New Ground

INNOVATIVE IDEAS TESTED ON-FARM BY RURAL PROFESSIONALS FUND PROJECTS 2023–24

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OUR LAND AND WATER

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New Ground

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Gratitude for our ground breakers

Jo Finer, CEO of NZIPIM

I'm delighted to introduce this fourth and final issue of *New Ground*, which highlights learning and insights from 10 projects funded by the Our Land and Water National Science Challenge through its Rural Professionals Fund.

This $3 million fund, a partnership initiated by the NZ Institute of Primary Industry Management, has once again demonstrated the vital role of collaboration and innovation in advancing our agricultural practices. It's been a valuable partnership and a rewarding four-year journey.

Since its inception in May 2020, the Rural Professionals Fund has inspired an impressive array of projects –49 in total out of over 150 innovative ideas submitted – with each endeavour aiming to deliver tangible improvements within our farming systems. Each project had up to $75,000 and nine months to rapidly test their ideas and innovations. A very high proportion of the 49 funded projects resulted in meaningful advice, new practices, or useful tools.

The projects showcased in this issue reflect the hard work and creativity of our rural professionals and farmers, who have bravely embraced the challenges of scientific inquiry and experimentation.

The collaborative approach, where most projects partner farmers with scientists, has fostered an investigative mindset. It is thrilling to see rural professionals and farmers taking the lead on research projects, applying scientific methods to their innovative ideas. This blend of practical experience with scientific rigor has enriched our understanding and management of the land.

A remarkable aspect of this initiative has been its embrace of both successes and failures. True to the spirit of scientific exploration, we have recognised that every outcome leads to deeper understanding of what works – and what does not.

Our commitment to sharing all results publicly and in detailed technical reports remains a foundational principle. This transparency ensures that the entire community benefits from every project, learning from each other's experiences and continuously pushing the boundaries of what is possible.

The projects featured in this issue have brought forward many meaningful advancements. From assessing the effectiveness of cow collar technology and the 2020 regulatory limit on nitrogen fertiliser, to finding onshore phosphorous resources and the profitability 'sweet spot' when reducing greenhouse gas emissions, these projects have sparked discussions and interest among the public and within our rural communities.

As the National Science Challenges come to an end in June 2024, all those involved in these projects over the past four years will carry forward the spirit of innovation and collaboration that has been nurtured by the Rural Professionals Fund. For many rural professionals and farmers, it has been their first opportunity to experience how research can be applied at farm scale, and we hope they will seek other opportunities to connect with relevant research and researchers in the future. This will ensure that our agricultural sector remains resilient and vibrant, with innovative ideas that can help us meet the challenges and opportunities of the future.

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New rules reduce nitrogen on dairy farms

Impact of nitrogen fertiliser restriction

Why: To investigate how farmers had responded to the regulatory capping of synthetic nitrogen (N) fertiliser at a maximum of 190 kg/ha/year onto pastoral farms, and the impact this had on N leaching and greenhouse gas (GHG) emissions.

Where: Twelve irrigated Canterbury and three Southland dairy farms.

Who: Phil Journeaux (Journeaux Economics), and Charlotte Glass and Chris Beatson (AgriMagic).

What:

- The restriction on synthetic N fertiliser application led farms to reduce applications (in most cases) to well below the 190 kg/ha/year limit.
- Overall, application of N fertiliser on the Canterbury farms reduced 30% on average (range -3% to -46%) and on the Southland farms reduced 41% (range -23% to -51%).
- The amount of total N input into the system reduced to a much lesser extent due to compensatory inputs: increased supplementary feeds, cropping and N fixation by clovers.
- Overall, total N within the system reduced 9% on average for the Canterbury farms and 18% for the Southland farms.
- The key effect was that N leaching decreased on average by 15% in Canterbury and 32% in Southland.
- Gross GHG emissions reduced 1% in Canterbury and 9% in Southland.

More: ourlandandwater.nz/outputs/n-reduction-report

A recently completed study shows nitrogen leaching has reduced on South Island dairy farms since a new 190 kg/ha/year limit on nitrogen fertiliser application was introduced.

Dairy farmers have reduced their use of nitrogen (N) fertiliser in line with the recently imposed 190 kg/ha/year limit, a recently completed study shows. While that has reduced the amount of N in the farm system, there are still large amounts of N inputs being added to farm systems in the form of supplementary feed and from fixation by clovers.

The project analysed 12 irrigated Canterbury farms and three Southland dairy farms (**Map 1**), comparing their OverseerFM files from 2020 and 2023, as well as interviewing the farmers about how they had managed changes.

The project was the brainchild of agricultural economist Phil Journeaux and follows on from research he did when the 190 kg restriction was first announced.

"I did some work then trying to analyse what the issue was, which really came down to the top quartile of dairy farms and irrigated dairy farms in terms of nitrogen usage," Journeaux recalls.

"At that stage farmers potentially could compensate for the reduction in nitrogen fertiliser by other sources, particularly by buying in supplementary feed, so I was interested to follow that up to just see exactly what they had done and what the outcomes had been."

Journeaux worked with Charlotte Glass and Chris Beatson of Agri Magic Ltd, with funding from Our Land and Water's Rural Professional Fund.

The team found 15 farmers willing to share their OverseerFM records and farm accounts and talk about the changes they'd made since the limit came in.

The results were in line with their expectations, although Journeaux says he's cautious to read too much into the findings, given most of the farms surveyed were in Canterbury (only three Southland farms were included).

"We found all the farmers had reduced their nitrogen fertiliser application below the 190 kg level, some of them substantially. But virtually all of them had increased the amount of nitrogen going into the farm via supplementary feed or increased cropping, and the amount of nitrogen being fixed by clover had also increased," he says.

Overall, there was a substantial reduction in the amount of N being leached from pastures.

Canterbury and Southland comparisons

Overall, the application of N fertiliser on the Canterbury farms has fallen 30% on average (range -3% to -46%) and 41% (range -23% to -51%) for the Southland farms. N leaching decreased on average by 15% in Canterbury and 32% in Southland (**Tables 1 and 2**).

The team found 15 farmers willing to share their OverseerFM records and farm accounts and talk about the changes they'd made since the limit came in.

The differences between Canterbury and Southland are mainly down to the different ways of farming, as well as different climates and different soils. Most Canterbury dairy farms are irrigated and most in Southland are not. However, too little information was available to say if the differences were statistically significant.

Supplementary feed replacing nitrogen

Nitrogen is an essential part of the dairy industry in New Zealand, vital to keep pasture growing to achieve the production needed to make farming

Map 1: Farm locations

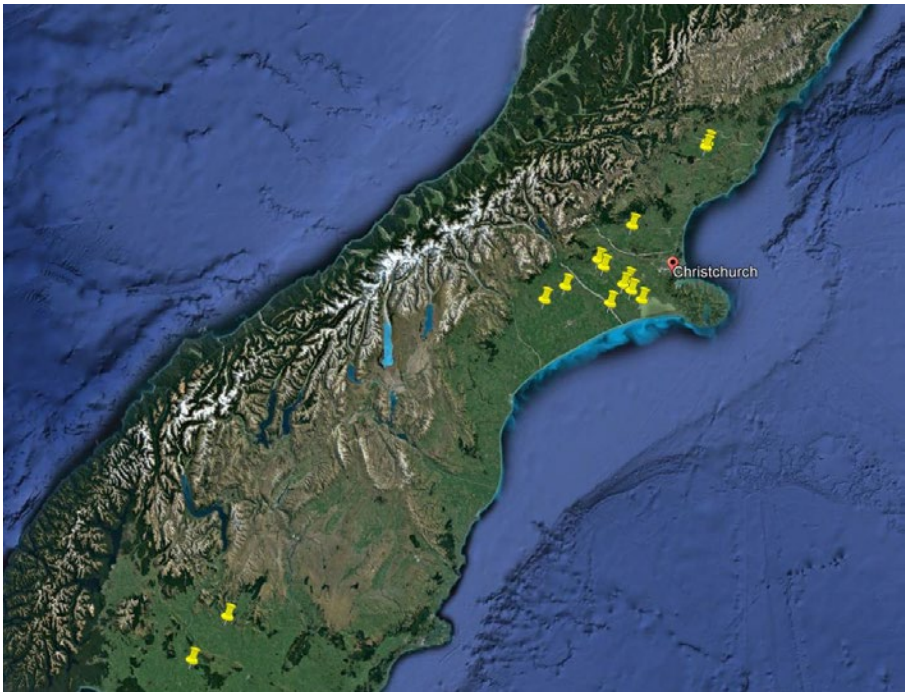


Table 1: Fifteen farms' average N input and change 2020 versus 2023

	2020	2023	kg N/ha change	% change
Canterbury farms (12)				
kg fertiliser N/ha	233	161	-73	-31%
Total N/ha	369	338	-32	-9%
kg N/ha N leaching	41	35	-6	-15%
Southland farms (3)				
kg fertiliser N/ha	260	151	-109	-42%
Total N/ha	385	316	-69	-18%
kg N/ha N leaching	69	47	-22	-32%

Table 2: Twelve Canterbury farms' average N inputs and outputs

	2020	2023	Difference	% difference
Fertiliser N (kg/ha)	233	161	-73	-31%
Irrigation N (kg/ha)	8.5	8.1	0.4	-5%
Supplement N (kg/ha)	33	46	13	38%
Clover N (kg/ha)	95	123	29	30%
Total N kg/ha	369	338	-32	-9%
kg N/ha leached	41	35	-6	-15%
N surplus kg/ha	267	238	-29	-11%
PNS* kg/ha	171	110	-61	-36%

* PNS = Purchased Nitrogen Surplus = Nitrogen from fertiliser and supplementary feed less nitrogen extracted as product

profitable, and Journeaux says it is effectively the cheapest form of supplementary feed.

"So, if you're not growing as much feed via using nitrogen fertiliser, then the next step up the ladder is to buy in supplementary feed, that's just a bit more expensive than nitrogen fertiliser. In a simplistic sense, that's exactly what happened," he says.

The farms in the trial were all applying more N fertiliser than 190 kg/ha/year before the rules changed, with Canterbury having a mean of 222 kg, much higher than anywhere else in New Zealand. Southland was also well up on the national mean at 185 kg.

"The top quartile in Canterbury were using over 300 kg per hectare," Journeaux says, adding that farmers had to adapt to achieve the production they needed.

"We interviewed them all as part of the programme and they had accepted the regulation, so they had to work out, 'I've got to reduce my nitrogen fertiliser, how do I adjust my farm system to make sure it continues to be profitable?'"

If the amount of forage available on-farm is reduced as a result of a limit on N fertiliser, then often the next best option (in an economic sense) is to use supplementary feed to "plug the gap", the report states.

Whether or not to use supplement is essentially a marginal cost versus marginal benefit calculation. The use of supplementary feed could mean that the total amount of N cycling through the farm is maintained and there is no reduction in nitrate leaching.

However, despite N coming onto the farm in sources other than artificial fertiliser, OverseerFM modelling confirmed that there was less total N in the system (9% less on average in the Canterbury farms and 18% less in the Southland farms) and N leaching has decreased significantly.

Overall, total N within the farms studied was reduced by 9% on average for the 12 Canterbury farms and 17% for the 3 Southland farms.

Total nitrogen was reduced

Overall, total N within the farms studied was reduced by 8% on average for the Canterbury farms and 17% for the Southland farms.

The research concluded that the total N input into the farms in the study reduced thanks to the new limits. However, the effect was limited due to 'compensatory' inputs in the form of increased supplementary feeds and increased cropping, and in particular an increase in N fixation by clovers.

"While limiting the use of nitrogen fertiliser has clearly reduced the amount of nitrogen in farm systems, that's only part of the picture," Journeaux says.

"It's the total amount of nitrogen in the system that's important, not just nitrogen fertiliser. There are other things like nitrogen in your supplementary feed and the nitrogen being fixed by clover that are pretty hard to regulate."

The main source of N is from cow urine. Nitrogen fertiliser increases pasture growth, which is eaten by animals, with the excess N then excreted as urine, from which the nitrate then leaches.

Another source of N is cropping. Nitrogen released from the bottom of the root zone via mineralisation at the end of a crop is difficult to manage, depends on the weather, and risks increasing N loss if farmers increase their area of forage crop.

"Nitrogen leaching is the same, whatever the source – nitrogen's nitrogen," he says. "You can restrict nitrogen fertiliser but it's the total amount of nitrogen in the system which is the important thing.

"What our report shows is that the total amount of nitrogen has actually decreased, mainly as a result of the reduction in the use of fertiliser nitrogen."

Surprising results

"The reduction in nitrate leaching was greater than I would have anticipated," says Journeaux. "I hadn't anticipated farmers would have reduced their nitrogen fertiliser so much.

