The project team will release a farmer 'cheat sheet' describing how to create a sediment trap, but this won't be finalised until the farmers, local community and experts get back together to de-brief and draw some conclusions. This has been delayed due to Covid-19 Level 3 restrictions in Waikato.

Getting farmers together on-farm with experts was enormously valuable, says Munta Nelson. He believes the three farmers involved in the project will continue to install one or two sediment traps each year. "That's what I want, where it just becomes part of the normal. We built one last year and if we build one this year and one next year, in 20 years' time I've got 20 of them, haven't I?"

If each sediment trap removes sediment from small waterways, eventually the total amount reaching the large Mokau River will be reduced.

"Personally, I think fundamentally they work," says Peter. "But have we found out a one-size-fits-all recipe? Probably not."

The three farmers involved have tried something that suits their farms and have shown that decreases in sediment can be achieved. "This will give other farmers the confidence they can do similar work in their situation and make a difference too," he says.

– Tony Benny for Our Land and Water National Science Challenge (CC BY-4.0)

Nelson site

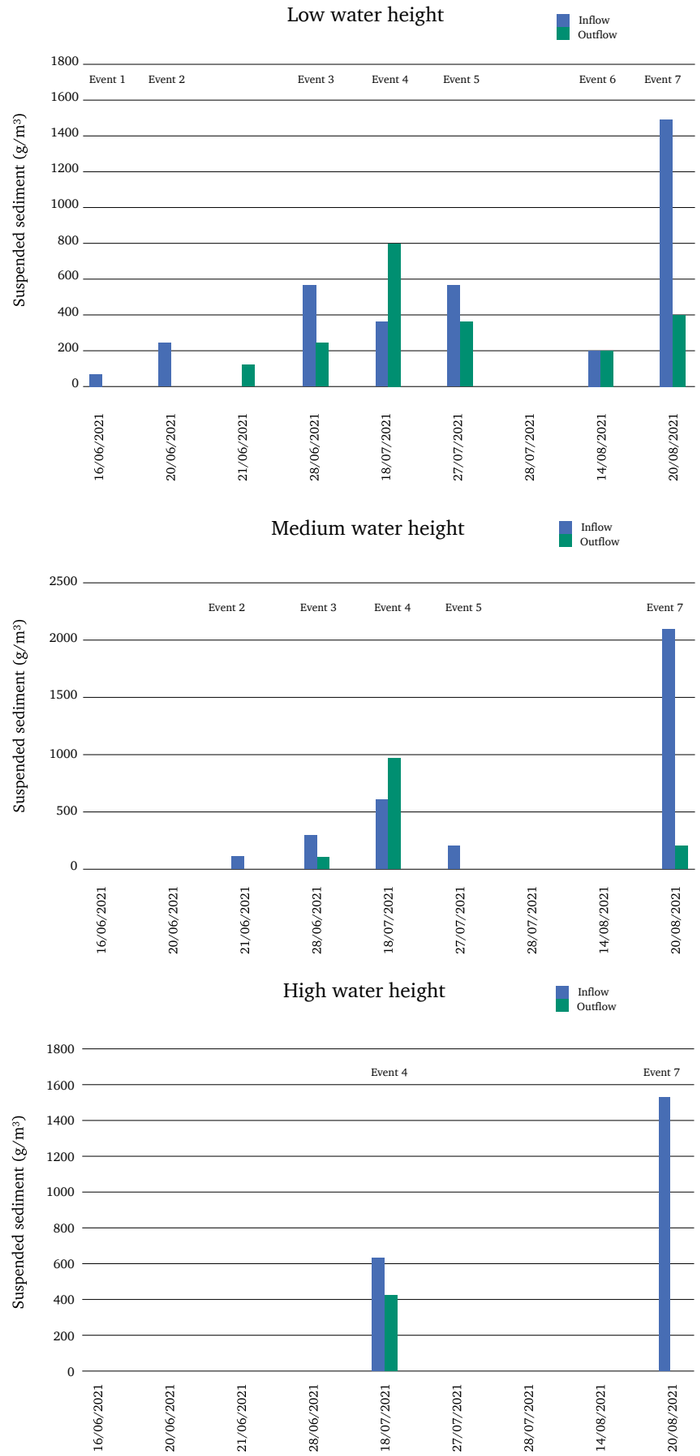


Figure 2: An example of the suspended sediment concentrations in the inflow and outflow to a sediment trap on the Nelson's farm, measured at low, medium and high water across seven rainfall events

Scheduling irrigation using satellite data

Remote sensing has potential in calculating crop coefficients to enable accurate irrigation decision-making, but more research is needed.

Application of remote sensing in spatial irrigation scheduling

Participants: Organic vegetable farm, Hororata, Canterbury

Project team: Cindy Lowe and Andrew Curtis (Water Strategies), Kelvin Hicks (farmer) and Hamish Brown (Plant & Food Research)

Report: Application of remote sensing in spatial irrigation scheduling (ourlandandwater/RPF2020)

Technical information

Project aim: To use the SWAN Systems™ platform, an automated water balance model, alongside remote sensing data to calculate crop coefficients throughout the irrigation season to assist with irrigation scheduling.

- The trial was conducted on an organic vegetable farm at Hororata, Canterbury on a milling wheat and a table potato crop.
- Soil moisture meters and rain gauges were monitored every 15 minutes and two infrared radiometers were installed to measure canopy cover.
- Limited satellite coverage of New Zealand and too many cloudy days made it difficult to provide accurate scheduling decisions.
- More frequent and reliable high-resolution satellite coverage became available late in the trial.
- Data was sufficient to develop a proof of concept to calculate crop coefficients and assist in irrigation scheduling of the crops. Additional work is required to develop the research into a commercial product.

