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THE JOURNAL

The Official Publication of The New Zealand Institute of Primary Industry Management Incorporated

TOOLS TO MANAGE CONTAMINANT LOSS • THE FUTURE OF THE GENERALIST FARM CONSULTANT
PASTURE SCIENCE AND MULTI-SPECIES SWARDS • WINTERING SYSTEMS IN CANTERBURY
ROBOTIC APPLE HARVESTERS • STRATEGIC ALLIANCES IN THE AG INDUSTRY • TREES ON FARMS

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The Journal is the quarterly publication of the New Zealand Institute of Primary Industry Management. *The Journal* is provided free of charge to NZIPIM's members from across the rural profession including farm management advisors, rural bankers, farm accountants, fertiliser consultants, rural valuers, specialised service providers, farm managers, representatives from industry good organisations, CRIs and universities. *The Journal* is a quality assured publication for rural professionals providing professional services within New Zealand's primary industries. The articles do not constitute advice. The Institute takes no responsibility for any decisions made based on the material in this publication. The opinions of the contributors are their own and not necessarily those of NZIPIM or the Editor.

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STEPHEN MACAULAY CEO

Sheer quantum of new rules and regs undermining faith in legislators

The farming community is currently being overwhelmed by the sheer weight of new regulations and rules likely to impact their farm businesses in future. Disjointed and often poorly drafted rules have created a great deal of confusion and anger from many farmers who feel disenfranchised from the process, manifesting itself in protests and consternation within the provinces.

It is easy to see why such confusion exists. How are farmers supposed to interpret how the Essential Freshwater reforms will interact with the National Policy Statement on Indigenous Biodiversity and other mandated policy settings (e.g. He Waka Eke Noa) against the backdrop of the Resource Management Act that is about to be repealed and replaced with three new Acts?

Throw in centralised control proposed under the Three Waters Reform Programme for good measure and its little wonder why farmers feel confused by the legislative programme and have become deeply concerned about the volume of new rules and regulations heading their way.

Deciphering how various new regulatory settings and policy drivers are linked in some form of coherent legislative framework is sadly missing, made worse by confused and mixed messaging from legislators, and underwhelming analysis and scrutiny from compliant media outlets.

In its current forms, farmers and their advisors are faced with a regulatory quagmire that they will need to navigate their way through. For some, this will inevitably focus on prioritisation of environmental areas that present an immediate risk to the long-term financial sustainability of the farming business. For others, I suspect this will most likely lead to inertia from fear that making the wrong investment decision could significantly reduce on-farm profitability or worse still cost them the farm.

I firmly believe that farmers have a strong desire to improve their freshwater and environmental outcomes – show me a farmer who doesn't! Yet there is no clear overarching vision or well-articulated statement about what success looks like to crystalise and motivate farming communities' support to move in the same direction as legislators.

The role of rural professionals in assisting their farming clients through the raft of new environmental rules and regulations is becoming absolutely critical to ensure farmers can continue to have sustainable and profitable farm business enterprises in the future. This does represent one of the biggest issues faced by the farming community in recent times.

I do believe members can have an important role in bringing the degree of pragmatism and knowledge needed to have informed and meaningful debate on changing environmental policy settings. Particularly in providing an expanded understanding of the implications of adapting complex farm systems steeped in real-world experience. I would therefore encourage members to become more engaged with the consultation processes in the development of new rules and regulations in future by sharing your expertise with policy-makers to ensure better outcomes for the farming community.

Farewell

This will be my last article as the Chief Executive of NZIPIM. I have thoroughly enjoyed my time at the Institute and getting to know the great people within the rural profession. I am very grateful for the support received from the membership over the last nine years.

I would like to acknowledge the fantastic support and guidance of past Presidents during my tenure as Chief Executive, including Wayne Allan, Hilton Collier, Guy Blundell, Craig Osborne and Carla Muller. We have been very fortunate to have such a group of high calibre individuals preside over the Institute, including those who came before them.

I also wish to thank Nico Mouton, the Chair of The Journal's Editorial Committee, for keeping the Committee on task in lifting the quality and profile of this highly regarded publication among the membership and wider primary industry. I have been extremely grateful to Nico for his encouragement in being able to freely express my comments within *The Journal* on a broad range of topics and issues impacting upon our great industry.

I wish the Institute's current President, Julian Gaffaney, the Board and the new incoming Chief Executive all the very best in taking NZIPIM forward. It has been an absolute privilege to have worked for and represented the Institute and I wish the members every success in the future.

Yours sincerely,

JOHN ROCHE

Dr John Roche, Chief Science Adviser at the Ministry for Primary Industries, says an independent technical review of Overseer has provided options for developing a new generation of decision support tools.

DEVELOPING THE NEXT GENERATION OF TOOLS TO MANAGE CONTAMINANT LOSS FROM AGRICULTURE

Overseer was developed to optimise fertiliser application rates on pasture, but a recent independent technical review raised concerns about its ability to accurately estimate total nitrogen loss on farms. This article provides context and further steps towards a Next Generation Overseer.

Background to the review of Overseer

Overseer was developed 30 years ago to optimise fertiliser application rates on pasture and has supported farmers to learn more about nutrient loss from their farms. It is jointly owned by the Ministry for Primary Industries (MPI), the Fertiliser Association of NZ and AgResearch Ltd.

Over the past couple of years, Overseer has undergone a thorough technical review following recommendations by the Parliamentary Commissioner for the Environment (PCE) in the report *Overseer and Regulatory Oversight: Models, Uncertainty and Cleaning Up Our Waterways* published in December 2018. The Commissioner recommended that if the Overseer model were to be used for freshwater regulations, 'a comprehensive … whole-model peer review should be undertaken by technical experts independent of those who performed the development work.'

The Panel concluded that they had significant reservations about Overseer's model structure, because important biophysical processes materially important to estimating total nitrogen loss were either absent from the model or were inadequately simulated.