"The case study farmers we picked were all using more than 190 kg of nitrogen prior to the regulations. That was quite an important stipulation, because we wanted to measure what they were using then versus what they're using now."

Interviews with farmers showed there was some surprise that N fertiliser applications had dropped

Table 3: Average GHG emissions (12 Canterbury and 3 Southland farms) 2020 versus 2023

	12 Canterbury farms			3 Southland farms		
	2020	2023	% difference	2020	2023	% difference
Methane (T CO_2e/ha)	9.3	9.6	3%	9.3	9	-2%
Methane (kg CH_4/ha)	373	385	3%	370	362	-2%
Nitrous oxide (T CO_2e/ha)	2.8	2.6	-9%	2.7	2.2	-18%
Total biological emissions (T CO_2e/ha)	12.1	12.2	0%	12	11.2	-6%
Gross GHG emissions* (T CO_2e/ha)	14.7	14.6	-1%	15.2	13.8	-9%

* Includes CO_2e emissions

as low as they had. There were also concerns that if the restriction was tightened further, then it would directly affect the profitability of their business.

The researchers suggest the higher-than-expected reductions were due to a combination of farmers coming to grips with the new regulatory regime and looking to 'fine-tune' their systems, as well as coping with climatic conditions.

Journeaux believes that reducing N in dairy farm systems is more complicated than simply limiting the application of N fertiliser. "While I think the result is somewhat serendipitous, overall nitrogen leaching has reduced, which is a key objective."

Financial implications

With pressure on to keep production up, it did not surprise Journeaux that farmers turned to supplementary feed to achieve that. He says farmers had to adjust their systems accordingly, which sometimes led to greater efficiency.

Farm accounts were analysed to see if changes in farm profitability can be linked to changed fertiliser rules, comparing the 2019/20 accounts to the 2022/23 accounts. The hypothesis was that costs would have increased as supplementary feed took the place of N fertiliser.

However, it was difficult to assess the financial implications of the restriction on synthetic N fertiliser usage, given the significant inflation of on-farm costs (27%) over the period. Expenditure on feed as a substitute for N fertiliser did rise significantly, both in nominal and real terms.

"I would say for some farmers who were putting on excessive nitrogen fertiliser to start with, the regulations forced them become more efficient,"

> **"There's probably no implication for their system other than saving a heap of money."**

he says. "Nitrogen fertiliser is an important input onto farms, but you have to use it very efficiently in terms of getting the best in monetary terms and having the least impact environmentally.

"Farmers need to think through the implication of that. If they're putting on excessive amounts, if they go from 300 kg to 190 kg, there's probably no implication for their system other than saving a heap of money."

GHG implications

The researchers also investigated the impact of the reduction of N fertiliser on greenhouse gas (GHG) emissions, reporting that the results are "somewhat mixed" (**Table 3**).

For the Canterbury farms, methane emissions increased by 3% due to the increase in supplementary feed but dropped 2% for the three Southland farms. Nitrous oxide emissions were down for the farms in both regions; Canterbury by 9% and Southland by 18%. Total biological emissions were static for the Canterbury farms but dropped 6% in the Southland farms.

Tony Benny for Our Land and Water National Science Challenge

Lowering emissions need not compromise profitability

Practical solutions to reduce on-farm emissions

Why: To uncover measurable differences in emissions – nitrogen (N), phosphorus (P) and greenhouse gases (GHGs) – among similar farms by examining what successful farmers are already doing.

Where: Pairs of farms from four regions – Waikato, Manawatu, Canterbury and Southland.

Who: Sarah Hawkins and Chris Lewis (Baker Ag NZ), Jeremy Savage (MRB), Clint Gulliver (AgFirst), Farmax and eight de-identified farmers.

What:

- Farms can have low GHG emissions and nutrient losses while remaining profitable. Reducing emissions (absolute emissions) doesn't need to compromise profitability (economic farm surplus/ha).
- There is no clear relationship between GHGs, profit and nutrient losses being dependent on a particular farm's soils, climate and location.
- Farmers need to find the sweet spot for the farm system for the location regarding profit and environmental effects. Changes in a GHG price or how it is measured (gross emissions or emissions intensity) will shift that sweet spot.
- That optimal farm system will likely change over time as environmental requirements change.

More: ourlandandwater.nz/outputs/emissions-reduction-report

Learning from farmers who have successfully lowered their greenhouse gas emissions shows it's possible to find the sweet spot that benefits both balance sheet and environment.

New Zealand farms can be profitable and have low greenhouse gas (GHG) emissions and nutrient losses.

New research led by Sarah Hawkins, agribusiness consultant for BakerAg NZ, used a 'learning from farmers' approach to provide answers to questions farmers had been asking for some time.

"Reducing absolute emissions doesn't need to compromise profitability," says Hawkins. She compared the performance of pairs of farms from four regions – Waikato, Manawatu, Canterbury and Southland – in a study funded by the Our Land and Water Rural Professionals Fund in 2023.

"In response to farmer enquiries about greenhouse gas emissions, our hypothesis was that significant and measurable differences in emissions (nitrogen, phosphorus and greenhouse gases) exist among similar farms," she says. "We aimed to uncover these differences by examining what successful farmers are already doing."

Anonymous farmers' thoughts

The eight farms were selected from the Dairy Systems Monitoring (DSM) database. They were paired based on having similar locations and soils, with differences in GHG emissions and minimal variations in profitability. The dataset used was from the 2022/23 season.

Pairing farms in the same regions was important to ensure the information was relevant, Hawkins

Jersey cows

says. "In many ways the research is not telling us anything we didn't already know, but it identifies some key drivers which can help reduce emissions without compromising the profitability of the farm.

"Some farms already achieve low greenhouse gas emissions while remaining profitable, but the methods employed by those successful farmers have not been thoroughly investigated. This lack of investigation leaves many farmers without the necessary knowledge about how to improve their existing farming systems. This study aimed to address this deficiency."

The exact location and identity of the farms in the research is anonymous, but some of the farmers who took part agreed to share their thoughts on its value.

One farmer says the research had shown ways in which improvements could be made on his farm to further lower emissions. Its value to the wider industry was that it compared like with like in the farms it focused on, making it easier for farmers to relate to.

Another farmer believes the report would stimulate discussion within the dairy industry and encourage farmers to question their current farming practices in relation to their impacts on the environment.

"I hope the research will prompt others to look closely at their systems and ways in which they can improve their impacts. It's independent, with no agenda pushed," he says.

Another farmer involved in the study says the research demonstrated that there was more than one way to achieve reductions in emissions while remaining profitable.

Change is inevitable

New Zealand farmers will have no choice but to reduce their environmental footprint, says Hawkins, but she believes we are not yet fully prepared for what is to come.

"In North America and European barn farms they know exactly what's going on with feed, greenhouse gas emissions and production. A different level of understanding is required for New Zealand's biological grass-based systems. Farmers have to estimate how much animals are consuming, as they are not measuring each day what they eat."

For New Zealand farmers, the 2019 Climate Change Response Act translates this to a substantial 24-47% reduction in GHG emissions by 2050.

As a major contributor to climate change, GHGs have triggered international initiatives such as the Paris Agreement, which sets out what different countries around the world have committed to achieving regarding emission reductions.

For New Zealand farmers, the 2019 Climate Change Response Act translates this to a substantial 24-47% reduction in GHG emissions by 2050 relative to 2017 levels.

"Not only are countries committing to these international agreements, but so are financial institutions and international companies, though using their own metrics. Many banks have joined the Net Zero Banking Alliance (NZBA), committing to net-zero financed emissions by 2050. Major players, like Danone and Nestle, are making commitments to achieve net-zero emissions by 2050."

There is a justifiable concern among farmers that reducing stock numbers (if this was the only solution) would result in a fall in profitability. "Some farmers are overwhelmed by the pressures to change. However, change is inevitable and if the New Zealand dairy industry doesn't meet new targets, some customers may not accept its products."

Knowing your numbers

Knowing what farm's GHG emissions are and where they came from is the first step towards reducing them.

"Knowing your numbers highlights whether or not the farm is producing a low emission product, the status of nitrogen leaching and what can be done to make changes. Without knowing current numbers, farmers can't progress forward," says Hawkins.

The study used Farmax and OverseerFM, but Hawkins says the final model for New Zealand's GHG accounting system is yet to be defined. Modelling systems used to predict GHG emissions and nutrient leaching need to take into account new research.

"Nothing is 100% certain in biological farming. Most of us operate on the 80/20 rule. However, models like OverseerFM and Farmax need 100% proof that something works before incorporating it into their models. But farmers need to be able to model the potential impacts changes in farm management may have on the environment now," one farmer says.

The research also raised the question of where the farm boundary should be when calculating emissions. "Do farmers need to account for all support land, young stock and wintering, or is it just the milking platform?" asks Hawkins. "What will be the measure for greenhouse gas accounting – emissions/ha or emissions/kg of product? The two measures have different drivers and will result in different outcomes for farmers and processors."

Hawkins believes that devising a GHG accounting system that is fair and equitable would not be easy. "Farmers are getting conflicting messages about what is required of them – and how. Our research highlights that some management practices can reduce gross emissions and improve emissions intensity – but not all do."

The study also found that there was potential for conflict between market drivers and government policy. International legislation required emission reductions measured at a gross level. Markets and processing companies tended towards requiring reduction in emissions intensity (fewer emissions per unit of product).

While corporations were targeting emissions intensity, it should not be at the cost of increasing total emissions. The global goal was to reduce emissions and minimise the impact of climate change on global warming. "The only way this will happen is to reduce total global emissions, hence government targets," says Hawkins.

The main levers to reduce GHGs that are reflected in the models were feed conversion efficiency, dry matter intake, nitrogen (N) fertiliser use and stocking rate. The major ways to reduce GHGs include:

- **Reducing fertiliser N**, as well as imported supplement. Reducing these will directly reduce GHG emissions and N loss to water, but will also indirectly reduce dry matter available for intake.
- **Improving feed conversion efficiency** through management, livestock performance and reducing feed and livestock wastage on-farm.

Table 1: Waikato farms' GHG comparison

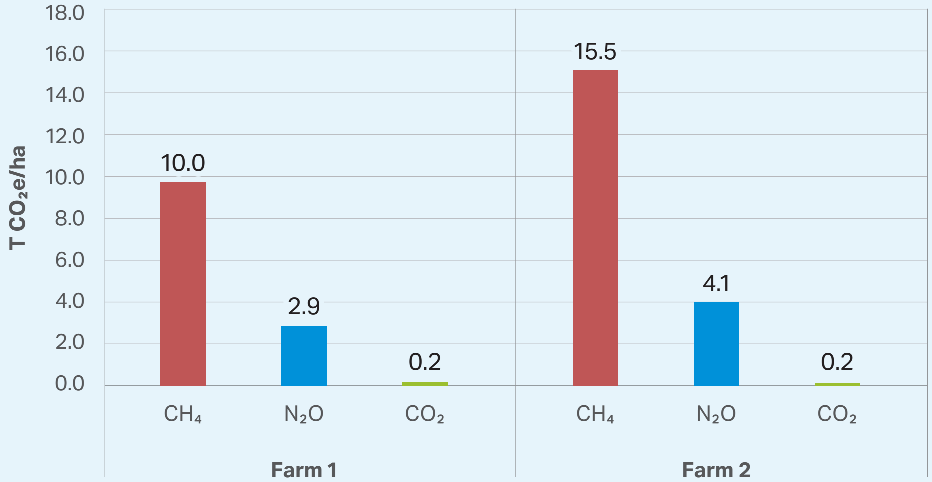
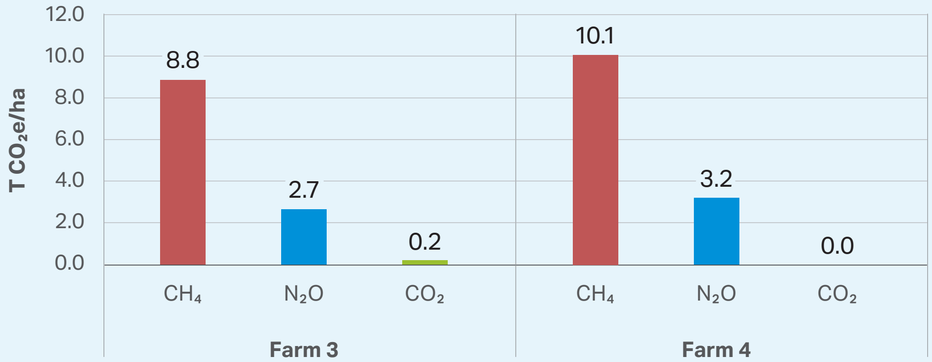


Table 2: Manawatu farms' GHG comparison



- **Targeting the sweet spot** for on-farm performance (physical, financial and environmental) – this is a factor of a farm's physical attributes, system design and management.