Irrigation management consultant Cindy Lowe dreams of the day she will not have to install soil moisture sensors for clients, but instead advise them when to irrigate by using crop coefficients derived from satellite imagery. "I think we're very close to that. It will come, it's just getting that data that's the sticking point," she says.

While the science of calculating crop coefficients using remote sensing has been around since the 1970s, a robust commercial product is not yet available. This is partly due to the lack of available high-resolution satellite imagery.

Water Strategies led an Our Land and Water Rural Professionals Fund project to assess the viability of using the data collected by satellite, together with suitable software to interpret that data, to give irrigation scheduling recommendations.

But while the trial showed promise, patchy satellite coverage of New Zealand, combined with too many cloudy days when a suitable satellite was overhead, made it difficult to provide accurate irrigation scheduling decisions based purely on satellite imagery for the entirety of the growing season.

"The technology is there but the frequency is not, that's the problem," says Cindy. "If we had good, reliable daily data we could make it work."

In the latter stages of the trial, more frequent satellite passes became available. These provided better, more timely, data but there is still more work to do to create a commercially viable model for New Zealand.

One practical output was achieved from the project – a method of calculating crop coefficients for any crop based on crop growth stages. Cindy says, "We have the capability to calculate crop coefficients for any crop based on the methodology we worked through with Plant & Food Research, not just milling wheat and table potatoes."

Two problems

Soil water management can make a huge difference to the profitability and sustainability of a farm. Applying the correct amount of water at the right time is one of the most challenging issues facing growers, especially arable growers.

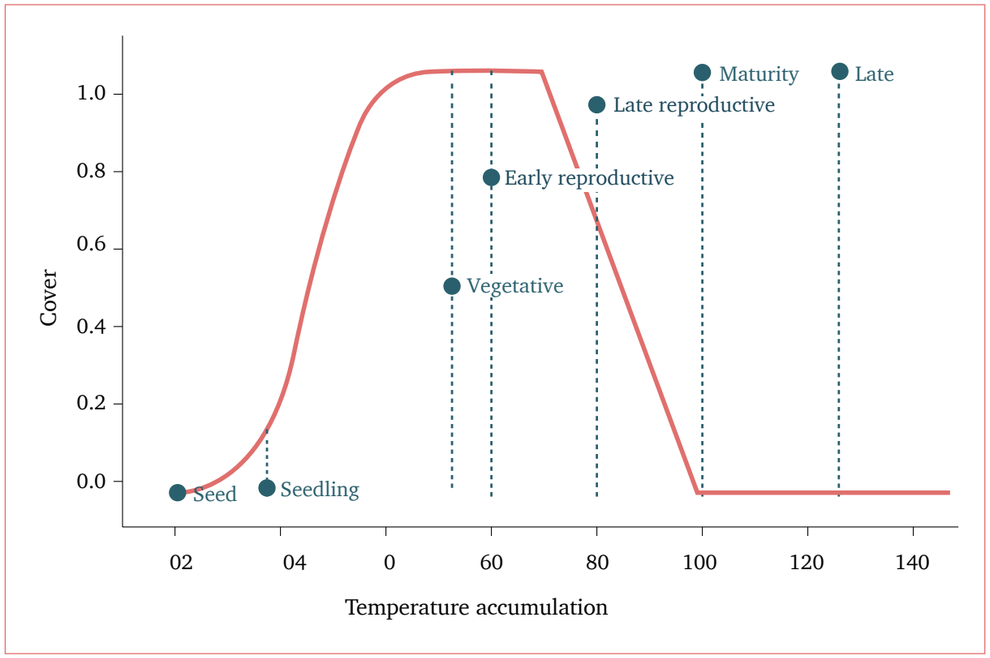


Figure 1: Crop coefficient curve shows increase as a sigmoidal function of thermal time until the canopy is closed, then a linear decrease as the crop matures

Crop sensing can automate the process of physically checking the growth of crops to determine how much water is needed.

Irrigation scheduling has typically been limited to one point measurement in a paddock using a soil moisture sensor. There are two main problems with this approach, particularly for arable growers who often have multiple crops under one irrigation system:

- First, to gather more useful results a grower would require one soil moisture sensor per paddock, which gets expensive
- Second, soil moisture monitoring measures what's readily available to the plant but doesn't provide any forecasting.

The aim of the project was to use the SWAN Systems™ platform, an automated water balance model, alongside remote sensing data to calculate the crop coefficients throughout the irrigation season.

Crop coefficients

Crop coefficients are almost synonymous with the amount of canopy cover. The development of the canopy follows a predictable pattern, with cover growing as temperature increases over time until the canopy is closed, then decreasing as the crop matures (see Figure 1).

Crop coefficients can be derived for any crop if relevant temperature data are available, from the sowing date, harvest date and the stage at which the crop is established (seed or seedling) and harvested (vegetative, early reproductive, late reproductive, maturity or late).

"Essentially the satellite measures canopy cover and then that's converted via various equations, which will tell you what stage the crop is at," explains Cindy. "You can do some irrigation scheduling by working to the averages. Nine times out of 10 you'll get it roughly right, but a lot of the arable farmers are looking to go beyond 'roughly'."

Methodology and results

The trial was conducted on an organic vegetable farm at Hororata, Canterbury where the two crops (winter milling wheat and table potatoes) were studied.