On this basis, the Prime Minister's Chief Science Adviser, Dame Professor Juliet Gerrard, along with the Chief Science Adviser from the Ministry for the Environment (MfE), Dr Alison Collins, and I selected a Science Advisory Panel (the Panel) to review Overseer and provide a measure of confidence in the accuracy of its nitrogen-loss figure.

The Panel consisted of experts in modelling, nutrient cycling, agriculture and horticulture systems from both New Zealand and overseas, and Mātauranga Māori. The Panel concluded that they 'did not have confidence that Overseer's modelled outputs tell us whether changes in farm management reduce or increase the losses of nutrients, or what the magnitude or error of these losses might be.'

While this is a very strong statement, it is not the disaster that many have concluded. It is important to contextualise the Panel's report in relation to the use of the Overseer model and the future needs of regional councils and landowners to ensure ongoing sustainable management of our natural resources.

Why did the Science Advisory Panel lack confidence in Overseer?

The Panel concluded that they had significant reservations about Overseer's model structure, because important biophysical processes materially important to estimating total nitrogen loss were either absent from the model or were inadequately simulated.

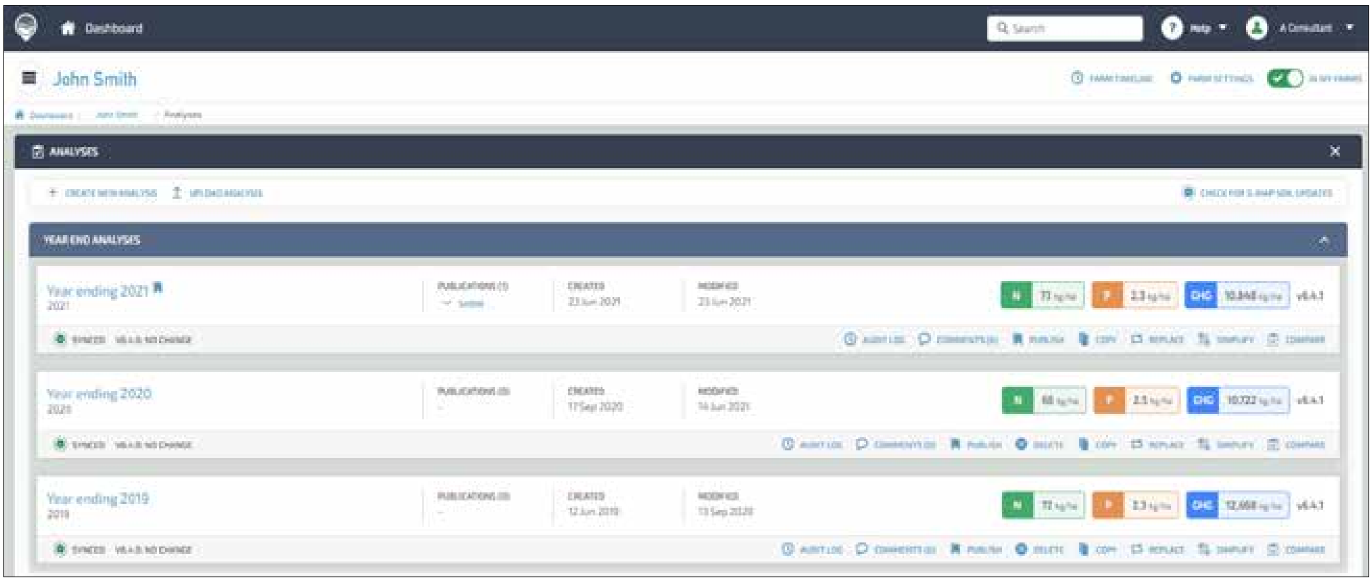
In particular, their concerns were that Overseer:

- is a steady state model attempting to simulate a dynamic, continually varying system
- uses monthly time-steps
- uses average climate data and therefore cannot model episodic events or capture responses to climate variation
- does not balance mass
- does not account for variation in water and nutrient distribution in the soil profile
- does not adequately accommodate deep-rooting plants
- focuses on nitrate and omits ammoniacal nitrogen and organic matter dynamics
- lacks consideration of surface water and nutrient transport, as well as critical landscape factors
- did not partner with Māori in the model inception or ongoing development.

Based on these findings, the Panel could not be confident that Overseer provided a robust estimate of total nitrogen lost (i.e. nitrate plus non-nitrate forms of nitrogen) across the multitude of farm types, landscapes and climates for which it was being adopted.

The Panel did not:

- consider the user-interface, greenhouse gas (GHG) modelling, or any other aspect of the suite of tools under the Overseer brand, as these were outside their Terms of Reference
- undertake a formal assessment of sensitivity or uncertainty of Overseer sub-models or examine whether it could be used as a social tool to encourage property-level management changes that reduce catchment-level nitrogen load.



The Panel recognised that Overseer's use of user-inputted data is a benefit to the usability of the tool, and they were clear that they were not questioning the environmental science behind the tool or the scientists involved.

Pathways of nitrogen loss in Aotearoa New Zealand

To address contaminant loads in our waterways, it is important to understand the pathways and loads of water contaminants from different land uses and how they are affected by farm management practices. Nitrogen can be lost by leaching through the soil profile (via sub-surface drainage) or by movement of dissolved and suspended nitrogen species in the overland flow of contaminated water. The relative importance of sources differs according to a number of factors such as soil, landscape, climate, farming system and management risk.

More than 60% of agriculture land in New Zealand is Class 5 or above (Land Use Capability), and the Panel estimated that imperfectly drained soils constitute around 9.5 million ha or about 56% of the productive land area (i.e. agriculture, horticulture and forestry).