Comparing two Waikato farms

Both Waikato farms are located near Morrinsville and supply Tatua. The farms have similar soils, with mostly gley, poorly drained soils. The remaining soils are volcanic-free draining soils on Farm 1 and imperfectly drained brown soils on Farm 2.

The Waikato case study showed that a 41% increase in stocking rate (Farm 2 versus Farm 1) led to a similar increase in profitability and a 69% increase in GHG emissions (**Table 1**).

Intensification increases gross emissions, but can improve emissions intensity. As feed conversion efficiency improves, emissions intensity reduces.

Nitrate loss to water was not necessarily a function only of fertiliser N, stocking rate or surplus N. The efficiency of feed conversion can also be a factor, as is soil type. Differences in soil types explain much of the difference in N losses to water.

Comparing two Manawatu farms

The two Manawatu farms (**Table 2**) are located on the plains between the Manawatu and the Rangitikei rivers. The soils are a mix of sedimentary gley soils and recent sandy soils. Farm 3 has a mix of gley and sand soils, while Farm 4 has only the heavier gley soils.

Table 3: Canterbury farms' GHG comparison

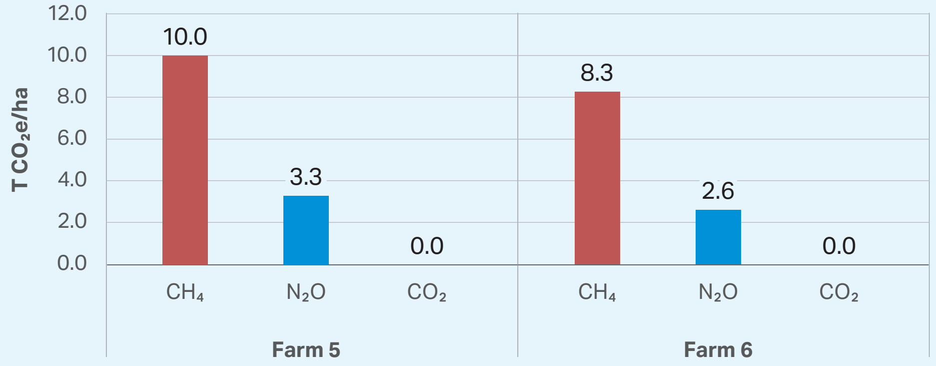
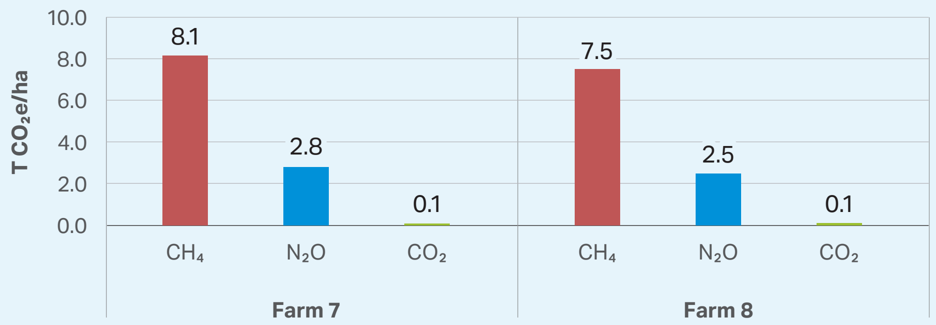


Table 4: Southland farms' GHG comparison



Given the economic farm surplus per kgCO_2e emitted, neither farm has strong economic resilience to compensate for an emissions charge.

Farm 4 is more at risk than Farm 3 once a farm-level emissions tax is implemented, as the current system has both high emissions and a lower profitability system. It is feasible for Farm 4 to lower their stocking rate and improve feed conversion efficiency. In doing this it can reduce emissions and improve operating profit.

Comparing two Canterbury farms

Both Canterbury farms (**Table 3**) are fully irrigated, highly productive farms located on the Canterbury plains. The soils are very similar, with mostly shallow free-draining Lismore soils, although Farm 6 has a small proportion of the farm with deeper moderately well-drained soils. The farms are a similar scale, with 210-235 ha effective area, and peak milking of 730-750 cows.

Finding the optimal balance of stocking rate, milk production, feed efficiencies and financial control will be important for each farm to ensure they can optimise the system for profit, GHG and nutrient losses.

Finding the optimal balance of stocking rate, milk production, feed efficiencies and financial control will be important for each farm.

Comparing two Southland farms

The two Southland farms (**Table 4**) run different systems. Farm 7 is mostly self-contained with 90% of in-calf cows wintered on-farm. Most young stock are on-farm from birth to milking. Farm 8 is run as a classic milking platform, with no young stock on after weaning. About half of in-calf cows are wintered on-farm.

Both farms have room to improve. Farm 7 can look to improve feed conversion efficiency, which will lower gross emissions and emissions/kgMS – and may well lower working expenses further. Farm 7 shows that for a self-contained farm system emissions intensity appears to be poor. When looking solely at milking stock, the performance can be good.

Farm 8 has good feed conversion efficiency and low wastage (feed and fertiliser on-farm), but a higher cost operating system. Farm 8 earns more profit per kgCO_2e and so is more resilient and able to manage a GHG tax. However, a further improvement in profitability or reduction in emissions will help the farm business.

Hawkins says when looking at the self-contained Farm 7 unit, the gross emissions and emissions intensity at face value was greater than a milking platform only. "This is due to the higher 'maintenance cost' of emissions produced by non-milking animals.

"However, there cannot be a dairy farm without young stock coming through – these costs exist for all dairy businesses. The issue is whether emissions are accounted for by farm or by business entity."

Hawkins says that in time there would be a single approved model to calculate GHG emissions. "With that there will presumably be clear guidelines on how to calculate those emissions. This will deal with the uncertainty of the farm boundary and how off-farm grazing and imported supplement are factored in."

Elaine Fisher for the Our Land and Water National Science Challenge

Cow collars proving their worth for dairy farmers

Cow collar evaluation

Why: To investigate the advantages and disadvantages of cow collar technology to the farm system and inform those considering adopting it.

Where: Case studies on one Manawatu and two mid-Canterbury dairy farms, and 10 interviews with farmers using six different technologies.

Who: Elizabeth (Liz) Dooley, Rachel Hammond, and Iona McCarthy.

What:

- Mating and labour were primary reasons for adopting collars.
- Eleven technologies were identified, with eight clearly being commercially available. Of these, only one offered virtual fencing capability (Halter).
- Collar technologies can be expensive, ranging from about $40 to $197/cow/year.
- Collars reduce the requirement for labour, particularly skilled labour, free up staff for other jobs and reduce costs associated with labour.
- Collars with virtual fencing had a number of additional benefits, which include managing critical source areas, pasture management, and to inform fertiliser use.

More: ourlandandwater.nz/outputs/cow-collar-report

A recent study shows cow collars can be effective in improving reproductive performance, stock health and pasture management. If approved by regulators, they could also reduce compliance costs.

Researcher Liz Dooley admits to being sceptical about the utility of high-tech cow collars when she launched a project to help inform farmers' decisions about whether to invest in the technology – before adding that she's more positive about the collars now.

"It does look like they're viable, particularly because they can improve pasture management (with virtual fencing) and pick up cows in heat, which is critical."

Liz Dooley led a team of researchers who evaluated the benefits and costs, both tangible and intangible, associated with cow collar technologies to help farmers make informed, confident decisions about whether to adopt and implement them.

They investigated the range of collar technologies available, including ear tags and boluses, ranging in price from about $40 to $197/cow/year and interviewed 10 farmers using six different technologies. See **Table 1** for a list of cow collar technologies.

Because of this considerable investment capital, the decision to adopt cow collar technology is not made lightly. Quantifiable information on benefits and costs of these technologies is limited and is usually provided by those selling the technology.

Of the 11 different technologies identified, eight are commercially available, with one (Halter) also offering virtual fencing capability (**Figure 1**).


Dutch Holstein black and white cow in a meadow. Photo by Venemama

The Halter collar is considerably more expensive than others in the market, meaning a trade-off between cost and features is something potential adopters must consider.

Benefits of collar technology

Interviews with farmers revealed their main drivers for investing in collars were for mating and to reduce labour requirements.

“I think they’re good if you employ staff because some don’t have the skills. That’s why it’s been picked up by quite a few people because it’s important to get your cows in-calf,” Dooley says.

Some new users took a cautious approach to using the devices for heat detection, but over time they learned to trust the technology.

“The onus is often on the owner or the manager to be in the shed over mating, but now some of them are getting so confident in the collar’s heat detection accuracy that next season they possibly won’t even be in the shed over mating.

“They use the tail paint or the buttons or whatever for the first year as well, and then after that they’ve found the app was just as effective at picking up cows so they’re confident in the app.

Interviews with farmers revealed their main drivers for investing in collars were for mating and to reduce labour requirements.

“In fact, by detecting a cow’s activity changes, some users report collars can out-perform the traditional methods of heat detection,” Dooley says.

“Some cows have silent heats and apparently that’s happening more often nowadays with the highly productive cows, so you can’t pick it up so easily. But you can see it on the app that there was activity a day or two beforehand – so when the app says so, she’s probably on heat.

Table 1: Cow collar technologies available in New Zealand (as at November 2023)

Name	Device type and ownership	Outputs	Compatible
Allflex	Neck collar (Lease or own)	• Mating • Cow health	• Allflex milk • Allflex SCC • MINDA • Protrack and Intelligate drafting
CowManager	Ear tag	• Mating • Cow health • Heat stress • Location	• MINDA • DeLaval and Protrack drafting
GEA CowScout	Neck collar	• Mating • Cow health • Cow location and identification	• Herd management software • MINDA
Halter® (NZ technology)	Neck collar (Lease)	**Dairy** • Mating • Cow health • Virtual fencing and shifting (in and between paddocks, to shed) • Cow location • Pasture management • Grazing heat maps (e.g. for pasture and nutrient application) **Beef** • Virtual fencing and in-paddock shifting • Cow location • Grazing heat maps	• MINDA • DTS • Bulk upload for csv files
smaXtec	Bolus – classic and pH types	• Mating • Cow health, including mastitis and heat stress (based on inner temperature) • Drinking behaviour	• MINDA
Tru-Test Active Tag	Neck collar or ear tag	• Mating • Cow health • Find my cow (locate cow or lost tag if nearby)	• Automatic drafters • Dairy WOW 4000 (weighing) • MINDA
Afimilk	Neck collar	• Mating • Cow health • Milk sensor integration possible	• Afimilk milk meters • AfiLab • AfiSort drafting • MINDA & Protrack (previously, 2020)
CowTRAQ (NZ technology)	Neck collar	• Mating • Cow health • Cow location	• TracHQ software • Waikato milk meter yield indicator • Sort gate 5500 (and others) • MINDA
eShepherd (Australian – with Gallagher)	Neck collar	**Beef** • Virtual fencing (being trialled in NZ)	
Connecterra's IDA	Neck collar (Own)	• Mating • Cow health (being trialled in NZ for sale via Fonterra Farm Source)	
Protag (NZ technology)	Ear tag	• Mating • Cow health • Location (recently released, being trialled)	

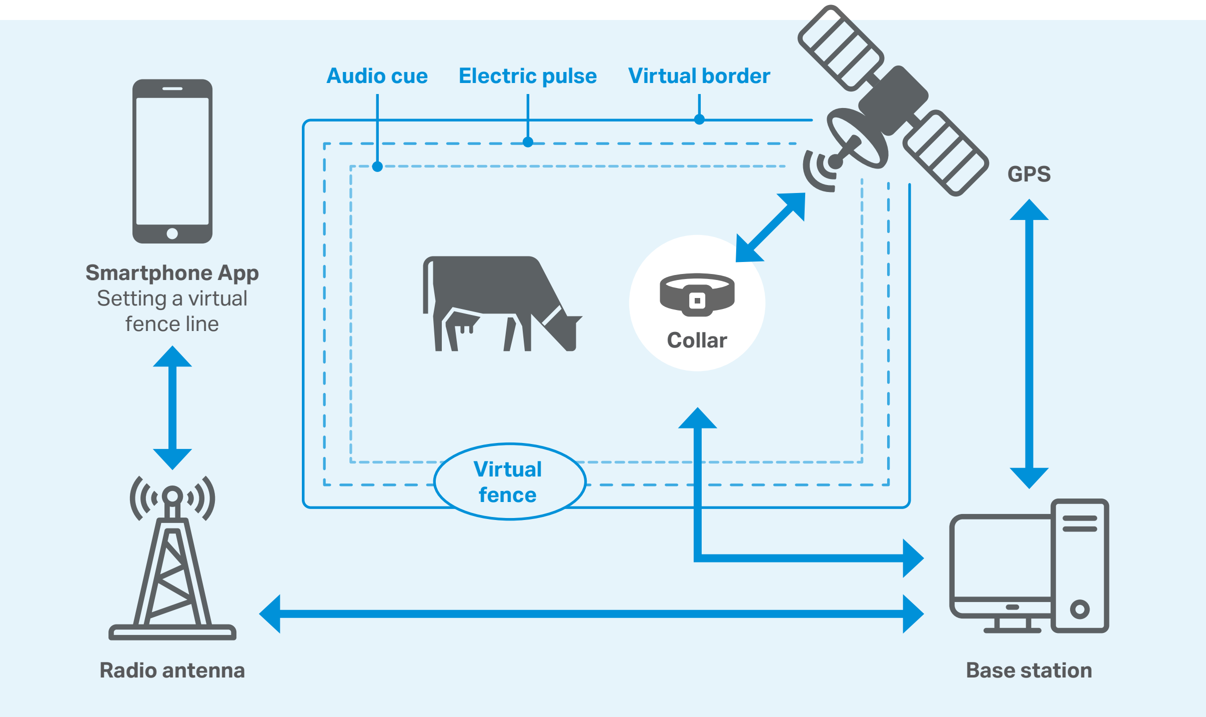


Figure 1: Concept of virtual fencing for grazing animals (from Golinski et al., 2022, p. 3)

"Some of the farmers were a bit cynical, but they mated her, and indeed she was in heat and she got in-calf."