An AquaCheck soil moisture sensor was installed that measured soil moisture and soil temperature at a 100, 200, 300, 400, 500 and 600 mm depth, along with a Davis rain gauge. All sensors were monitored using Halo Systems telemetry. Two SI-111 infrared radiometers were installed in the potato paddock to measure canopy cover. This data was recorded using a Campbell Scientific data-logger.

Satellite data were obtained through SWAN Systems™ via the Sentinel-2 and Planet satellites and DataFarming via the Planet satellite. Note that the Planet data only became available late in the season (from February 2021). The location of the sensors is shown in Figure 2.

While the sparse satellite data hampered the project, a reasonable model of crop cover was obtained. However, the approach is not commercially viable without being automated and integrated into a software platform. For example, the combination of the SWAN Systems™ water balance model, alongside weekly high-resolution satellite data, has the potential to provide farmers and growers with more accurate irrigation scheduling information.

Soil water management can make a huge difference to the profitability and sustainability of a farm.

Figure 2: Farm map

Next steps

High-resolution (0.8 m) satellite data will be available daily via Planet for the 2021–22 irrigation season, and it will be possible to continue refining the crop coefficient calculations. Water Strategies intends to investigate the potential to extend this research project given the improved data availability.

SWAN Systems™ are currently working on an update to automatically calculate crop coefficients from remote sensing data, which should be available for the 2021–22 irrigation season. Testing this update in New Zealand conditions and further refining the integration of NDVI data would be useful.

Cindy says the trial was a success, despite the limited satellite data available during the growing season, because when reliable data came on-stream in February it showed what was possible. Now she would like access to research done on crop coefficients in New Zealand to help streamline the model.

"The next stage is getting all the crop growth stage data that's filed in various people's filing cabinets at government institutions out and into something useful. They've done a lot of crop coefficient work already so we can interpret some of that data. The technology's definitely coming and hopefully in five or so years it will be viable in New Zealand," she says.

– Tony Benny for Our Land and Water National Science Challenge (CC BY-4.0)

Clarity needed for drone use in environmental compliance

An investigation of farmers' and rural professionals' perceptions of adding drones to environmental compliance processes, such as farm environmental plan audits, reveals a lack of clarity about how information gathered by 'eyes in the sky' might be used.

Canterbury farmers' and rural professionals' perception of drone use in environmental management

Participants: Eight Canterbury farmers (arable, sheep/beef, dairy and dairy support) and six rural professionals

Project team: Dr Sharon Lucock (Lincoln University), Dr Victoria Westbrooke (Lincoln University), Sam Mander (The Agribusiness Group) and David Stevenson (farmer)

Report: Project Final Report – Canterbury Farmers' and Rural Professionals' Perception of Drone Use in Environmental Management (ourlandandwater.nz/RPF2020)

Technical information

Project aim: Identify barriers to the use of drones in environmental compliance, monitoring and management, and incentives to overcome these barriers.

- Eight Canterbury farmers and six rural professionals were interviewed about the use of drones as part of farm environment plan (FEP) audits.
- Trust between farmers and auditors was identified as a fundamental requirement before farmers would permit a drone to be used.
- Benefits of using drones for environmental management include time-saving, providing additional evidence, and the reduction of health and safety risks. Additional evidence needs to be backed up by site visits and discussion, particularly when it reveals an environmental problem.

Unmanned aerial vehicles (drones) are increasingly used on farms for everything from mustering stock to mapping, but have not yet been widely used to monitor environmental compliance. However as New Zealand entered Alert Level 2 restrictions during the Covid-19 pandemic in 2020, to maintain his social distance from farmers Sam Mander of The AgriBusiness Group trialed using drones in FEP audits.

When Sharon Lucock, a senior lecturer in agribusiness management at Lincoln University, heard about Sam's trial, she was intrigued. She thought it would be worthwhile to undertake an investigation to uncover the perceptions of farmers and rural professionals about the use of drones for environmental compliance purposes. "At the time there were also some concerns expressed by regulatory agencies about whether drones would be an effective tool," she says. A successful application to the Our Land and Water Rural Professionals Fund provided the opportunity to collect information.

Sam Mander operates a drone business, Dronescape, in Canterbury, alongside his role as a rural professional and environmental consultant. Sam mainly uses drones for mapping and analysis. He believes drones could be a valuable tool for farm environmental consulting. "They make our workflow for certain tasks much more efficient and accurate. You can fly around the farm instead of driving everywhere, and you're gathering higher-quality evidence through geo-referenced aerial photos and videos, which leads to a higher degree of environmental monitoring," he says.

In Sam's experience, drones provide a valuable alternative insight into what's happening on-farm that you can't get from the ground.

In the project, researchers observed interactions between eight Canterbury farmers and three rural professionals as

Drone-captured image of Canterbury farm

The farmers who participated in the research project were generally apprehensive about allowing drones to fly over their property.

they audited compliance with FEPs, and then interviewed both the farmers and the auditors. Another three rural professionals, who were aware of drone use in FEP audits but currently do not use them, were also interviewed to understand their perspectives.

Farmers apprehensive

The farmers who participated in the research project were generally apprehensive about allowing drones to fly over their property. "My observation has been that some farmers are anxious about having an eye in the sky going over their property because it's a bit invasive," says Sam.

Canterbury farmer David Stevenson had already been through one FEP audit before Sam approached him with the idea of using a drone to help with his next one. "I felt really comfortable about it, but that's because I'd gone through one audit and this was my follow-up audit for the year. I only had to show the auditor a couple of things I had to do to get my grade up, so it was easy that way," he says.