Collectively, these statistics imply that more than 50% of our productive land has a significant slope and/or drainage impediment and is prone to loss of non-nitrate forms of nitrogen, particularly through overland flow. When we consider these statistics, and the fact that overland flow is not adequately modelled in Overseer, it becomes easier to see why the Panel lacked confidence in its nitrogen-loss estimation for all of Aotearoa New Zealand.

Although the Panel's assessment of landscape characteristics is correct, our most nitrogen-enriched waterbodies are nitrate-nitrogen dominant. For example, in an assessment of trends in river water quality across 77 monitored catchments, total nitrogen was relatively high in one-third of the catchments, with most of these also relatively high in nitrate-nitrogen species.

Total nitrogen was negatively correlated with catchment slope, which means that nitrogen concentrations were relatively high in lowland (low-slope) catchments and low in high-slope catchments. Although it is not explicitly stated, the presented data indicate that most nitrogen in over-allocated waterways associated with agricultural use is nitrate-nitrogen. Research undertaken in intensively managed grasslands supports this view. The dominant (more than 70%) nitrogen species lost in our most enriched catchments is nitrate-nitrogen, which is lost by sub-surface drainage (i.e. leaching).

This does not diminish the importance of overland flow as a contaminant-loss pathway or the loss of other forms of nitrogen. In certain months, overland flow can be the dominant source of nitrogen loss and the likelihood of this will increase on landscapes with greater slope and less free-draining soils. However, it does point to the critical need to identify and encourage the uptake of practices that minimise leaching losses of nitrate-nitrogen to improve water quality in our most nitrogen-enriched waterways.

Putting the Panel report in context

Most people are familiar with the old adage that 'all models are wrong; but some are useful'. However, the Panel's conclusion that they did not have confidence in the nitrogen-loss figure or that Overseer could accurately predict if nitrogen loss was increasing or decreasing with farm management change has been met with varying degrees of disbelief. The disagreement primarily relates to definitions of accuracy.

If we consider the question 'Does the model work?' the answer depends on how we interpret it. To the Panel, working means they would have high confidence that the model represents total nitrogen loss across the variety of land uses, landscapes and climates in Aotearoa New Zealand. By the presentation of a 'nitrogen-loss' number, this is (in effect) what is claimed. The Panel does not have confidence that Overseer meets this standard, for reasons previously outlined.

To many Overseer users, however, working means that the model provides the answer that they expect to see with a particular change in land use (i.e. what some commentators have termed 'the sensibility test').

These are two different standards: helping a user to understand what they don't know (i.e. modelling) versus confirming and potentially quantifying what the user thinks will happen because of a particular action (i.e. a confirmatory calculation).

Landscape, climate and land-use variability make predicting nitrogen loss difficult

In evaluating the model, the Panel was asked if Overseer adequately represented nitrogen loss across the variety of land uses, landscapes and climates in Aotearoa New Zealand to allow the comparison of farm management scenarios. We farm: from the top of Te Taitokerau (Northland) to the bottom of Te Waipounamu (the South Island); on high country stations and right down to sea level; and in regions receiving 600 mm p.a. of rain (with and without irrigation) and others receiving more than 6 m of rain.

To add to this complexity, across these landscapes and environments we have dairy, sheep, beef, deer, vegetable, horticulture, viticulture, arable and forestry, with different levels of intensification between and within enterprise types. Importantly, different catchments also have different environmental challenges. When this diversity of land use and environmental challenges and how Overseer estimates nitrogen loss are considered, it is easier to understand the Panel's conclusions, which allows us to chart a course forward.

As a country, we need to accomplish significant reductions in nitrogen loading in over-allocated waterbodies in accordance with resource use limits set by regional councils.

Overseer was not originally developed to estimate total nitrogen loss

Overseer was originally developed for use in the pastoral sector (and primarily dairy) as a decision support tool to help with planning fertiliser applications and, more recently, reducing nitrogen loss and GHG emissions. As the dominant form of nitrogen loss from this sector is nitrate through sub-surface drainage, it makes sense that the model's focus was on estimating nitrate leaching.

Although there are allowances for overland flow losses in Overseer, they are not well developed. Also the current modelling approach is, arguably, not the best way to attend to these less predictable pathways of loss, which are largely driven by unpredictable episodic rainfall events. As mentioned previously, this does not mean that overland flow losses are unimportant, but merely that they should be dealt with in a different way.

When Overseer's focus on nitrate-nitrogen loss is considered, with little emphasis on overland flow losses of other species of nitrogen, it is easy to understand why the Panel could not have confidence in Overseer's estimation of total nitrogen loss, or that it could accurately predict change in total nitrogen loss with changes in management for all enterprise types across Aotearoa New Zealand.

Next generation of tools to help achieve freshwater aims

The Panel's concerns around Overseer can be compartmentalised into two key areas:

1. Concern about Overseer's effectiveness in assessing nitrate-nitrogen loss; and
2. Overseer's poor representation of overland hydrological processes and the loss of non-nitrate-nitrogen species.

The review made it clear that we need more than one tool and it identified key areas where we could improve Overseer for it to be used confidently as a tool to estimate nitrate loss.

As a country, we need to accomplish significant reductions in nitrogen loading in over-allocated waterbodies in accordance with resource use limits set by regional councils. Regional councils, scientists, industry bodies and the Overseer company have expressed their desire for modelling (decision support) tools that:

- provide a reasonable representation of the size of the change in nitrogen loss from a farm management change
- are easy for landowners and their advisers to use
- encourage property-level change and innovation by enabling landowners to choose strategies that reduce nitrogen loss from their land.