While reducing labour requirements was another driver, farmers reported that rather than reducing staff they were able to use staff time more effectively.

"They thought they would cut a labour unit but they don't. The staff are getting all those other jobs done on the farm that didn't used to get done, which is also probably going to improve things – and the workers are probably happier as well."

Most collars in the study focused on heat detection and cow health (using rumination as a key measure). Sensors measure cow activity (accelerometer), and possibly temperature (via eartag or bolus), heart rate, pressure (for rumination).

Only the Halter collars offer virtual fencing, keeping cows where they're put and sending a signal telling them to come in for milking, which adds up to considerable labour savings. But Dooley says one of the biggest advantages of the Halter virtual fencing capability is its pasture management.

"People who are using virtual fencing are getting significantly more pasture because you're back – fencing behind the cows, which you can do at the push of a button, keeping cows off areas they've already grazed.

"If you're having a damp day you can cut out a bit of the paddock you don't want trampled and they're just getting much better pasture quality because it hasn't been trampled."

The report concludes there is potential for these technologies to become increasingly used in the industry and integrated across the farm system.

Sensor and data capture technology is evolving rapidly, and ongoing data analysis and machine learning will improve algorithms and prediction over time. It's likely to be relatively straightforward to add more sensors to cow collars in future. Integration with other precision agriculture technologies will expand their potential.

"Things evolve, don't they?"

Dooley's initial scepticism has been replaced with an understanding of how useful this technology can be on-farm. If regulators accept the effectiveness of virtual fencing it could offer additional advantages, she says.

"If the technology becomes accepted it has the potential to save a lot of fencing costs or even [for farmers] to pay less for compliance if they can use the outputs to prove the cows weren't in any waterways."

While the study concentrated on dairy farming, virtual fencing is also an option for other farmers.

Cow collar. Photo by Tony Benny

"If the technology becomes accepted it has the potential to save a lot of fencing costs or even [for farmers] to pay less for compliance if they can use the outputs to prove the cows weren't in any waterways."

For example, they could use virtual fencing to keep animals out of waterways on hill country that were previously impractical to fence because of the terrain.

"You could make a significant improvement there because you can't get quite the same pasture quality you can on a dairy farm where they have rotational grazing and electric fences, so you've got quite a low utilisation rate.

"But if you virtually fence the rough areas, you could keep them on the bit of the hillside they don't really like to eat, and when they come back next time it'll be better pasture."

The data the collars provide is now also being picked up by vets to help them advise their farmer clients. They can analyse trends and use that to work with their clients."

Dooley says some basic farms skills, like heat detection and pasture management, are already in short supply among new staff, so the collars fill that need.

"I think those skills (pasture and animal management) are probably not going to get any better if you bring in something like this. Things evolve, don't they? People will become very skilled at using this and understanding the data and interpreting and reacting to that instead," she says.

Tony Benny for the Our Land and Water National Science Challenge

Turning a profit while turning paddock corners into shady oases

Integration of agroforestry systems with irrigated dairy farms

Why: To establish how agroforestry could be incorporated into the dryland corners of irrigated dairy farms for economic gain through carbon credits, with the possible benefit of shade for cows.

Where: Modelling planting exotic trees in dryland corners of two dairy farms in Waimakariri, Canterbury, one with a small number of high-value timber trees and the other with some natives and transitioning from exotics to natives over time.

Who: Kyle Wills, Dr Sandra Velarde Pajares, Dr Electra Kalaugher, Nathan Capper, Dr Istvan Hajdu and Lisa Arnold (all with WSP), Sam Spencer-Bower (farmer), Logan Robertson (Ngāi Tahu Farming Limited) and Erin Harvie (Waimakariri Landcare Trust).

What:

- Gaining carbon credits made agroforestry in the dry corners of irrigated paddocks economically viable, producing a long-term alternative income stream.
- Shade for cows was gained, with trees also slowing hot dry winds, with a benefit for pasture of reducing evapotranspiration.

More: ourlandandwater.nz/outputs/agroforestry-report

As summers on the Canterbury Plains get warmer and winds stronger, trees could offer shade and forage to dairy cows while creating biodiversity havens – and not a pine tree in sight.

The Canterbury Plains were once a patchwork of native trees – kahikatea, matai and totara, with beech forest on the slopes. Warm and dry summer winds, having dumped their moisture on the West Coast, swept over the Southern Alps, belting down the slopes east of the divide and into the treetops on woodland plains, leaving the shaded forest floor cool and moist beneath.

The landscape has changed dramatically in the centuries since people arrived. The shady forests full of wildlife are long gone, replaced by a patchwork of pasture and cropping paddocks, turning the plains into one of the most productive agricultural areas in the country. The hot and dry nor'westers in summer now pull moisture out of the soil and vegetation through evapotranspiration.

Irrigators sweep the landscape, with dairy cows and other livestock grazing out in open, mostly unshaded paddocks. With irrigator pivots too low for shade trees, and potentially three months of hot days over 25°C by the end of the century, there are increasing animal welfare concerns over heat stress. This problem already sees a reduction in milk production in dairy cows in summer.

For 25 years, the Animal Welfare Act and the Ministry for Primary Industries have advised farmers that livestock need protection from heat stress, cold stress and extreme weather, but action has largely been insufficient to prepare for the changing climate.

Agroforestry

Shady oases

Kyle Wills, a farming systems consultant with WSP, is among consultants who now see stronger legislation for the better protection of livestock, including to provide shade, as being likely in the future. This has seen him focus on the estimated 35,000 ha of dryland corners across the plains that are outside the reach of irrigation pivots.

With funding through Our Land and Water's Rural Professional Fund, Wills looked at the economic and physical benefits of incorporating agroforestry in these lower-quality pasture corners by planting them with forage trees that cows can graze under. This will allow farmers to diversify while offering shade for stock, slowing down winds, and reducing moisture loss through evapotranspiration.

The cost of establishing trees was the biggest drawback for the farmers surveyed, along with a lack of knowledge about agroforestry generally and no local examples to look at.

Wills wondered if the trees pay their own way and provide a new income stream through the Emissions Trading Scheme. Would the negatives of shading on pasture be countered by increases in nitrogen (N) in the soil from N-fixing trees in the mix, better growing conditions from a cooler and moister micro-climate under the trees, increased pasture growth downwind of the trees, and the benefits to cows of tree fodder and less heat stress?

Getting underway

Wills and his team modelled two dairy farms at Waimakariri. The Claxby Farms 647 ha property had 93% irrigation coverage and 61 ha of dry paddock corners, while the Ngāi Tahu 335 ha Hamua farm had 95% coverage and 25 ha dry corners. Both farms ran around 3 cows/ha.

Wind- and drought-tolerant forage poplars and mulberry, with honey locust to fix N, were modelled for both farms. Being deciduous, the trees would allow good levels of daylight onto pasture during spring growth.

The Claxby Farms would have a handful of high-value black walnut trees in the mix. The Ngāi Tahu farm would include natives like N-fixing kowhai and fast-growing ribbonwood to attract native birds, with the intention that natives would replace exotics over time, eventually becoming a native agroforestry setting (**Table 1**).

Table 1: Agroforestry species, their role in the system and proportion planted at each farm

Species	Claxby Farms (planted)	Ngāi Tahu (planted)	Role in agroforestry
Poplar	32.7%	25%	Forage, soil conditioner, medium canopy
Mulberry	32.7%	25%	Forage, medium-to-dense canopy
Honey locust	32.7%	25%	Forage, nitrogen fixer, sparse canopy
Black walnut	2%		Timber, high-risk high return timber opportunity with small exposure
Kowhai*		12.5%	Behave as an island for indigenous flora and fauna to be attracted to, encouraging reforestation, nitrogen fixer
Ribbonwood*		12.5%	Behave as an island for indigenous flora and fauna to be attracted to, encouraging reforestation

* Semi-deciduous

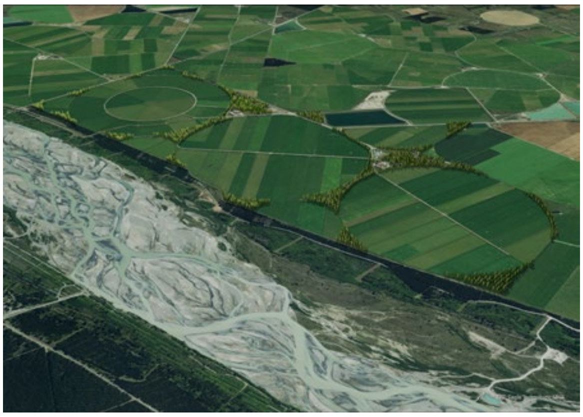
Rows of trees 20 m apart, with trees 10 m apart within the rows, would run north to south where possible to maximise both sunlight on pasture and provide wind shield to reduce evapotranspiration under the trees and downwind in adjacent pasture. Where natives were planted they were 2.5 m apart.

This would exceed the 30% canopy cover needed under the permanent forest category to qualify for carbon credits through the Emissions Trading Scheme, by around 10% canopy cover to allow for replacing trees over time. Along with providing shade for stock, some tracks and yards – unproductive areas – would now be earning carbon credits as they would be underneath tree canopies.

Ngāi Tahu chose to fence off the rows to partition their more open spaces and allow for habitat growth around the trees. While they still have some individual tree protectors, they have a higher proportion of fenced rows than Claxby. Claxby Farms went for a cheaper option of individual tree protectors and stakes to allow for more flexible management.

Claxby's costs sat at $3,974/ha. Double fencing increased establishment costs for Ngāi Tahu to $5,017/ha and sees lower financial gains long term.

Wind- and drought-tolerant forage poplars and mulberry, with honey locust to fix N, were modelled for both farms.