David believes he would probably have felt differently if it had been his first audit and understands other farmers' anxiety. "I think the biggest thing that all farmers are scared of in the current climate is drones being flown around and pictures being taken, and videoing being done from above, and where those pictures and videos will end up," he says.

A variety of other obstacles to the effective use of drones on-farm were identified during the project, including weather. Drones do not perform well in high winds and cannot be flown in the rain, so weather is one of the biggest issues in overcoming farmer's distrust of how they might be used.

Trust critical

The report says that without a critical level of trust between the farmer and auditor, the drone would not be allowed to fly on-farm. The audit process was stressful for the farmers, with those interviewed expressing a sense of relief when the audit was completed and the auditor had left. The farm tour also changed from the 'farmer driving the auditor around' to the 'auditor flying the farmer around', which is a change in who is driving that part of the process.

"There is consistency around the level of trust that the farmer has for the auditor as a determining factor for whether or not the drone is going to be allowed to be used," says Sharon.

Providing clarity around the use of drones is key to the successful use of the technology during environmental audits.

Three principal benefits were identified from using drones for environmental management purposes (see Figure 1):

- Time-saving
- Providing additional evidence from an aerial perspective
- A reduction of health and safety risks, e.g. driving on steep or slippery farm tracks.

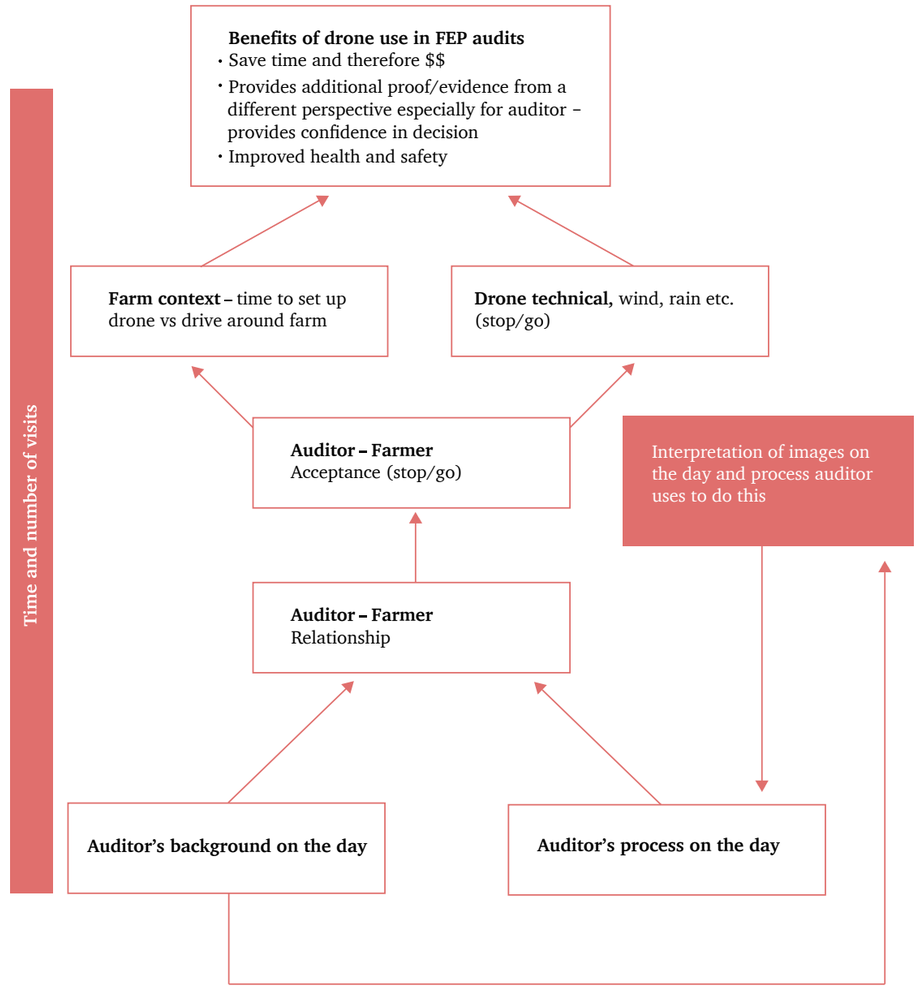


Figure 1: Conditions and advantages of drone use in FEP audit process

One of the requirements for the audit process when drones are used is that farmers can view the same pictures being beamed down to the auditor on a separate screen so that the farmer and auditor can talk about what they're seeing.

Sam says he's found that once farmers become familiar with the technology and how it's used in the audit process, and get to know the auditor, some of the barriers usually break down.

"Once you're flying the drone and interacting with them on the screen, they can see what it's viewing and that increases their confidence in being willing to use them. A lot of the time, by the end of an FEP audit when you've been using the drone, they thought it was a cool technology."

He believes drones are a valuable tool, and that compared with other countries New Zealand agriculture has been slow to take advantage of them.

"The rest of the world's been using them for a lot longer. I think it's going to be really helpful for industry, for farmers and for consultants when used appropriately," he says.

David believes that drones will eventually be accepted. "It will take a little bit of time and a few guinea pigs just to show that all these pictures aren't going to go anywhere, that you can't be prosecuted from them or anything like that. It's the same as if someone walks or drives around the farm, so it's just part of the audit and that's it," he says.

Next steps

The project team has planned workshops to deliver the research findings face-to-face to interested farmers, and to seek feedback about how future research can be directed.

– Tony Benny for Our Land and Water National Science Challenge (CC BY-4.0)

Finding out about stream health for themselves

Manawatu catchment group members have investigated the ecological health of the stream they share and are tweaking their systems to look after it better.