The Government has committed to ensure farmers/growers and regional councils have the tools needed to make sound land-use decisions and contribute to the effective management of freshwater. It recognises that more than one tool will be required to meet these needs and has signalled it will put in place one or more of the following options:

- The creation of a new Risk Index Tool, potentially using elements of Overseer, including the user interface; and
- The development of a 'Next Generation Overseer' to address the issues raised by the Panel and ensure it is fit for purpose as a tool for limited use in appropriate regulatory settings; and/or
- Greater use of controls on practices and inputs to manage nitrogen loss, including through amendment to the National Environment Standard for Freshwater; and/or
- A completely new approach to understanding and managing diffuse nutrient loss risk, which might include, for example:
  i. near real-time monitoring of water quality at the local scale
  ii. a tool that provides detailed understanding of nutrient loss risk based on the characteristics of land
  iii. a new nutrient loss model.

MPI and MfE have started work programmes on these four items in conjunction with regional councils and Māori. Our initial thinking is that these next generation approaches to decision support could be components of a property's farm environment plan (FEP) in accordance with farm plan regulations and regional council requirements to manage catchment nutrient loads.

The next generation of Overseer

The Panel's report identified key parts of the Overseer model that could be improved to give greater confidence in its ability to estimate nitrate leaching.

At its core, Overseer estimates the nitrogen surplus from properties throughout the year, which is a key risk factor for nitrogen loss. Loss of nitrate through leaching is driven primarily by rainfall relative to evapotranspiration (i.e. climate) and the soil drainage characteristics. The Government and Overseer have agreed on a development programme to improve these model components. The programme will also improve Overseer's ability to incorporate crops with different rooting depths and model transparency. With the development plan completed, farmers and growers can have confidence that the Next Generation Overseer will better reflect nitrate leaching losses from their property.

Next generation decision support tools will help to improve freshwater quality by helping to understand the pathways and loads of water contaminants from different land uses and how they're affected by farm management practices

The Risk Index Tool

The design and scope of a Risk Index Tool is also underway. The intent of this approach is to provide regional councils and farmers with:

- a measure of the risk for nutrient loss posed by particular management strategies at key times, considering relevant climate and landscape data
- the effect that potential mitigation strategies and practice changes can have on overland flow pathways for nitrogen loss.

Risk assessment and management approaches have been used as a means of managing a range of contaminants in both Aotearoa New Zealand and internationally. Where they have been developed based on accepted nutrient management science, they have successfully reduced contaminant losses from farms in several jurisdictions, including in Aotearoa New Zealand.

Ownership of Overseer

Overseer is currently owned by MPI, AgResearch and the fertiliser companies, Ravensdown and Ballance. This ownership structure reflects the collaboration between farmers, who are shareholders of the fertiliser companies, science (through AgResearch) and the Crown (through MPI).

It is important that any tool used in regulations has the confidence of both regulators and users. The owners are committed to setting the model up for success by supporting the agreed development programme.

Conclusion

The Panel undertook a rigorous assessment of the current version of Overseer. They concluded that they lacked confidence that Overseer's modelled nitrogen loss would be accurate across the vast array of landscapes, climates, land uses and enterprise intensities in Aotearoa New Zealand.

Their assessment has provided options for developing a new generation of decision support tools to help regional councils and landowners. This will help to meet our aspirations for managing freshwater in Aotearoa New Zealand and protect this important taonga for our future generations.

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JULIAN GAFFANEY AND NICO MOUTON

THE FUTURE OF THE GENERALIST FARM CONSULTANT

The farm consultancy profession is facing the many challenges of increased client and regulatory demand and the requirement of increased upskilling for the farm consultant. This article gives a background to the profession and the opportunities and possible future requirements of the generalist farm consultant.

Changing operating environment

The operating environment for agriculture and farming is changing at a rapid pace as the 'global reset of food production systems', which is measuring food production against strict new climatic, social and environmental standards, takes place. This reset is happening globally as well as in New Zealand, and the onset of a global pandemic in the midst of this has both complicated and enhanced some of the drivers that are re-shaping the operating environment. This reset is creating uncertainty and increasing the need for the support and revision of food and fibre producing farm systems, which is where the generalist farm systems consultant plays a key role.

Historically, the most common type of farm or horticultural management consultant has been the 'generalist' or 'whole-farm management consultant'. This title is a broad description that reflects practitioners who have generally had a number of years of experience and who often operate as senior consultants in firms. These practitioners have delivered services that have traditionally covered most of their farming client's needs. One could argue that the generalist is actually a specialist in whole-farm management.

Background of the 'generalist' consultant

The establishment of private consultancy services followed the break-up of the former Ministry of Agriculture and Forestry (MAF) advisory services in the early 1990s. The generalist consultant was commonplace through the 1990s-2000s at a time when the requirements of regulation and compliance programmes were relatively basic at a farming type or enterprise level and not as focused on specific operations.

This operating space suited a generalist consultancy, which would usually be defined as one or two main enterprise areas (i.e. sheep & beef plus deer, arable or dairy) for an individual to be undertaking. Within those enterprise types, the consultant might be offering advisory services that covered animal, plant, soil, nutrient, irrigation, financial and compliance/environmental management, as well as succession, farm purchasing and development.

One could argue that the generalist is actually a specialist in whole-farm management.

Increasing specialisation

Over the past 15 years the growing complexity of the regulatory, political and operational environment has driven the need for increasing specialisation in areas like nutrition and agronomy to include environmental, financial services, irrigation design and soil fertility, offered at both the individual and the consultancy firm level.

Some further specialist skillset areas include:

- Environmental management support
- Precision farming technology
- Farm emissions calculation and mitigation
- Health & Safety compliance and management
- Farm financial management: financial software (e.g. Cash Manager Focus and Figured)
- Legal trusteeship obligations
- Requirements of regional council regulations and policies
- Use of mapping systems and other software programmes (e.g. Farmax or Overseer^{FM}) to improve and monitor on-farm performance
- Changes to the banking environment (e.g. the recent requirement of debt reduction and for banks to have independently produced budgets)
- Integration and working with accountancy practices.

What is shaping our operating environment today?