Agroforestry at Claxby Farms

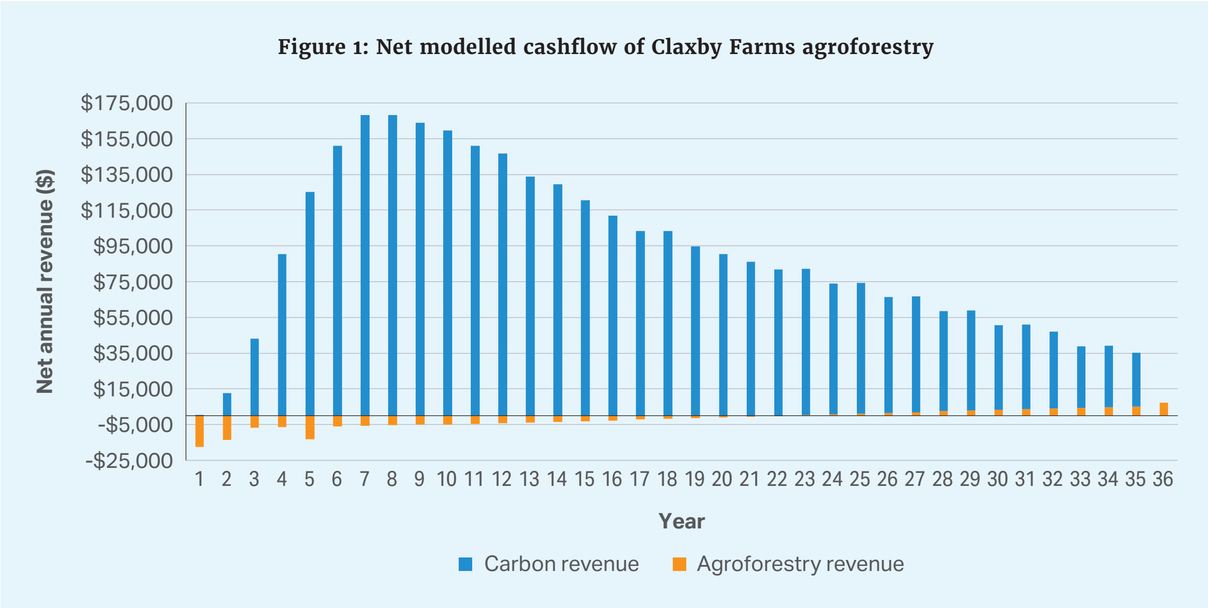
A changing landscape

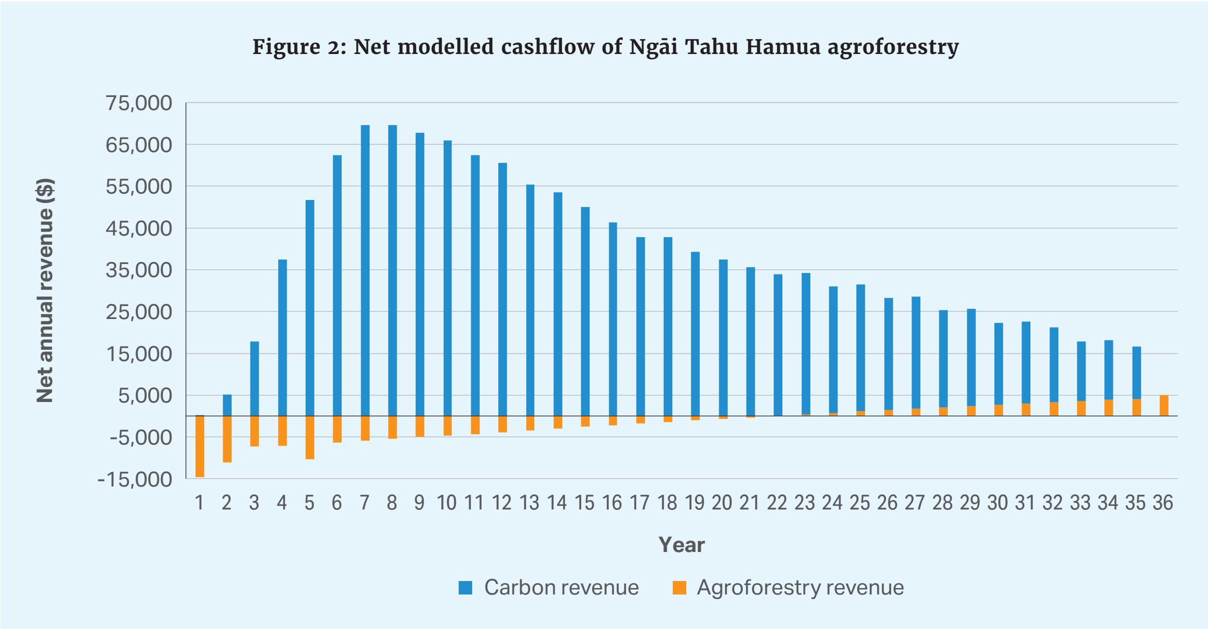
Modelling the economic effects saw both farms identify agroforestry as a land-use diversification opportunity that would pay for itself while seeing a new income stream, with all-important shade now provided to the cows.

Income from carbon credits climbed quickly during the first seven years, peaking at around $170,000 annually for Claxby and $70,000 for Ngāi Tahu, before a slow decline to the 35-year mark.

Carbon credits were the clincher for profitability as the projects run at a 7% loss without them. The sums were run with a carbon price of $70/$CO_2$e tonnes. This saw the internal rates of return (IRR) for Claxby sitting at 26% and an annual return on investment (ROI) over 36 years of 32%. For Ngāi Tahu the IRR was 20% with an annual ROI of 24% (**Figures 1 and 2**).

Should the carbon price drop to $20/tonne, the net present values (NPVs) would stay in the black for





Carbon credits were the clincher for profitability as the projects run at a 7% loss without them.

Claxby at around $123,000, but fall into the red for Ngāi Tahu by nearly $14,000.

Income from carbon credits was deemed to end at 35 years after which the trees would bring in a modest $7,300 annually for the Claxby Farm and $5,000 annually for Ngāi Tahu.

The $7,300 for Claxby and the $5,000 for Ngāi Tahu after carbon credits was from increased milk production from shade, taking into account a decrease in pasture production of 20% and increase in tree forage of 1 t DM/ha.

"This research shows a good economic incentive to look into this design further – the economics work," says Wills. He is pleased both farms are now looking at implementing this design in some shape or form.

Delwyn Dickey for the Our Land and Water National Science Challenge

Fragile balance between environmental and economic sustainability

Cumulative impact of land-use diversification

Why: To assess how land-use diversification impacts environmental management and freshwater quality, and the associated economic considerations.

Where: Three farms (Leslie Hills, Chamrousse and Edale) located within the Waiau Uwha River catchment close to Culverden in the Hurunui District of North Canterbury.

Who: Harry Millar and Josh Brown (Rural Consulting Ltd), John and Maury Penno (Leaft/Okoura Foods), Greg Dryden (Fruition Horticulture), Matt Gardner (Edale Farms), Grant Florance (Chamrousse Farming) and Duncan Rutherford (Leslie Hills Partnership).

What:

- The cumulative environmental impact in the catchment of changes modelled across the three case study farms revealed the potential for: a 13% decrease in total nitrogen (N) loss below the root zone (5,969 kg/N/year); an 8% reduction in phosphorous (P) lost in run-off (77 kg/P/year); and a 3.6% reduction in greenhouse gas emissions (GHGs) (430 CO_2-e tonnes/year).
- Uptake of land-use diversification will hinge on the individual's financial situation and ability to absorb substantial changes to their current systems.
- Each land-use diversification option shows merit in addressing key environmental metrics of N, P and GHGs while still offering medium-to-long-term financial viability.

More: ourlandandwater.nz/outputs/lu-diversification-report

Land-use diversification presents challenges and opportunities for three North Canterbury farms involved in a recent study.

Diversifying land use may bring environmental benefits. However, there is a fragile balance between environmental sustainability and economic viability, according to a study of land-use diversification challenges and opportunities for three North Canterbury farms.

"Farmers want to reduce their environmental impacts, but it is important to appreciate the economics of change. If changes are drawn out over a period of time they are more achievable, which is a factor to be considered if regulators want to encourage people to invest in land-use diversification," says study author Harry Millar of Rural Consulting.

The three farming businesses that were part of the study funded by the Our Land and Water Rural Professionals Fund, were each committed to improving both the environmental and economic sustainability of their operations.

"This study was very much farmer-driven. The three farms, all members of the Upper Waiau Independent Irrigators Group, have been actively involved in catchment projects which they have been working on intensively for the last three years.

"The owners had expressed interest in understanding more about different land-use options in the district, which could contribute to improving environmental sustainability, and which led us to design this project," says Millar.

Located in the Waiau Uwha River Catchment close to Culverden in the Hurunui District of North Canterbury, the farms are Leslie Hills, Chamrousse and Edale (**Map 1**).

> **Farmers want to reduce their environmental impacts, but it is important to appreciate the economics of change.**

Aerial view of dairy and cropping farms in Canterbury

The options investigated were converting 25 ha to apples at Leslie Hills, introducing an arable catch crop following the winter crop at Chamrousse, and constructing a composting barn for the wintering of dairy cows at Edale.

Quantifying the environmental benefits

Desktop modelling utilising OverseerFM compared how these changes, which aimed to suit the biophysical and operational abilities of each business, could benefit the environment in the same catchment.

"With relevance to farm systems throughout New Zealand, the project also attempts to quantify the potential benefits of working collectively within a catchment to address freshwater quality, using solutions tailored to the capability of individuals and their farms' inherent natural features," says Millar.

The research showed that if all three properties adopted the modelled land-use changes, there would be a cumulative reduction in nutrients and GHGs from the catchment (**Tables 1–3**).

However, Millar says two of the proposed conversions – building a composting barn and establishing an apple orchard – would be expensive. The lowest cost, but still effective in its environmental impacts, was planting an arable catch crop in late winter.

Case study farm 1: Leslie Hills

Leslie Hills is a 2,266 ha diverse farm system run by the Rutherford family. The farm incorporates an irrigated dairy platform alongside irrigated dairy support. Dryland hill country is utilised for sheep and beef breeding. A mix of fodder beet and kale is grown through the winter. Annual rainfall averages 850 mm to 900 mm.

Map 1: Case study farm locations

Table 1: Summary of key drivers impacting GHG reductions – Leslie Hill farm

Source		Basefile (CO_2-e kg/ha/yr)	Apples included (CO_2-e kg/ha/yr)	Percentage reduction
Methane	Enteric	6,900	6,501	5.78%
	Dung	72	69	4.17%
	Effluent	53	50	5.66%
Nitrous oxide	Excreta paddock	1,481	1,405	5.13%
	Excreta effluent	16	15	6.25%
	N fertiliser	435	402	7.59%
	Crops	46	37	19.57%
	Indirect	398	371	6.78%
Carbon dioxide	N fertiliser	615	574	6.67%
	Fertiliser organic inputs	133	122	8.27%
	Lime	115	105	8.70%
	Supplements	640	609	4.84%

The Rutherford family are considering establishing an apple orchard. While there would be a significant saving in relation to land costs, total capital costs of $12,751,474 for converting to an apple orchard presented a challenge.

"Development costs make up half the capital outlay, which introduces an immediate financial hurdle to any landowner wishing to pursue this venture," says Millar.

Benefits to the environment were modelled, and included:

- Converting 25 ha to apples would result in a 5.6% reduction in total cow numbers, an assumed decrease in winter fodder crop area by 6 ha and a subsequent fertiliser input reduction of 7.7% of total nitrogen (N) applied. This reduction in fertiliser application would in turn reduce total N loss and N loss per hectare, alongside an 8.3% reduction in N leaching from urine patches as a result of the area removed from grazing. N surplus would reduce by 5.5%
- Total phosphorous (P) loss would reduce by 6.1% and P surplus by 8.6%, mainly driven by an 8.3% reduction in P fertiliser inputs
- Reduced fertiliser use and an assumed reduction in manufacturing requirements would combine to contribute to a total decrease in GHG emissions of 3.8% or 306.4 tonnes Co_2-e/year.

The conversion would require a significant increase in staff numbers, from the current nine permanent full-time equivalents (FTEs) to 69 casual FTEs during harvest.

"This highlights a potential risk given the challenges the agricultural industry is facing regarding the acquisition of skilled staff," says Millar. Providing accommodation during harvest for casual employees was another consideration.

Case study farm 2: Chamrousse

The Chamrousse operation run by the Florance family is spread across two blocks known as 'Chamrousse' and 'Pass Stream', which together account for 610 ha. More than 50% of the property is irrigated. This irrigation enables consistent winter crop yields and the ability to winter dairy cows through the June and July period on fodder beet and kale, while also growing out young dairy replacement stock on high-quality grass. Annual rainfall averages 850 mm to 950 mm.

The Chamrousse land-use diversification option investigated a subtle change to an existing cropping rotation to maximise the potential environmental outcomes for limited costs. The study showed catch crops had the potential to produce gross margins of $1,261/ha on average.

The lowest cost, but still effective in its environmental impacts, was planting an arable catch crop in late winter.

Table 2: Summary of key drivers impacting GHG reductions – Chamrousse farm

Source		Basefile (CO_2-e kg/ha/yr)	Barley included (CO_2-e kg/ha/yr)	Percentage reduction
Methane	Enteric	3,566	3,445	3.39%
	Dung	76	77	1.30% (increase)
	Effluent	1	1	0%
Nitrous oxide	Excreta paddock	682	616	9.68%
	Excreta effluent	0	0	0%
	N fertiliser	96	92	4.17%
	Crops	73	98	25.1% (increase)
	Indirect	167	139	16.80%
Carbon dioxide	N fertiliser	104	98	5.77%
	Fertiliser organic inputs	121	120	0.83%
	Lime	69	51	26.09%
	Supplements	83	83	0%

Table 3: Summary of key drivers impacting GHG reductions – Edale farm

Source		Basefile (CO_2-e kg/ha/yr)	Barn included (CO_2-e kg/ha/yr)	Percentage reduction
Methane	Enteric	4,013	3,995	0.45%
	Dung	44	41	6.82%
	Effluent	57	111	48.65% (increase)
Nitrous oxide	Excreta paddock	909	879	3.3%
	Excreta effluent	5	62	91.94% (increase)
	N fertiliser	219	210	4.12%
	Crops	36	9	75%
	Indirect	251	254	1.18% (increase)
Carbon dioxide	N fertiliser	308	294	5.77%
	Fertiliser organic inputs	131	131	4.55%
	Supplements	34	33	2.94%

Sowing barley in late August with the crop harvested for grain in February would have minimal impact on stocking rates. However, this would lead to significant increases in total grain yield and a reduction of the area sown in winter fodder crop by 13%.