Seeing, Understanding, Believing: a farmer-led project into waterway improvement

Participants: Three Manawatu farmers

Project team: Christine Finnigan (farmer), Terry Parminter (KapAg), Juliet Milne and Amanda Valois (NIWA)

Report: Project Summary – Nguturoa SUB project (ourlandandwater.nz/RPF2020)

Technical information

Project aim: To package practical methods for farmers to self-monitor waterway condition and ecological health and integrate the results with strategic farm and catchment planning.

- Three farmers learned to use the NIWA-developed Stream Health Monitoring and Assessment Kit (SHMAK) to assess stream health.
- Freshwater mussel (kāhaki) population spread was limited by lack of kōaru (whitebait), highlighting the need to transport juveniles.
- Nguturoa Stream sediment, phosphorus and *E. coli* were found to be more significant pollutants than nitrogen.
- Environmental DNA results indicated that most of the *E. coli* in the Nguturoa Stream was coming from cattle and ducks, but some from human sources. Stormwater from State Highway 57 was likely to be a source of sediment and heavy metals.
- Farmers identified their critical source areas that are contributing most contaminant loss.
- This information is being used to identify practical actions to mitigate losses, including more fencing and riparian planting within farm plans. One farmer is considering developing a wetland to trap nutrients.

Christine Finnigan jokes that her biggest contribution to a community project she initiated, centred around the Nguturoa Stream, was its name – Seeing, Understanding, Believing – but she says the title was fundamental to its success.

"If you see it and you do something about it, then see the result, you get buy-in. That was where we came from and that's such an important aspect with practical people," she says. "You can tell them till you're blue in the face, but if they don't see the result or the relevance or how it affects them, you know, out of sight out of mind, you're not going to go anywhere."

Christine joined fellow farmers, farm consultant Terry Parminter and NIWA scientists Juliet Milne and Amanda Valois, to find out what was happening in their stream, as opposed to what might be assumed to be as a result of farming.

Five years ago she bought a 160 ha property near Linton, at the foot of the Tararua Ranges, in partnership with her son James and daughter-in-law Hanna. Christine enjoyed the farm's stand of native bush and became interested in starting a catchment group to look after the Nguturoa Stream which runs through her and her neighbours' farms.

She tried to get her local DairyNZ discussion group interested, but when other members didn't show much enthusiasm, she went ahead and started work herself and invited community members to a catchment meeting. To her surprise 30 people turned up. Christine found that despite the differing backgrounds of the group members they shared values around protecting and enhancing the catchment. The group didn't have much knowledge about the stream's ecological health, so they decided to undertake water testing. When she told Terry Parminter he saw the potential to show farmers what they could do themselves while also finding out something valuable about their waterway. He applied for funding from the Our Land and Water Rural Professionals Fund and contacted NIWA to get some expert scientific help.

Assessment kit

NIWA has developed a stream health monitoring and assessment kit (SHAMK). NIWA scientists and project team

Christine Finnigan, Terry Parminter, and Kim Bills beside the Nguturoa Stream on the property of Kim and Peter Bills

members Juliet Milne and Amanda Valois worked with three farmers to show them how to use the kit to build a picture of the health of the Nguturoa Stream. The kit tells you some, but not all, of the necessary information required to judge stream health. It was augmented by traditional water sampling for nitrogen and phosphorus species, sediment (as indicated by turbidity) and the faecal indicator bacteria *E. coli*.

Using the kit and water sampling, stream water quality and ecological conditions were measured at four sites on multiple occasions:

- At the top of the catchment where the stream begins
- At a drainage point for each of the farms where they enter the stream
- At the lower end of the catchment below all of the farms (see Table 1).

The expectation, from what is often reported in the media about livestock farming and water pollution, was that the tests would reveal high concentrations of nitrates in the stream water as a result of farming. However, what was revealed was that phosphorus, sediment and *E. coli* were more serious issues.

"You could assume our catchment was really high in nitrogen and then you could have spent a whole lot of money mitigating that when, in actual fact, the best thing we could have done is address critical source areas, or all the septic tanks up the road, or something like that. Knowing what you've got and then doing the right mitigations is really important because you can waste a lot of money," says Christine.

An important part of the project, Terry Parminter says, is empowering farmers to do the work themselves and not rely on regulators to tell them what to do. "Any farmers,

As a result of the project, the three farmers involved are making management changes to reduce sediment and phosphorus run-off.

Table 1: Selected water quality results for the Nguturoa Stream as it enters and leaves the catchment

Measurements and units	One Plan target*	Manawatu R at Opiki Br**	Nguturoa upstream		Nguturoa downstream	
			Median	**Range**	**Median**	**Range**
Turbidity (NTU)		4.27	3.16	1.92-6.31	4.45	2.52-5.52
Nitrate N (mg/L)		0.306	0.013	<0.005-0.080	0.157	<0.005-0.440
Ammoniacal N (mg/L)	<0.400	0.080	0.016	0.012-0.023	0.024	0.011-0.044
Dissolved inorganic N (mg/L)	<0.4444	0.0430	0.026	0.017-0.077	0.181	0.016-0.393
Total N (mg/L)		0.76	0.19	0.13-0.34	0.72	0.50-1.0
Dissolved reactive P (mg/L)	<0.010	0.019	0.013	0.008-0.022	0.055	0.0026-0.116
Total P 9(mg/L)		0.053	0.04	0.02-0.05	0.11	0.04-0.25
E. coli (MPN/100 ml)	<260	160	97	<5-146	**682**	10-3,870

*These are not absolute standards that must be met on every sampling occasion. Typically, the median value of a dataset for one or more complete 12 month periods would be compared against these values.