At the NZIPIM one-day forum held in Hamilton in 2021, Lee Matheson (Perrin Ag Consultants) outlined some of the global factors and trends that are impacting our operating environment today. In his presentation he stated that the world we thought we farmed in with stable or falling interest rates contained inflation and had reducing trade barriers. There was unconstrained movement of people and capital, unfettered digital access to information, and a stable 'rules-based' geo-political system.

According to Lee this has now changed with revised factors to consider: vulnerable global supply chains grinding to a halt; a redefined social licence to operate; curtailed immigration; accelerating impacts of climate change; destabilising geo-politics; and fake news. This has been a major shift over a relatively short timeframe of two to three years, which is re-shaping the rural profession today.

These changes have included:

- Practice change on-farm being increasingly driven by consumer preference or consideration of social licence, as opposed to solely science-led extension programmes underpinned by institutional research
- Policies to address the over-allocation of contaminants sometimes being enacted (and given legal effect) before the accompanying regulations, tools and legal precedents or rulings have been fully developed
- Novel, reimagined or rediscovered agricultural practices displacing established techniques, often accompanied by potentially polarising or confronting value systems and conversations.

Tertiary qualifications

Are universities and colleges up to producing the right graduates for the future? We have seen positive trends in the numbers of graduates in both Agricultural Science and Environmental studies over the past decade (see article in *The Journal* by Victoria Westbrooke, 25(2):10). However, the numbers of Farm Management and Agribusiness graduates (despite having increased) are a smaller proportion of the combined Agricultural Science and Environment graduate numbers (around 10%). Another question to consider is whether the course profiles are up to date with industry requirements. Feedback from environmental consultants working at the upper level of the industry is that there is no specific degree that meets the needs of the modern environmental consultant.

There will be an increasing requirement for a degree that combines the disciplines of Animal, Plant and Soil Science, Farm Systems Management and Economics, as well as covering the new requirements including Freshwater Science, Resource Management, Cultural Needs, Te Mana O te Wai, Matauranga Māori, Emissions and Climate Change Adaptation.

Changing knowledge paradigms

The evolution of the internet and the development and maturing of social media platforms over the past 15 or so years have fundamentally altered how we can access and receive information. Information for decision-making that may have been only accessible by referring to a specialist person or publication, which was likely not immediately at hand, can now be accessed on a smartphone or tablet in the field in real time. This has also lifted the level of knowledge and expertise held by farmer clients and demanded by them of their farm advisors.

There has also been a fundamental shift in knowledge streams and the development of 'alternative truth' or 'parallel knowledge' paradigms. This is driving a shift in the 'currency' of rural professionals from being the absolute provider of knowledge and answers, to a more holistic type of 'currency' of asking questions and supporting adaptive redesigning of farm systems for the future.

The shift from a purely nutrient and chemical-based focus to a biological and ecological-based approach to soil and plant productivity is an example of the change that is occurring. This type of shift coalesces in 'confronting value systems and conversations' that rural professionals aren't necessarily able to provide all the (or full) answers to, and this creates a challenge for our profession. In addition to the value systems challenge, we believe that existing farm management consultants have to 'lift their game' and upskill as required to deliver value at a higher level. This aligns with the shift and lift in farmer knowledge that information access and software have enabled. Thus, the need is there for consultants to support farming businesses as they navigate the future, both more strategically and at a governance level.

Further specialist education

As the regulation landscape continues to intensify, further demands will be made for specialist upskilling

The need is there for consultants to support farming businesses as they navigate the future, both more strategically and at a governance level.

by farm consultants. The profession is currently in the midst of this, with demand being boosted by government policy at both the national and regional level over the next four years. With the widespread implementation of farm environment plans or FEPs (with freshwater farm plan or FWFP components) and intensive winter grazing regulations, there will be a requirement for certification and training to be undertaken by a large number of rural professionals.

Greenhouse gas regulation and the upcoming changes in biodiversity regulation will also put pressure on consultants for these specialist areas, and the need for upskilling will continue for the foreseeable future.

Continued professional development (CPD) has always been an important part of the generalist consultant's maintenance of currency, but this has now been elevated to a higher plane.

Generalist future

The challenge for consultants is therefore to be well equipped to meet the multitude of challenges that the farming sector faces. The generalist will require a good understanding of all the current and pending regulations, but will use specialists from time-to-time to achieve detailed and good information and results for farmer clients.

There has also been the gradual redevelopment of the structural organisation of medium-sized consultancy firms. There are (generally senior) consultants who act in the generalist capacity for both the firm and for longer-term clients, who provide a filtering role for the multitude of information and knowledge sources that are directed into the primary sector.

The generalist consultant in this role may not be able to answer every specific question or challenge that the client is facing. However, they are able to have the lens of an overview of the whole-farm system, and the challenges and regulations that it faces, and can then access the specific skillsets required through their more specialised consultants (either within the firm or beyond in established networks).

There is also an increasing trend towards inter-firm collaboration between farm management consultancy and environmental consultancy firms working together for common or shared clients to provide the suite of outputs required.

New Zealand's primary sector operates in an increasingly complex and dynamic landscape, and there is no let-up of new regulations facing the sector. It is important to recognise that this is also the landscape that our international competitors are operating in. From a positive viewpoint this reflects the immense global opportunity for high-quality, verified, climate-efficient and sustainably-produced products.

With farmers and growers adapting to new paradigms in environmental, social and innovation management, the need for advice and support is now higher than ever. The 2021 NZIPIM survey of members gave a strong picture of the areas of challenge seen by consultants with 'Compliance and Regulation', 'Climate Change' and 'Environment' ranking as the top three challenges. Not surprisingly, these three areas also topped the research priorities identified by members.

For the opportunities ahead, the members ranked 'Market', 'Environment' and 'Farm Systems' as the top three areas. The membership base of the Institute is much broader than just farm management consultants and has representation from all sectors involved in the primary industry.