Including barley could result in a total N loss reduction of 27% and 26.3% when measured using the kg/ha metric. The primary drivers include a 6.5% decrease in N inputs via fertiliser, a 22.2% lowering of urine patch leaching and a 36.4% reduction in other leaching.

Decreases in total P loss and P surplus were driven by additional P removal through barley grain harvested and transported off the farm, along with a perceived change in plant-available P in the inorganic soil pool. The change was attributed to an expanded area under feed barley production.

Case study farm 3: Edale

Managed by the Gardner family, Edale is a 545 ha diverse farm system incorporating an irrigated dairy platform alongside dryland dairy support and sheep breeding and finishing enterprises. Barley grain is also grown, as well as winter crops of fodder beet and kale. The annual rainfall ranges from 850 mm to 1,000 mm.

The Edale model looked at the construction of a composting barn housing 510 cows. "The upfront capital requirement of $2,283,270 for the project is a formidable barrier and potentially requires additional incentives beyond environmental improvements to warrant this type of investment," says Millar.

An overall decrease by 4.6% in total GHG emissions was predicted by the model. This was driven by decreases in N_2O emissions from crops and

reductions of methane in dung, as most dung would be captured during the time in the barn.

Total P loss reductions of 4.1% were minor and driven by additional product removed as supplement to feed cows in the barn. There were no changes in stocking rate modelled. Winter fodder crop area reduced by 86% and a 4.2% decrease in total N fertiliser was assumed.

Millar says he had expected to see a bigger reduction in N loss at Edale. However, the modelling reflected the farm's existing practices, which are extremely effective in managing N leaching already.

Farmer motivations

Each case study farm had an ambition to build continued resilience into their individual businesses. A consistent theme across all three case study farms related to the ability to maintain business viability into the future. Each individual landowner was committed to be future-focused and progressive to ensure they continued to have sustainable businesses.

While the economics of each option investigated were of considerable relevance, much of the motivation was to enhance environmental sustainability. While each option explored on the three case study farms was unique, each was driven by the landowner's ambition to understand the potential positive outcomes for their catchment and surrounding community.

The process has highlighted the importance of supporting farmers to initially investigate the viability of these types of opportunities.

Another insight was regarding the change in skillsets required to efficiently manage any new system. This was particularly emphasised for the Leslie Hills and Edale operations where the suggested changes would involve a reasonably new way of farming.

"Taking part in this study has certainly ignited a greater level of discussion among each farm team. The process has also highlighted the importance of supporting farmers to initially investigate the viability of these types of opportunities, directing them to expert assistance so they can fully understand what each option will entail and whether this aligns with the business's objectives for the future," says Millar.

Elaine Fisher for the Our Land and Water National Science Challenge

New Zealand phosphate resources could supplement imports

Sustainable phosphate future

Why: To analyse the quality and environmental impact of sourcing phosphate from onshore deposits in New Zealand.

Where: Sites in Otago and Canterbury were analysed via geological data, modelling, mapping and sampling.

Who: Stuart Ford, Ann Moriarty, Jon Manhire (The AgriBusiness Group) and David Manhire (L&M Group).

What:

- Five regions were identified that warrant detailed evaluation for phosphate deposits. The combined North Canterbury and Kaikoura areas have the potential to contain 10-20 million tonnes of phosphate.
- New Zealand phosphate could be competitive with imported products.
- There would be relatively minor environmental effects from the quarrying process.

This project reveals greater deposits of phosphate than previously believed possible in New Zealand.

A widely-held belief that New Zealand imports the essential agricultural input phosphate from North Africa because the element doesn't exist here naturally has been turned on its head. A new study shows the South Island's east coast has the potential to contain phosphate deposits that could significantly supplement imported product.

The research project by The AgriBusiness Group and L&M Group undertook a fresh approach to the analysis of geological records derived from a wealth of geological studies and drilling data dating back many decades. They concluded that resources are potentially much larger than previous surveys revealed.

"It could not totally replace the need for imported phosphate based on the different raw material quality requirements. However, the scale of the resource would suggest there's enough there to provide quite a large percentage of New Zealand's phosphate needs for quite a long time in the future," says The AgriBusiness Group director Jon Manhire.

New Zealand's largest known onshore phosphate deposits are at Clarendon, midway between Dunedin and Balclutha, and these have been mined intermittently since early last century (**Map 1**). Approximately 140,000 tonnes of phosphate rock were mined from there between 1902 and 1924.

When Japan captured the Pacific island of Nauru (the main source of phosphate for New Zealand farmers) in WWII mining was resumed at Clarendon, with around 30,000 tonnes taken between 1943 and 1955. The mine was abandoned again when supplies from Nauru resumed.

Ewing Phosphate works, Clarendon, Otago

New Zealand's largest known onshore phosphate deposits are at Clarendon, midway between Dunedin and Balclutha.

Today the only sign there was ever a phosphate industry in the region is the long disused Ewing Phosphate Company building on SH1, just north of Milton, something of a local landmark.

While the extent of the resources is not widely known today, as recently as 2008 Ravensdown took another look at the Clarendon area.

"The team at Ravensdown have been very generous with their time and advice and have shared information with us. At the time they decided not to go further with it," says Manhire. "But since then much has changed, for both the science and in global politics."

Phosphate supply issues

"Phosphate was originally surveyed in the early 1900s, so the science of geology has moved on a bit. The whole issue around security of supply has become a lot more questionable," Manhire says, referring to international tension around the politics of the phosphate supplied by Morocco.

While the Moroccan resource is vast, capable of supplying New Zealand's needs for hundreds of years, other sources of supply (like China where 10% of our phosphate used to come from) have now closed. That makes New Zealand vulnerable to any interruption to shipments from North Africa.

"To be honest, we'd be screwed," says Manhire. "Phosphate is an essential element for pastoral production and without it your productivity is depressed. There could be options to bring it in from Australia, but those resources aren't that well developed and if New Zealand has phosphate in our back door, why not use our stuff? I think these strategic issues around mineral use and availability are becoming quite important."

L&M Group has been investigating phosphate resources for mining potential in New Zealand for several years. Their analysis led to the development of revised geological models that suggest the size and quality of the local onshore resource is bigger than had previously been believed.

While Clarendon is the only location where there has been detailed exploration and mining for phosphate, L&M Group also has prospecting permits for deposits further up the east coast of the South Island at Waitaki, South Canterbury, North Canterbury and Kaikoura (**Figure 1**).

Building on these initial investigations by L&M Group, five regions were identified that may warrant detailed evaluation. Criteria for selection were primarily the potential size and grade of the deposit, and secondarily, the location in relation to transport and infrastructure.

L&M Group has calculated that based on the ore thickness and grades indicated by drilling, the deposits have the potential to contain significantly more resource than that indicated by the areas drilled to date.

The combined North Canterbury and Kaikoura exploration permit areas have the potential to contain 10-20 million tonnes (Mt) of phosphate resources. Depending on grade and beneficiation efficiency, the total could be considerably higher.

There is insufficient data available to assess the Waitaki and South Canterbury resources, but given the extent of the target formations there is potential for multi-million tonne deposits.

Map 1: L&M Group prospecting permits (green)

Figure 1: Zone of phosphate nodules at base of Spy Glass Formation, North Canterbury

Environmental benefits and risks

One potential advantage of New Zealand phosphate is that it contains less cadmium than imported supplies.

"We used to get a lot of phosphate from Nauru and that had very high cadmium levels," explains Manhire. "We ended up with quite a large problem in New Zealand of cadmium soil contamination. Cadmium bio-accumulates in kidneys of sheep and you can't buy adult sheep kidneys in New Zealand because of the cadmium loading."

New Zealand resources generally contain lower levels of phosphate than imported supplies.

"We can lift it to very close to that level but that adds cost to it. There are also uses for the lower grades as well that haven't been that well investigated," he says.

As well as supplementing the raw material used to produce soluble superphosphate, the local product could be used in other forms of the fertiliser, including Reactive Rock Phosphate (RPR) and Partially Acidulated Phosphate Rock (PAPR).

"These products have lower solubility so the risk to water pollution is significantly lower, and there can be a win-win there in terms of achieving

Table 1: Summary of likely resource consents for the proposed quarrying and processing activities

Activity	Regional Water Plans	Regional Air Plans	District Council Plans
Emissions to air		●	
Water takes, divert and discharge surface water and groundwater	●		
Bulk earthworks and removal of indigenous flora and fauna	●		●
Discharge to land or water	●		
Noise			●
Road access and realignments			●
Contaminated land	●		●

New Zealand resources generally contain lower levels of phosphate than imported supplies.

environmental gains as well as decreasing the cost of inputs," says Manhire.

The project's report concludes there would be relatively minor environmental effects from quarrying (**Table 1**), like those for limestone (**Figure 2**).

Another potential environmental gain for locally sourced phosphate is that if it was used to produce Single Super Phosphate (SSP) in place of imported raw material, its carbon footprint would drop by more than half. This result is largely due to the much shorter transport routes.

"A comparative analysis of the carbon footprint from imported and New Zealand sourced phosphate for the production of SSP indicate that the GHG emissions from the New Zealand source phosphate rock is 76 tonnes of CO_2 per tonne of SSP, which is 49% of that of the imported material," says Manhire.

The AgriBusiness Group also analysed projected costs of mining and processing the resource, but noted that this was light on detail because of the limited available data. Although this analysis suggested the deposits could be mined, without additional data there remains questions over whether the deposits are economically viable compared to imported phosphate ore.

"Based on the work carried out so far, the indications are that there are some quite big resources there and I think some of the geological models that L&M have applied to the resource suggest that it's a lot bigger than was originally looked at," he says.

Most New Zealanders don't know about our phosphate resources – even farmers whose land has the mineral beneath the surface.

"It might be a surprise to people that we've got it here. In fact, I know from L&M, when they've been going onto farmers' land they just didn't have any clue. We know a lot about the resource down in Otago, we've got some pretty good data on that, but for the other ones I think there needs to be a little bit more done."

The report contains a strategic analysis relating to the use of New Zealand phosphate and identifies a range of economic, environmental and social benefits with comparatively few weaknesses. The use of New Zealand sourced phosphate for fertiliser appears to be viable and feasible, while providing potential economic and environmental benefits.

"It might be a surprise to people that we've got it here… I know from L&M, when they've been going onto farmers' land they just didn't have any clue."

Phosphate is a critical input to sustain pasture production and New Zealand farm productivity

Most New Zealanders don't know about our phosphate resources – even farmers whose land has the mineral beneath the surface.

Suggested follow-up actions include a more detailed analysis of the environmental and economic impact of using New Zealand phosphate resources and an increase in farmer awareness of the advantages of using alternative (and less soluble) phosphate fertilisers.

Manhire says many countries list the strategic elements in their territory and try to protect them, and he believes New Zealand should do the same thing with phosphate.

"The EU and Australia have phosphate really high up there. New Zealand is in the process of developing a list so hopefully our report will highlight the need to have phosphate on that list," he says.

Tony Benny for the Our Land and Water National Science Challenge

Figure 2: Gee Greensand at Gees Beach north of Kakanui (the backpack is sitting on Otekaike and Ototara limestones)

Digging into winter fodder beet with strip-till

Using strip-till cultivation to reduce soil damage and nutrient run-off during winter grazing of fodder beet

Why: To establish whether strip-till cultivation affects nitrogen (N), phosphorus (P) and sediment movement, and conduct a financial comparison of methods, to assess the feasibility of strip-till technology being more widely adopted in Aotearoa New Zealand.

Where: A 5 ha winter crop paddock of fodder beet on a sheep farm near Greta Valley, North Canterbury.

Who: Megan Fitzgerald (Agricultural Consultant, Tambo), Simon Bailey (Frames Grain and Seed) and Jim Earl (farmer).

What:

- There was no difference in crop growth from strip-till and conventional cultivation on the single farm studied.
- There was no significant difference in sediment and nutrient run-off between fodder beet crops established using full cultivation and strip-till.
- Collecting a larger sample size across a range of soil types and over several years is needed to distinguish if there is any significant difference.

More: ourlandandwater.nz/outputs/fodder-beet-report

Strip-till cultivation leaves the soil structure more intact compared to full cultivation and could be a useful tool to reduce sediment and nutrient run-off issues with winter grazing of fodder beet.