**Median values from monthly sampling by Horizons Regional Council staff over the last five November to June periods (36-37 data points).

Dr Amanda Valois (NIWA) found some toxic algae in the stream headwaters during the project's first field day

any community, anywhere in New Zealand could do this and have some way of interpreting the results and linking them back to management. It's about empowering, rather than making them dependent," he says.

As a result of the project, the three farmers involved are making management changes to reduce sediment and phosphorus run-off. More fencing and riparian planting is planned, and one farmer will install a stock water supply so animals don't need to drink from the stream, reducing deposits of faeces and *E. coli*. Another farmer is considering installing a wetland to trap phosphorus and pathogens.

Inter-connected ecology

As well as measuring water quality, the farmers and scientists examined what was living in the stream (invertebrates and fish) and looked closely at the freshwater mussels (kākahi) found on Christine's farm. They found out that although the kākahi were there, there wasn't any sign that the population was growing or spreading to other parts of the stream.

That turned out to be a lesson in how inter-connected different aspects of stream ecology are. Kākahi rely on their free-swimming larvae being able to attach to the gills of native kōaro (whitebait) to hitch a ride to new locations upstream, but if there are only a few of the fish around kākahi can't spread.

The community agreed on the importance of supporting kāhaki in the stream, so are starting to look at culverts and other ways to help whitebait swim all the way up to the Nguturoa catchment from the sea. By minimising sediment, the group will also help the kākahi, which are filter feeders.

Terry Parminter sees this as an example of how finding out what's happening in their local stream has influenced farmer attitudes. "We've started to have farmers thinking about all of this and starting to change their management," he says.

Involving farmers in hands-on water quality measurement led to them thinking more about what the numbers mean and reflecting on them as part of their day-to-day management.

Next steps

Terry Parminter believes an important role for rural professionals is 'connecting the dots' to ensure farmers make sense of the numbers coming from monitoring. "It's hard to get excited and passionate about numbers, but turn it into animals and bugs and life in the stream and it starts to make more sense to people," he says.

Rural professionals and farmers can connect those dots to decide on possible farm management changes and apply strategic thinking to include actions in a farm environment plan (FEP).

Resources for measuring stream health

- Find more information, a manual for use, and purchase a SHMAK kit from NIWA: niwa.co.nz/freshwater/management-tools/water-quality-tools/stream-health-monitoring-and-assessment-kit
- Instructional videos demonstrate the correct procedure for carrying out measurements using SHMAK, including the collection of water samples: https://niwa.co.nz/our-science/freshwater/tools/shmak/videos
- Our Land and Water has a repository of resources for catchment groups and catchment planning: ourlandandwater.nz/get-involved/in-your-catchment

– Tony Benny for Our Land and Water National Science Challenge (CC BY-4.0)

Water availability and other barriers to diversification

The availability of water for irrigation and complex processes to get water use consents have been identified as key barriers to land use diversification by Waikato farmers.

Facilitating farmer economic understanding of alternative land uses and the barriers to adaptation and land use change

Participants: Eleven Waikato dairy and sheep and beef farmers

Project team: Phil Weir (farmer), Phil Journeaux, Jeremy Hunt and James Allen (AgFirst) and Tracy Nelson (AgResearch)

Report: Barriers to diversification (ourlandandwater.nz/RPF2020)

Technical information

Project aim: To investigate the challenges faced by landowners when they seek to diversify via land use change.

- Eleven Waikato farmers assessed diversification options. Three farmer workshops were facilitated to provide information on alternative land use options, due diligence requirements, economic analysis, risk criteria, as well as provide expert industry perspectives.
- Obtaining good information, particularly economic, on the options under consideration is critical, and the lack of this information was a major barrier. Similarly with information/access to a value chain or to markets.
- For individuals, the biggest barrier faced was time availability – to continue to run the existing enterprise while doing due diligence on the proposed land use change.
- The biggest barrier to change land use to horticulture was access to water for irrigation and working through the bureaucracy around this.
- Overall, while land use change may well be desirable, there are significant barriers to achieving this. Diversification is complex and multi-faceted.

Waikato sheep and beef farmer Phil Weir and his young family have a 240 ha property at Te Pahu in the Waikato. Phil had been thinking about diversifying their operation to better provide for the next generation. For him, this decision was an equity growth issue for their children, with a 20 to 30-year development horizon to progressively convert land that might be worth $20,000 to $30,000/ha into land worth $500,000/ha.

The family's land has long been recognised as having potential for horticulture. Phil had visited kiwifruit growers and talked to industry service providers to understand what was involved, but he had not pushed the go button.

In addition to farming full-time for the past five years, Phil Weir works part-time as a consultant with AgFirst and had worked with the Waikato Regional Council on a project exploring diversification options for the region's farmers. As he was involved in that project he seized the opportunity to continue the work when funding became available through the Our Land and Water Rural Professionals Fund.

Clients were saying to Phil, "I'm a dairy farmer but what else can we do on my farm?" So AgFirst staff thought, why not look at what barriers farmers actually face when they are trying to look at a diversification option? Once the funding was sorted Tracy Nelson from AgResearch also became involved.

Participants and motivations

The Waikato has one of the highest proportion of high-quality soils in the country and alternative land use options are becoming a very hot topic. Eleven Waikato farmers were recruited for the project, which comprised three workshops and plenty of homework.