Summary

The future landscape for primary sector production and consultancy will continue to evolve, and be more complex, and the generalist will remain an 'important director and filter' of the increasingly diverse information flow to assist the client's decision-making process. Continuing with upskilling and training will be a feature for both the generalist and specialist farm consultant into the future.

While it is understood that no one single professional can provide the entire suite of solutions required by the farmer, there remains the need for the generalist who acts as the overall 'integrator'. This person (who can have a comprehensive helicopter view of the farm system and farming business and how it fits in this complex operating environment and then direct and source the specialist skillsets as required) will deliver value to the modern farming client. To be operating at a higher level, the consultant needs to have enhanced skills and knowledge at an advanced level, but also recognise they need to liaise with others.

This role is vital for the future optimisation and success of farming businesses in New Zealand. *The Journal* will further expand on the theme of the future of farm consultancy in an article by Lee Matheson in 2022.

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ALISTAIR BLACK

PASTURE SCIENCE INFORMS SEED MIXTURE DECISIONS FOR SIMPLE AND MULTI-SPECIES SWARDS

This article describes a series of pasture mixture experiments, and how they can help farmers make informed decisions about which and how many species to include in a new pasture sowing.

Improving pasture production and resilience

In pastoral farming a seed mixture decision is a necessary first step towards improving pasture production and resilience. Conventional agriculture has promoted monocultures, simple mixtures and multi-species pastures to improve soil, plant and animal components in farm systems. Which species to grow, and how many species to grow where, have depended on the growing conditions and purpose of the pasture. Similarly, advocates of regenerative agriculture propose multi-species swards to maintain productivity and other ecosystem services with minimal inputs such as fertiliser.

The challenge of pasture scientists is to provide pasture seed mixture formulations to meet different farming needs as sustainably as possible. This requires knowledge of the role of each individual plant species and how they interact with other species to utilise natural resources as a plant community. Recent work in Europe and at Lincoln University has examined these complex species identity and interaction effects operating in pastures. Some key findings are summarised in this article.

Most pastures are mixtures

The vast majority of New Zealand's pastures are formed by mixing together two or more forage species. Some examples of the many and varied blends we use are:

- Dairy pastures consisting of perennial ryegrass *(Lolium perenne)*, white clover *(Trifolium repens)* and plantain *(Plantago lanceolata)*
- Herb pastures made by blending plantain, chicory *(Cichorium intybus)*, white clover and red clover *(Trifolium pratense)*
- Dryland pastures with cocksfoot *(Dactylis glomerata)* and mid- and late-flowering cultivars of subterranean clover *(Trifolium subterraneum)*
- Tall fescue *(Schedonorus arundinaceus)*-based pastures with cocksfoot, timothy *(Phleum pratense)*, white clover and red clover
- Short-term pastures using Italian ryegrass *(Lolium multiflorum)*, red clover and balansa clover *(Trifolium michelianum)*
- Horse pastures consisting of pasture brome *(Bromus valdivianus)*, cocksfoot, timothy, browntop *(Agrostis capillaris)* and Yorkshire fog *(Holcus lanatus)*.

Mixture experiment with Italian ryegrass red and balansa clovers

The vast majority of New Zealand's pastures are formed by mixing together two or more forage species.

In each example, one or more functions of the pasture are generally of interest to the farmer, agronomist or experimenter who is responsible for mixing the ingredients. Such functions are animal production, annual and seasonal dry matter (DM) yield, nutritional composition, resistance to pests and diseases, including weeds, rainfall penetration and resilience to seasonal drought. In every case, the measured response of the pasture depends on the percentages or proportions of the individual plant species that are present in the formulation.

The individual species and cultivars in the mixture are chosen based on their suitability to the abiotic (water, temperature and nutrient status) and biotic (grazing regime, pest and disease) conditions and animal feed requirements of the particular farm system (i.e. the purpose of the pasture). Most pastures exploit the advantage legumes have over most grasses and herbs in their ability to utilise soil inorganic nitrogen (N) – nitrate (NO_3–) and ammonium (NH_4+), as well as fix atmospheric N (N_2) via symbiotic bacteria (rhizobia) in root nodules.

Pastures usually end up with some weeds in them as well, such as 'low fertility' grasses like browntop, crested dogstail (*Cynosurus cristatus*) and meadow grass (*Poa trivialis*), and broadleaf weeds, including volunteer white clover and plantain, which divert scarce resources (light, water, nutrients and labour).

Historical wisdom

An important point to make here is that New Zealand has a rich history of grassland research spanning more than 80 years. However, much of that information is at risk of being forgotten unless we refer back to it now and again. Many articles are freely available at the New Zealand Grassland Association website: www.grassland.org.nz

The literature shows that improved pasture production through the optimal formulation of species mixtures is a recurring theme of dairy, and sheep and beef research in New Zealand. The work done by Cockayne and Levy in the 1910s to 1930s, the seminal papers by Brougham and Harris in the 1950s and 1960s, and the more recent studies by Fraser, Stevens, Nobilly, Woodward and others have all contributed to the scientific basis that underpins our seed mixture decisions for new pastures.

A very useful example of mixing together cultivars in mixture experiments was that described by Harris in an article in the 1968 *Proceedings of the New Zealand Grassland Association*. In the discussion part of the article, it says:

Asked about models to describe competition in mixtures of more than two species, Harris replied that at this stage these were not precise. It was stated that results from a series of two-species mixtures could be used to explain the complex competitive interactions involved in a multispecies sward.

Since this article, the design and analysis of mixture experiments, and their application in agricultural systems, have evolved considerably. The model analyses now allow the experimenter to disentangle the complex inter-species interactions operating in multi-species swards, to predict the response of any mixture of ingredient species, and to identify the optimal mixture should it not be one of the blends included in the experiment design.