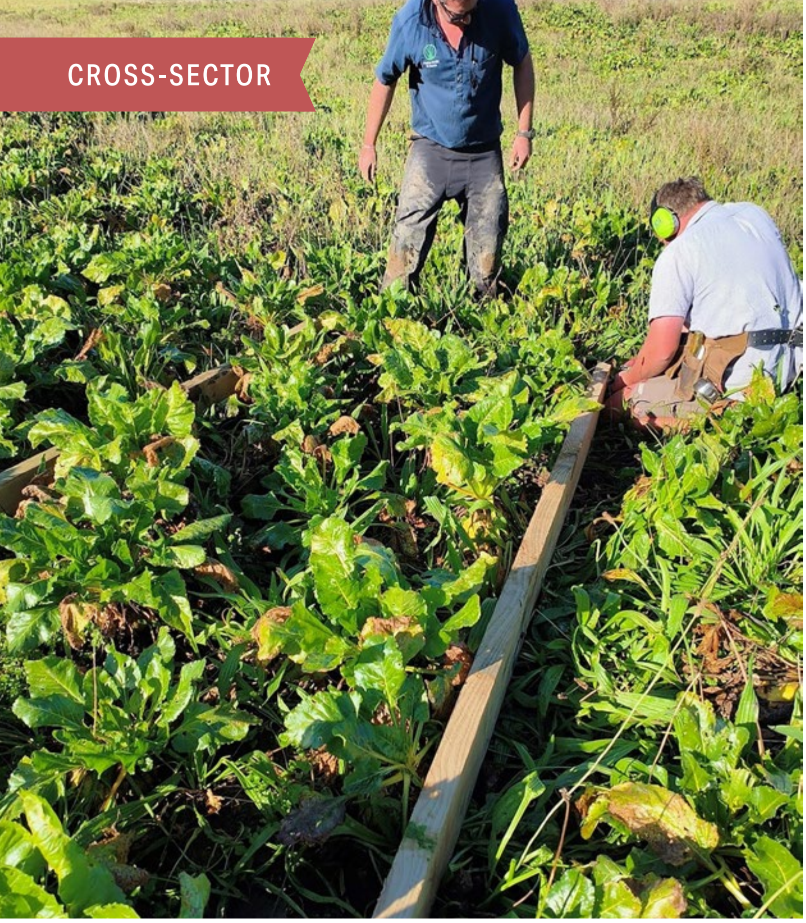
Growing fresh feed for stock during winter can be a challenge. Fodder beet is a popular choice for many farmers because it provides high-quality feed in a small area in winter, enabling them to provide fresh feed for stock through the colder months. Between 40,000 ha and 50,000 ha of fodder beet is grown annually.

North Canterbury sheep farmer Jim Earl uses fodder beet as a winter grazing crop for his stock. Over the past few years, he has switched from full cultivation to strip-till and has been pleased with the condition of his paddocks and the yields.

Strip-till is widely used in arable farming as it leaves the soil structure more intact and retains more moisture in the soil. The roots from previous crops remain in the soil, strengthening its structure and adding carbon, while residue on the soil surface leads to less erosion from wind and rain. Fertiliser and seeding can be done with a single pass of the tractor, generally making strip-till cultivation cheaper than full cultivation.

Recognising most other livestock farmers don't use strip-till methods, Earl was keen to be involved with research by agricultural consultant Megan Fitzgerald of Tambo and her team. The aim was to compare run-off from the two methods, with funding from Our Land and Water's Rural Professional Fund.

"A handful of farmers are planting their fodder beet with strip-till and have observed less



Agronomist Simon Bailey on the left and farmer Jim Earl setting up the fodder beet strip-till trial

compaction and maintained yields compared to their conventionally tilled fodder beet crops," says Fitzgerald.

Fodder beet is one of a handful of forage crops that reduce the amount of methane produced by dairy animals by about 20% compared to pasture, along with halving nitrous oxide. But methane reduction only kicks in when fodder beet makes up 70% or more of their diet, with muddy soil conditions wiping out nitrous oxide benefits.

Given its value as a fresh winter feed source and the potential of reducing methane in dairy animals and other ruminant stock for part of the year, getting on top of saturated soil damage and run-off issues is important.

Switching to lower soil impact strip-till cultivation may help. Compaction has significant effects on soil, including leaching and increased risk of erosion. Because of less tractor use with strip-till, this cultivation method could lower environmental impacts while maintaining yields, says Fitzgerald.

Planting and management

In mid-October 2022, 3.5 ha of a 5 ha pasture paddock (previously sprayed out) was planted with fodder beet variety Robbos. With around a 5% slope on the conventional plots and a 7% slope on the strip till, the plot slopes were within the 10% maximum in the 2020 national policy standards (**Figure 1**).

A single pass created six rows of 150 mm cultivated soil, to a depth of 200 mm, and 350 mm of uncultivated soil.

The remainder of the paddock was deep-ripped and disked, rotor-spiked, harrowed and Cambridge-rolled over three passes, before being precision-drilled. A fine seed bed is recommended for fodder beet, and is easier to achieve with full cultivation, which is why farmers use this method when planting this as a winter feed crop.

For ease of management, aside from the initial seeding, the two areas were managed and treated the same. This saw a crop-start fertiliser mixed and then broadcast spread over both areas.

Figure 1: (left) Location of the study – red dot shows location; and (right) Paddock treatments – purple is strip-till and red is conventional till (dots depict the location of the plots)

Table 1: Average suspended sediment (TSS), total nitrogen (TN), nitrate (NO_3), dissolved reactive phosphorus (TDRP) and total phosphorus (TP) measured in surface run-off from conventional and strip-till treatments

Treatment	TSS ($g\ L^{-1}$)	TN ($g\ L^{-1}$)	NO_3 ($mg\ L^{-1}$)	TDRP ($mg\ L^{-1}$)	TP ($mg\ L^{-1}$)
Conventional	0.855	0.024	0.223	0.252	1.95
Strip-till	1.229	0.026	0.29	0.15	1.948

A handful of farmers are planting their fodder beet with strip-till and have observed less compaction and maintained yields compared to their conventionally tilled fodder beet crops.

Herbicide, pesticide and fungicide control was also sprayed – once pre-emergence and three times post-emergence. Six weeks into the trial, 100 kg/ha of nitrogen (N) fertiliser was spread.

There were five plots measuring 2 m x 3 m in each of the strip-till and conventional areas. The wooden sides sat 150 mm below the soil, with 50 mm above, and with run-off collected from the metal downward slope end into a semi-buried 20 litre bucket. Soil samples were taken at various spots in both areas, along with weekly soil moisture measurements.

Normalised Difference Vegetation Index (NDVI) by overhead satellites mapped the amount of plant material within the paddock approximately once a month over the trial period, although data from this wasn't used if the sky was cloudy. This showed no difference in plant mass over time, with the fodder beet plants reaching canopy closure at the same time in both areas.

The sheep tuck in

Around 1,000 in-lamb ewes started strip-grazing in the paddock for five hours a day in late June, taking around five weeks to graze it out.

While acidosis on fodder beet isn't usually a problem with sheep as it can be with dairy animals, it's still not recommended as the only feed source for pregnant ewes. To ensure a balanced diet the sheep also had ryegrass pasture in a run-off paddock and baleage.

It's fair to say the trial didn't run as well as hoped due to irregular weather patterns. It was very dry during the initial growing period before turning into a wet winter. Although there were many damp days, only three rainfall events produced run-off, including a very heavy event that flooded the trial buckets.

Rainfall exceeding 19 mm within a 24-hour period seemed to trigger the run-off events. The sheep were grazing in the paddock during the first two events.

Within 24 hours of a run-off event water in the buckets was stirred vigorously to mix up any sediment, with 500 ml collected and frozen until the end of the trial.

Testing for total sediment, N, nitrate, dissolved reactive phosphorus (P) and total P showed similar results between strip-till and conventional samplings (**Table 1**).

Testing for total sediment, N, nitrate, dissolved reactive phosphorus (P) and total P showed similar results between strip-till and conventional samplings.

Dry northern Canterbury weather is hampering run-off collection

Costings

While a 15% cost saving with strip-till compared to conventional tillage would generally be expected (including less fertiliser, chemical use and tractor passes), because all management after the initial seeding remained the same for both areas for convenience, there was just 0.5% saving for the strip-till areas.

Given previous positive outcomes from strip-till cultivation and the difficulties experienced during this trial (including limited run-off events and small sample areas), larger-scale research over a longer period is needed, says Fitzgerald.

Delwyn Dickey for the Our Land and Water National Science Challenge

Daffodils could be a new crop on South Island sheep farms

Daffodil production for galanthamine

Why: Galanthamine extract to treat symptoms of Alzheimer's disease could create a new income stream for sheep farmers in hill country, with little management change needed to current operations.

Where: Seven sites across the South Island, with a range of altitudes, soil fertility and environments (including a coastal site) from sea level to 630 m above sea level.

Who: Nick Pyke (Leftfield Innovation), Kevin Stephens (Agroceutical Products), Michaela McLeod (AgEvaluate), and Travis Glare and Josefina Narciso (Lincoln University).

What:

- Commercial concentrations of galanthamine were produced on all the daffodil sites.
- Stress may produce higher levels of galanthamine in daffodils, but altitude, soil pH or phosphate levels weren't shown to be stressors.
- Micropropagation of bulb tissue to produce the high numbers of bulbs needed for commercial planting was shown to be achievable, but it needs more refinement.

More:

ourlandandwater.nz/outputs/daffodil-report

Daffodils grown to produce galanthamine, an active ingredient in medication to treat Alzheimer's disease symptoms, have been successfully trialled on South Island sheep farms.

Many families have gone through the heartbreak of watching a loved one slowly succumb to Alzheimer's disease. Despite billions being poured into the dementia drugs market for research and development over the last 20 years, there are still relatively few drug options available to treat the growing number of people who live with dementia, of which Alzheimer's disease is the most common type.

Though not a cure, one drug on the market shown to slow Alzheimer's progress and reduce symptoms (including memory loss) comes from galanthamine, an alkaloid substance found in some plants. There are high levels in some daffodils.

Daffodils are the favoured source for commercial extraction of galanthamine by UK-based Agroceutical Products who are behind large-scale daffodil production already underway in Wales. They were looking for a southern hemisphere source to enable year-round production.

While found in many plants, other sources of galanthamine tend to have lower levels, with the plants killed at harvest. Daffodils, on the other hand, are a no-fuss perennial and can be harvested for years.

It's thought daffodils produce higher concentrations of the compound when stressed, including through poorer soil, challenging climates and higher altitudes. Sheep's aversion to eating them,

while grazing around them, makes daffodils easy to integrate into existing high country farming operations. Such an operation would potentially add a new diverse revenue stream for farmers on poorer soils.

Nick Pyke, crop technologist and director of sustainable arable farming consultancy Leftfield Innovation, approached Our Land and Water for funding through the Rural Professionals Fund to carry out growing trials. The team at Leftfield is looking to find a way to multiply the bulbs quickly for the big numbers that would be needed for commercial production.

Trial plantings got underway in seven South Island sites in autumn 2023 (**Figure 1**), to see how the daffodils fared in different environments and if they would produce high enough concentrations of galanthamine.

Seven sites in the South Island were trialled, from coastal and almost at sea level on Banks Peninsula, to 630 m above sea level in Otago. Soil pH and fertility (Olsen P) were recorded for each site.

Plots of one square metre with a minimum of 100 bulbs were planted on each site. Larger 10 square metre plots were also set up on several properties,

Though not a cure, one drug on the market shown to slow Alzheimer's progress and reduce symptoms comes from galanthamine, an alkaloid substance found in some plants.

with rows of bulbs at 70 cm apart to simulate commercial planting. A 10 square metre site at Methven was planted with the higher density of at least 100 bulbs per square metre for a comparison in yield potential.

Four months later, 10 plants from each site were removed, along with separate bunches of leaves, and tested for galanthamine. The use of High Performance Liquid Chromatography (HPLC) enabled the team to gauge and compare how many milligrams of galanthamine per plant were being produced across the different sites.

Figure 1: Seven site locations

During their annual hibernation daffodils store energy from the current growing season in the bulb to spur on growth in the next season. These stored metabolites may have offset some of the effects of a harsher environment and different nutritional levels the plants experienced during the trial, potentially affecting the amount of galanthamine they produced.

Any carry-over influence the previous season's environment has on galanthamine levels should become clearer this coming season. Allowing the daffodils to settle in over a couple of seasons on the sites will also likely give a clearer picture of how stressors, including altitude, affect galanthamine levels (**Figure 2**).

Micropropagation process tested

Also getting underway in autumn 2023 and lasting six months was work at Lincoln University to nail down a cost-effective way to multiply bulb tissue in a laboratory – similar to pine production. The daffodil bulbs used weren't the same as those in the trials, coming instead from a commercial garden nursery with their variety unknown.

Surprising results

Concentrations of galanthamine varied in each plant across the various sites, as did the size of the plants. While the plants grew bigger at some sites, there was little correlation between plant wet weight and the concentration of galanthamine. There was also no relationship between soil pH or phosphate levels. Nor was there a trend with elevation, which is contrary to the current understanding from Welsh production.