The participants farmed a diverse range of enterprises: dairy, sheep and beef, and lifestyle. Most were considering a combination of diversification enterprises, including kiwifruit and dairy sheep, dairy sheep and blueberries, and kiwifruit and vegetable production (see Table 1).

In the workshops, the 11 farmers looked at the options available, the need for good due diligence, access to information (especially financial), and the challenges and barriers participants came up against and how they approached these.

The second diversification workshop was held in Phil Weir's woolshed, with guest speakers from EastPack, Maui Milk, hydrogeologist Clare Houlbrooke and a farmer who is diversifying into avocado

The group of farmers were all thinking about diversification seriously, but many of them were uncertain, not knowing exactly where to start. AgFirst had already developed a due diligence list that was used as part of their consultancy, so they walked the participants through this. Another project team member, Phil Journeaux, noted a few lightbulb moments when some of the farmers connected with elements on the list, but others were feeling it was all quite complicated.

Four key motivations were identified among the group (in order): financial gain, the desire to try something new, the desire to reduce their environmental footprint and the need for succession planning (see Figure 1). Generally, people wanted to get ahead financially while doing something they perceive to be better for the environment from a nutrient loss and carbon perspective, and setting up for the future.

The general age band of the group was between 30 and 50 – enough time to take on debt and hopefully to make the debt work for itself.

During the project, participants had to do their own work researching diversification options for their farms. Project leaders deliberately tried not to assist them, instead saying, "You might need to talk to this organisation or this person." Quite a few of the farmers they were working with commented on how difficult it was from a time perspective, given they still had to run their farm and do homework to work out whether they should change their farming system.

Finding information and perseverance

Finding the information needed to inform diversification decisions proved difficult. While information about pastoral farming is easily available, outside the large horticultural industries such as kiwifruit and pipfruit, it is more difficult to access information on other horticultural crops.

"If you get into the smaller horticultural things like berries, the number of people doing it are relatively small. It is very competitive, and most people aren't keen on sharing information," says Phil Journeaux.

Phil says that farmers who have been dairy or sheep and beef farming for 20 years sometimes do not appreciate how well the value chain serves them with their current operation. "If I'm a dairy farmer, I produce the milk and miraculously a tanker turns up every morning and takes it away. Whereas, if I was looking at getting into some obscure horticultural product, that whole value chain simply does not exist so if I want to get into it, I have to create it."

A farmer can grow a crop, but what happens after that? "You've got to process it, pack it and market it which all burns a lot of time, energy and money," says Phil.

He advises that to see a diversification project through to the end farmers need perseverance. "Some of the barriers are certainly able to be overcome in the sense you just have to persevere and hunt around. At the end of the day, you might have to take a punt." Harder to overcome, he believes, are regulatory barriers and access to water.

Several of the group were interested in horticulture, so the project leaders conducted a few sessions talking about water and irrigation and they very quickly found how difficult it is to get water for irrigation.

This has also been the experience of Phil Weir as he worked his way through the due diligence process and finding out the feasibility of putting part of the family farm into kiwifruit. Even though he had a background in the Resource Management Act from being a consultant, it was still not easy.

For instance, he says, "There are different takes and different types of groundwater, and certain areas are over-allocated, yet you know there are water rights [given in similar circumstances] elsewhere. It's just not a very clear or easy environment to navigate for the average farmer. The ironic thing is from a regulatory viewpoint it would be far easier for me to split my farm up into lifestyle blocks and flog them off than it would be to convert it into an orchard or something like that."

Water issues

Phil Weir's stock water comes from a local stream, but that is not deemed sufficient for irrigation. He looked at whether he could collect water from other parts of the farm, but that was not allowed under the rules either because it would restrict surface flows into the Waikato River. The next option was to drill for water. Phil notes that it is this part of the diversification process that tests people's nerves. The family has spent about $100,000 already, drilling deep beneath their farm.

It has cost this much to confirm there is water down there and they are currently going through the consenting process. The result is that the family now plan to go ahead with developing a kiwifruit block and will probably plant kiwifruit next winter or the winter after.

Phil Journeaux believes access to water will be an issue for farmers looking for diversification options all over New Zealand. "A lot of catchments are over-allocated," he says.

The final project report highlights five areas of frustration among participants around water issues:

1. Accessing information on water resources and council regulations.
2. Costs for investigation and the risk of not finding the quantities required.
3. The time and cost of obtaining consents.
4. The abundance of surface water on their farms with high flows during off-peak periods, but the constraints in harvesting and storing this for summer use.
5. Given the high rainfall in the region, water storage for irrigation could be relatively efficient. A key question was how to weigh the environmental impact of accessing water compared to the opportunity to reduce nutrients and greenhouse gases (GHGs) through land use change.

Individual farmers will take time to diversify and need perseverance to navigate their way through the process, making sure it stacks up financially and ticks all the regulatory boxes. But some will be under more pressure and will have to diversify to stay in business, says Phil Weir.