Mixtures with Caucasian clover

Caucasian clover (*Trifolium ambiguum*) is well known for its slow and difficult establishment, but once established it can increase the legume content of permanent pastures. A mixture experiment was set up at Lincoln University to study the blending properties of Caucasian clover with perennial ryegrass and white clover. The three species were drilled as monocultures and four mixtures in November 1999 and grown with and without irrigation for five years. Figure 1 shows the average annual yields.

The three species differed in their monoculture yields, with Caucasian clover out-performing white clover in the long term. The monoculture performance of a species is a measure of its potential effect on pasture function, which grassland ecologists call the 'identity effect'. Therefore, Caucasian clover demonstrated a strong potential to contribute to pasture yield and weed suppression. In the mixtures the species interacted to produce 'diversity effects', which are defined as the excess mixture performances over that expected from the component species' monoculture performances. Diversity effects can increase yield and reduce the need for weed control and N fertiliser.

The strength of the diversity effects depended on the species. There was no interaction effect between Caucasian and white clovers, but both clovers interacted strongly with perennial ryegrass to increase annual yield. There was no complex three-way interaction effect among all three species and therefore the three-species mixture yielded the same as the two clover-ryegrass mixtures.

The interactions operating among forage species in pastures include niche partitioning and facilitation. Niche partitioning (differences in resource use among species) can allow for a more complete use of resources. For example, legumes can fix atmospheric N via rhizobia and utilise soil inorganic N when available, whereas most non-legumes can only utilise soil inorganic N. Facilitation occurs when species help other species to grow by changing the environment, such as legumes that help non-legumes by increasing soil inorganic N.

The irrigation treatment represents a process variable that is sometimes included in a mixture experiment when the researcher suspects the process condition will affect the blending properties of the mixture ingredients. In the Caucasian clover experiment, the effects of soil moisture availability on the species identity and interaction effects were studied. The identity and interaction effects were robust across the dryland and irrigated conditions (Figure 1).

There was considerable variation in the species identity effects over time. This reflected the slow establishment and temporal persistence of Caucasian clover, which started to out-perform white clover in the second year. These changes resulted in major shifts in species' relative abundances in the mixtures over seasons and years, but the diversity effects persisted.

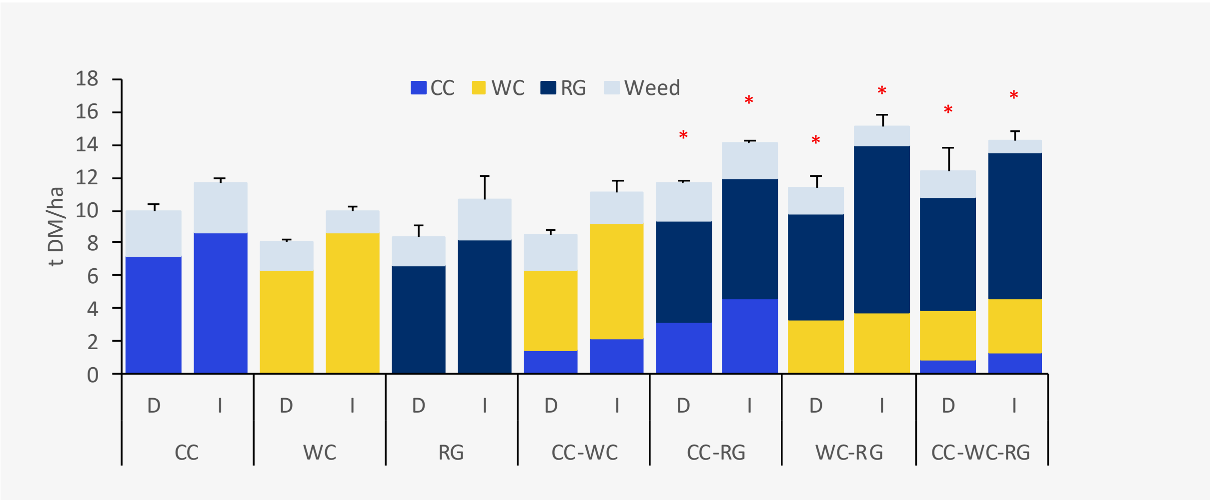

***Figure 1:** Annual dry matter (DM) yield response to monocultures and mixtures of Caucasian clover (CC), white clover (WC) and perennial ryegrass (RG) grown in dryland (D) and irrigated (I) conditions averaged over five years at Lincoln University. Asterisks indicate over-yielding by mixtures*

Multi-site agro-diversity experiment

My own research has included a grassland scientist position with Teagasc at its Grange Beef Research Centre in County Meath, Ireland in the early 2000s. Work was carried out on a multi-site agro-diversity experiment that examined the blending properties of several different forage species in intensively managed grasslands across a wide range of environments throughout Europe (and one site in Canada).

A common experimental design and protocol allowed the grassland scientists involved to examine the blending properties of four species adapted to their own local environment, within functional groups of two grasses and two legumes. At each site, there were four monocultures and 11 mixtures that varied widely in sown relative abundances of the chosen species, each repeated at two levels of overall initial abundance, or total seeding rate. The plots were managed by cutting.

There was also the option to include a management or environmental factor in the experiment design and many participants examined the effects of applied N and genetic diversity within species (e.g. narrow vs broad genetic base). The effects of perennial ryegrass, timothy, white clover and Caucasian clover with two levels of applied N (75-100 and 150-200 kg N/ha p.a.) were examined at three Irish sites: Grange (east), Athenry (west) and Moorepark (south). However, at Grange the swards were overcome by chickweed and failed to establish.

Overall, the agro-diversity experiment found that the different mixtures of two grasses and two legumes provided greater annual yields and better weed suppression than the average monocultures ('over-yielding') and sometimes the best-performing monoculture ('transgressive over-yielding'). At low levels of applied N, the diversity effects persisted across sites and years alongside major changes in botanical composition, albeit at reduced strength as legumes declined. At high N levels the diversity effects were reduced and even declined in the third year. The diversity effects on yield were not accompanied by reductions in nutritive value. At the Moorepark site, earthworms favoured swards dominated by perennial ryegrass with low rather than high N inputs.