Dry matter (DM) produced from the high-density plantings at Methven was significantly more at nearly 3,000 kg of DM/ha, compared to the yields of 622 kg/DM/ha at the Oxford site and 382 kg/DM/ha at High Peak Station near Darfield.

Because of the wide variation in galanthamine levels across the sites, the team weren't confident about estimating an exact weight of galanthamine that would be produced per kilogram of DM.

"Production levels vary at different sites as the growth of the plant and galanthamine levels are not strongly correlated, so any figure is just a guide," says Travis Glare, research director with Lincoln University.

The team estimates between 310 g and 440 g of galanthamine could be extracted from a hectare of DM.

Galanthamine concentrations

Daffodils grown across the South Island all had detectable levels of galanthamine in the subsamples. At most sites, the concentration in daffodil leaves exceeded the results from trials in 2021 and 2023. The exception was Leeston, which was not the variety planted at all other sites. The highest concentration was at High Peak at 490 m above sea level.

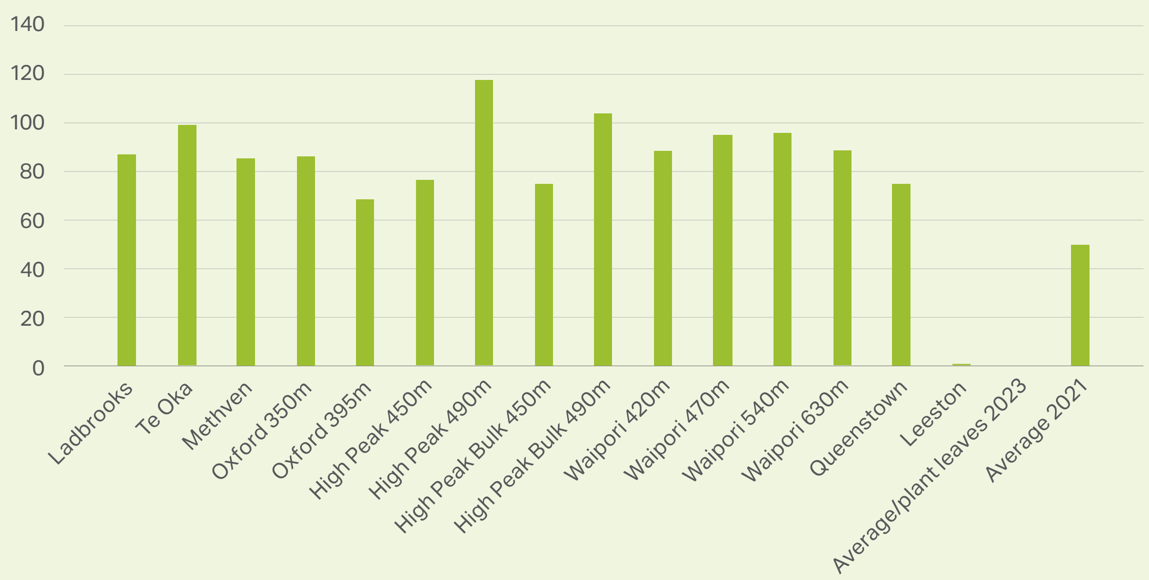


Figure 2: Average galanthamine concentration (µM) in leaves of daffodils at each site. Average results from 2021 and 2023 are shown on the right for comparison

Propagation wasn't as straightforward as hoped, with early issues over fungal contamination resulting in poor regeneration. The process was then tweaked to single rather than multiple baby plants grown in a commercial plant growth medium. This resulted in less fungal issues and better regeneration.

After three months the healthy regenerative tissue was then grown on in fresh growing mediums with varying amounts of root initiator and sucrose, producing 18 regenerant plants. While not a large number of plants, the team are confident the process can be further refined, making micropropagation an option to produce the large number of bulbs needed.

Following on from the trials, an entity will now be formed to develop a business plan along with more research and development in New Zealand, says Nick Pyke. A business model that delivers the value directly back to the farmers, as much as possible, will be part of this process.

Also getting underway in autumn 2023 and lasting six months was work at Lincoln University to nail down a cost-effective way to multiply bulb tissue in a laboratory – similar to pine production.

Delwyn Dickey for the Our Land and Water National Science Challenge

Building up clover on hill country farms – for free

Strategic grazing for legume persistence

Why: To assess whether deferring grazing over summer on hill country farms could encourage clover persistence in pasture while protecting vulnerable soils.

Where: A beef and sheep farm in Lower Kaimai, Bay of Plenty, with a financial and systems analysis on a sheep and beef farm in the Waikato.

Who: Blake Gunn (Agricom); Allen Coster and Paul Anselmi (Mataiwhetu Station); Angee Nagra (Agricom); Brett Te Whare (Aramiro Station); Grant Rennie, Graeme Doole, Katherine Tozer, Tracy Dale and Maryann Staincliffe (AgResearch); Ian Tarbotton (Ballance); Jen Corkran (Barenbrug NZ); and Steve Howarth (AgFirst).

What:

- December-deferred grazing reduced ryegrass pressure and saw clover already present able to thrive in pasture and persist once grazing was resumed.
- Undersowing saw an increase in red clover and lotus.
- Farmax modelling showed little change compared with the current management practices (without deferred grazing), as the farm was already high-performing, matching feed demand with pasture supply.
- There was no increased weight advantage for cattle on October-deferred grazing.
- Estimated there was little difference in greenhouse gases produced.

More: ourlandandwater.nz/outputs/strategic-grazing-report

Tweaking deferred grazing times on hill country farms could encourage clover persistence in pasture while protecting vulnerable soils.

Farming the hill country has some unique challenges, particularly when it comes to establishing and maintaining pasture in areas too steep for machinery. Deferred grazing is a popular technique for some farmers.

Allen Coster has been using deferred grazing on his beef and sheep farm in Lower Kaimai, Bay of Plenty for 15 years. Not only does it provide late summer feed, but he also uses it to help establish his new ryegrass paddocks, sowing grass in the autumn and deferring these eight months later. It also helps him manage weeds, and reduces the facial eczema spore count.

Not far away in the Waikato, Bill and Sue Garland have also started using deferred grazing on their 362 ha sheep and beef property, Rahiri Farm, near Maungatautari Mountain. They have been happy with the results, including reducing the prevalence of some weeds without spraying.

Further west, Jon and Fiona Sherlock run breeding ewes and winter trade beef heifers on 660 ha of mostly steep hill country at Waingaru. Relatively new to deferred grazing, they have found it very useful for maintaining pasture quality in spring, supplying feed in the summer dry and rejuvenating pasture.

What is deferred grazing?

Shutting up paddocks during the spring flush until the end of summer is a good way to let pasture grasses re-seed naturally, including in areas that are

Jon Sherlock, farmer interviewee

too steep for machinery. It is also a cheap, no-fuss option to provide feed in late summer when other pasture may be struggling.

Deferred grazing is a tool already used by some hill country farmers to better manage their feed. This practice sees them shutting up around 10% of their farm in late October until mid-February when paddocks are grazed again.

But timing is key to its success, and some farmers who have done it unintentionally have been less than happy with the results. This has left them with a negative opinion of deferred grazing overall.

Increasing clover content in pasture without over-sowing would be useful for all these farmers, which led Coster and the Garlands to offer up their farms for a project led by Blake Gunn, forage systems specialist with Agricom. The project received funding from the Our Land and Water Rural Professionals Fund. Gunn was looking at tweaking the lock-up time of the paddocks in an effort to encourage clover to persist more in pasture.

Deferred grazing is an old-school system that some farmers have used for decades, says Gunn. Because of this he reckons it flies under the radar a bit.

While some farmers use deferred grazing simply to help manage the rest of the farm during peak spring growth, it's getting more attention now as a low input system with other benefits, he says. This includes bigger root systems, better topsoil moisture and better ground cover – holding onto vulnerable erosion-prone soil.

> **Using deferred grazing to add more clover to pasture would see better quality pasture for livestock, while costing farmers nothing.**

Plenty of nitrogen-fixing clover in pasture is good for animal health and aids fertility in poorer soils. Hill country farmers often struggle to maintain high levels of clover as it can be swamped by grasses. One way to reintroduce clover is by regular oversowing.

Gunn, along with senior scientist Katherine Tozer at AgResearch, wanted to know if allowing grazing later into early summer, before locking up the paddock, would knock the ryegrass enough to allow clover species to thrive and persist into the following season and beyond. Using deferred grazing to add more clover to pasture would see better quality pasture for livestock, while costing farmers nothing.

Two similar paddocks on Allen Coster's beef and sheep farm were used to trial deferred grazing timing. One was shut up between mid-October 2022 and mid-February 2023, and the other between mid-December and mid-February. Red clover (two varieties) was undersowed at 8 kg/ha along with 6 kg/ha of lotus, which contains condensed tannins. These tannins can reduce methane production when eaten by ruminant livestock, although it does not persist well in most grazing systems.

Hiccup proves an eye-opener

The pastures were grazed in late summer. By early winter, there was a higher clover and lower ryegrass content in the December-deferred paddock than the October-deferred paddock, although there was also more unwanted Yorkshire fog, annual poa and broadleaf weed.

Figure 1: October-deferred paddock: a) on 28 February 2023 just after grazing the deferred pasture; and b) on 4 May 2023 showing prolific perennial ryegrass seedling emergence from the seedbank within the strips to which glyphosate had been applied to reduce pasture competition prior to undersowing legumes. December-deferred paddock: c) on 28 February 2023 soon after grazing the deferred pasture; and d) on 4 May showing prolific clover regrowth. Clover was not killed by the glyphosate application but regrew from existing stolons. Emergence of white clover seedlings from the seedbank was minimal. All photos are of pasture in the undersowing treatments

There was a hiccup during the preparation for the undersowing part of the trial when the weak solution of glyphosate spray, intended to knock back ryegrass growth, killed it instead. The upside to this was it clearly showed the team how much locking up the paddock had replenished the seedbank. It was equivalent to broadcasting a few hundred kilograms of seed to get the amount of ryegrass that established. Another surprise was the lotus seed mix turned out to be half white clover. Commercial lotus seed can only be bought from smaller growers and had cost $60/kg.

"The amount of white clover seed in the lotus was an eye-opener, given the cost of it," says Tozer "It's very difficult to keep it out and is the reason why main seed companies don't sell it – they can't guarantee the purity of it." By winter, small red clover and lotus plants were visible in the drill rows, which amounted to about 5% of the total amount of seed sown.

The October-deferred and December-deferred scenarios (**Figure 1**) were then compared in Farmax for Bill and Sue Garland's Rahiri Farm. This farm runs a high-performance ewe flock of 1,700 ewes, 120 finishing steers and 240 finishing bulls over winter. Production, profitability, as well as environmental impacts and gains, were all looked at.

Results from deferring grazing

Both pasture growth and feed eaten was slightly higher under both deferred scenarios.

In the October-deferred scenario there were minor gains from a small increase in the number of bulls. This was accompanied by a minor reduction in bull carcass weights, due to lower weight gains while grazing the deferred area.

In the December-deferred scenario, the bottom 25% of mature aged ewes and ewe lambs grazed the deferred area, which resulted in improved tupping weights.

In the model, the improved feed quality on the deferred area enabled growth rates of 160 g/day for ewe lambs and 100 g/day for ewes. This resulted in an increase of 3 kg in tupping weights of the ewes and lambs grazing the deferred area, or an overall lift of 6% in lambs weaned. Because the hoggets at lambing are heavier, the weaning weight of hogget lambs increases by 0.7 kg.

At a whole-farm scale, the October-deferred and December-deferred scenarios led to an improved gross margin of $2,445 ($7/ha) and $5,032 ($14/ha), respectively. Overall, there was little difference in greenhouse gas emissions between the two scenarios, with only slightly greater emissions for the October-deferred scenario.

At a whole-farm scale, the October-deferred and December-deferred scenarios led to an improved gross margin of $2,445 ($7/ha) and $5,032 ($14/ha), respectively.

Adding a dry summer to the mix had little effect on the scenario outcomes, with similar financial performance.

Under perfect grazing management a similar amount of spring feed is carried into summer, whether this is spread across the whole farm or contained in a deferred grazing area. In practice, however, having an area shut as deferred grazing would provide more certainty that this feed will be available in February.

Overall, the modelling showed little change compared with the current management practices without deferred grazing because the farm was already operating well, with a high level of performance and good matching of feed demand and pasture supply. Therefore, further gains to pasture production and financial benefits were small.

If the farm was performing poorly, changes may well have been more pronounced.

"This was a pilot study, with preliminary evidence that you might be able to shift the composition in favour of legumes," says Tozer. "It's worth looking into it further. Deferred grazing shows great potential as as tool to increase the legume content of hill country pastures. We need to now do some really robust [research] work."

Delwyn Dickey for the Our Land and Water National Science Challenge

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