Table 1: Land use change considered by participants

Land use change considered	Number of respondents
Dairy, sheep	4
Vegetable production	4
Maize	2
Blueberries	2
Kiwifruit	3
Dairy, goat	1
Other horticulture (nut trees, citrus, 'anything')	4
Other (forestry, raw milk, meat processing, honey, nursery, native trees, carbon)	8

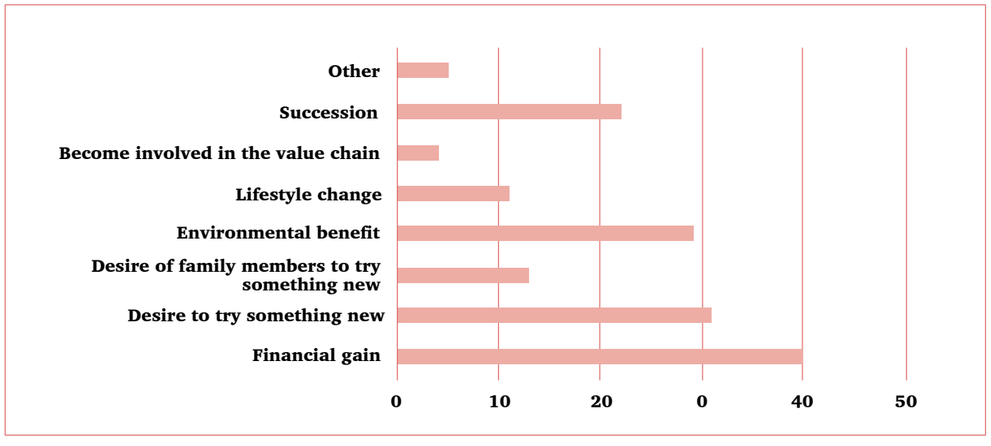


Figure 1: Key motivations for diversifying ranked by participants

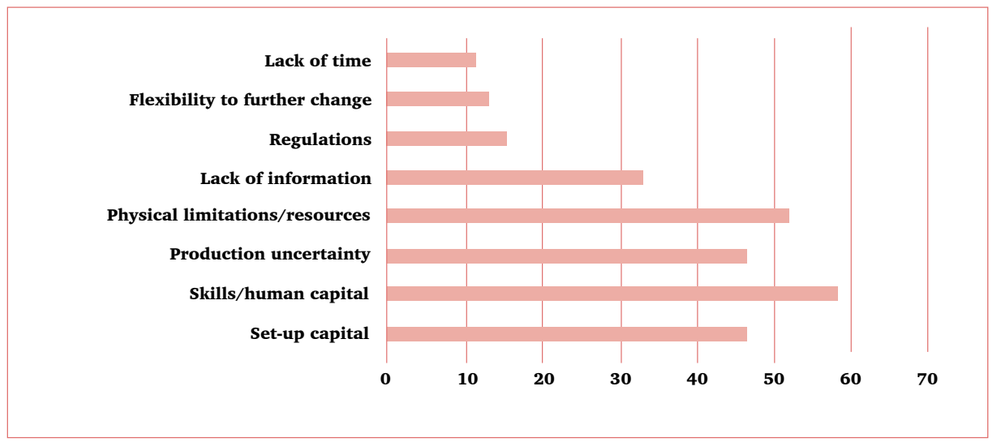


Figure 2: Key barriers to progressing diversification options

"If you look at what's happening in terms of water quality and GHGs and the regulatory costs on some farms, I would say that could actually force them to look at diversification. That gets a bit tricky because if I'm going broke because of the regulatory cost on my farm, I'm not going to diversify because I won't have the capital. What'll happen is, I'll sell my farm to you, you've got the capital and you do the diversification."

The real key to whether farmers diversify might come down to their personal circumstances and their appetite for change as much as it does to other factors, believes Phil Journeaux.

"AgFirst do an annual financial survey of dairy farming in the Waikato/Bay of Plenty and the payout at the moment is pretty good. Some of the people who are interested in diversification have said, 'I'm making reasonable money out of dairying, so let's flag the diversification, we'll keep on trucking for a few years'. Whereas on the other side, some are saying, 'We've got a bit of surplus cash now so let's get serious, I'll hire someone, and they can do some of this donkey work for me'."

– Tony Benny for Our Land and Water National Science Challenge (CC BY-4.0)

Next steps

- More in-depth analysis of farmers diversifying in a specific region, focusing on both the farmers and their support network.
- Case study approach: a focus in on one diversification pathway/option (e.g. dairy cows to dairy sheep or adding kiwifruit to a dairy platform), and tracking farmers' experiences as they progress towards implementation.
- Develop Fact Sheets on useful information when considering land use change.
- Review government policies and regulations that inhibit land use change, particularly those that result in lower environmental footprints.
- Review of value chain and markets – if there is a large-scale conversion to horticultural crops can the value chain/market accommodate this?
- The following are considerations that need to be addressed at a regional and national scale:
  - How can we make land use diversification more appealing?
  - What are the steps that can be put in place to enable change to happen?
  - How can we support the industry to provide better information?
  - If access to water is such an issue, how can this be overcome?
  - The easier alternative pathway to diversification is subdivisions/lifestyle blocks.

Research Partners

agresearch – āta mātai, mātai whetū
GNS Science Te Pū Ao
Manaaki Whenua Landcare Research
Cawthron – The power of science®
ESR – Science for Communities
Lincoln University – Te Whare Wānaka o Aoraki
Lincoln Agritech Ltd
NIWA – Taihoro Nukurangi
The University of Auckland – Te Whare Wānanga o Tāmaki Makaurau – New Zealand
Massey University – Te Kunenga ki Pūrehuroa – University of New Zealand
Victoria University Wellington – Te Whare Wānanga o te Ūpoko o te Ika a Māui
The University of Waikato – Te Whare Wānanga o Waikato
Scion – Forests • Products • Innovation
University of Canterbury
University of Otago – Te Whare Wānanga o Otāgo – New Zealand

Contact Us
E: ourlandandwater@agresearch.co.nz

Learn More
W: ourlandandwater.nz

twitter.com/OurLandandWater
facebook.com/OurLandandWater

National SCIENCE Challenges
OUR LAND AND WATER
Toitū te Whenua, Toiora te Wai