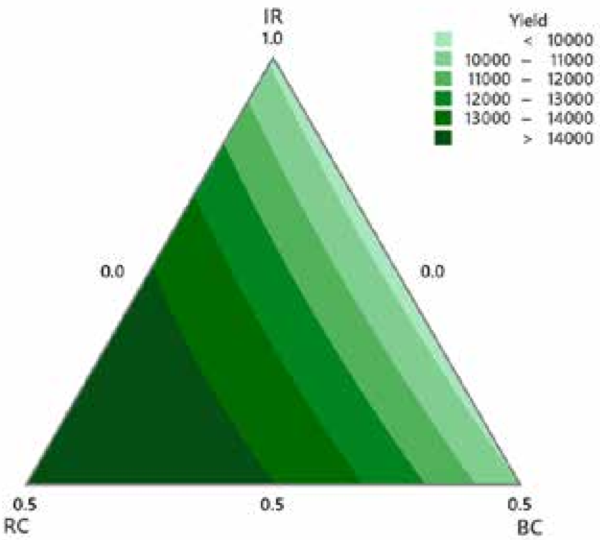

Figure 2: Contour plot of the relationship of accumulated total yield (kg DM/ha) with sown proportions of Italian ryegrass (IR), red clover (RC) and balansa clover (BC) in a short-term dryland pasture 12 months after a March sowing at Lincoln University

Italian ryegrass-clover blends for short-term pasture

At Lincoln University, four mixture experiments were run in predominantly grazed situations on university farmland from 2011 to 2021. Looking at short-term pasture options for dryland systems, the next experiment that followed in 2011 examined if mixtures of Italian ryegrass, red clover and balansa clover (a top-flowering annual) can yield more forage and suppress weeds better than Italian ryegrass alone.

Thirteen blends of the three species were drilled at 20 and 30 kg/ha in March 2011. The minimum proportion of Italian ryegrass in the seed mixtures was constrained to 50% because dryland systems need good cool season growth and this is a feature of Italian ryegrass. Plots were harvested six times over 12 months and were neither irrigated nor fertilised with N.

The inclusion of red clover increased annual yield by 41% compared with Italian ryegrass sown alone (13.79 vs 9.75 t DM/ha; Figure 2), and provided effective weed suppression (<5% of total yield) and high quality forage (crude protein 17.5% and metabolisable energy (ME) 11.3 MJ/kg DM). No benefits to yield and quality were gained from adding the balansa clover. The optimum seed mixture was 12 kg/ha Italian ryegrass, 8 kg/ha red clover and no balansa clover.

Four-species mixtures with species drilled in alternate rows

In addition to studying the blending properties of pasture species, recent work has also studied the effect of separating species in alternate drill rows to improve species evenness in swards. At Lincoln University four pasture species – perennial ryegrass, plantain, white clover and red clover – were used to create four monocultures and 15 mixtures varying widely in species richness and relative abundance. The effect of species separation was examined by replicating four mixtures of perennial ryegrass, plantain and white clover with the species separated in alternate drill rows. Red clover was not included in this test because the precision drill separated up to three species.

The plots were drilled in March 2015, grazed by sheep eight times annually, irrigated and did not receive any N fertiliser for six years. Over these years, sowing method did not influence the identity and interaction effects. Yield, weed suppression and quality were driven by identity effects

Simple blends of one legume with one non-legume species, such as white clover with perennial ryegrass, performed just as well and sometimes better than the mixtures with three or four species.

and strong pairwise interactions between the legumes and non-legumes. The identity effects differed among species and varied over time, reflecting the different establishment, seasonal growth and persistence traits of the four species. Perennial ryegrass and white clover out-performed plantain and red clover in the long term. There were major changes in the botanical composition of the swards over time (Figure 3).

The two legumes interacted strongly with both perennial ryegrass and plantain to produce diversity effects of increased pasture yield and weed suppression. The pairwise interactions depended on the relative abundances of the species involved so they weakened as plantain and red clover declined.

More complex, multi-species interactions involving three or four species were rare and weak so they did not contribute much more to the diversity effect. Therefore, the simple blends of one legume with one non-legume species, such as white clover with perennial ryegrass, performed just as well and sometimes better than the mixtures with three or four species.

Pasture mixtures under N loss and application restrictions

New regulations about the use of N fertiliser will impact future seed mixture decisions. To help inform these decisions, the effects of applied N on identity and interaction effects were further examined at Lincoln University.

Three monocultures and seven mixtures of perennial ryegrass, white clover and plantain were drilled at two overall sowing rates in March 2017 and grown ±N fertiliser. The +N level was reduced from 275 kg/ha in Year 1 to 200 kg N/ha p.a. in anticipation of a restriction on the application of N fertiliser on grazed pasture. Plots were grazed by sheep eight times annually and irrigated. Over four years, the applied N affected the relationships of average pasture yield and quality with species relative proportions in the seed blend (shown for yield in Figure 4).

An equi-proportional mixture of perennial ryegrass and white clover (based on seed count) optimised annual yield, weed suppression, ME and crude protein regardless of N level. The optimal sowing rate was 12 kg/ha perennial ryegrass and 7 kg/ha white clover. The average annual yield of the optimal blend was 20.5 t DM/ha with 4% weed, 11 MJ/kg DM ME and 21% protein. Pasture yield and quality responded to changes in species proportions away from the optimal mixture, including the addition of plantain. The magnitude of the yield and quality responses was larger with than without applied N because the identity effects of perennial ryegrass and plantain, and the way all three species interacted, depended on N level.

Multi-species swards

A pasture mixture of multiple forage species (five or more) is at times promoted as the key to the improvement of pasture production. However, a simpler mixture of two,

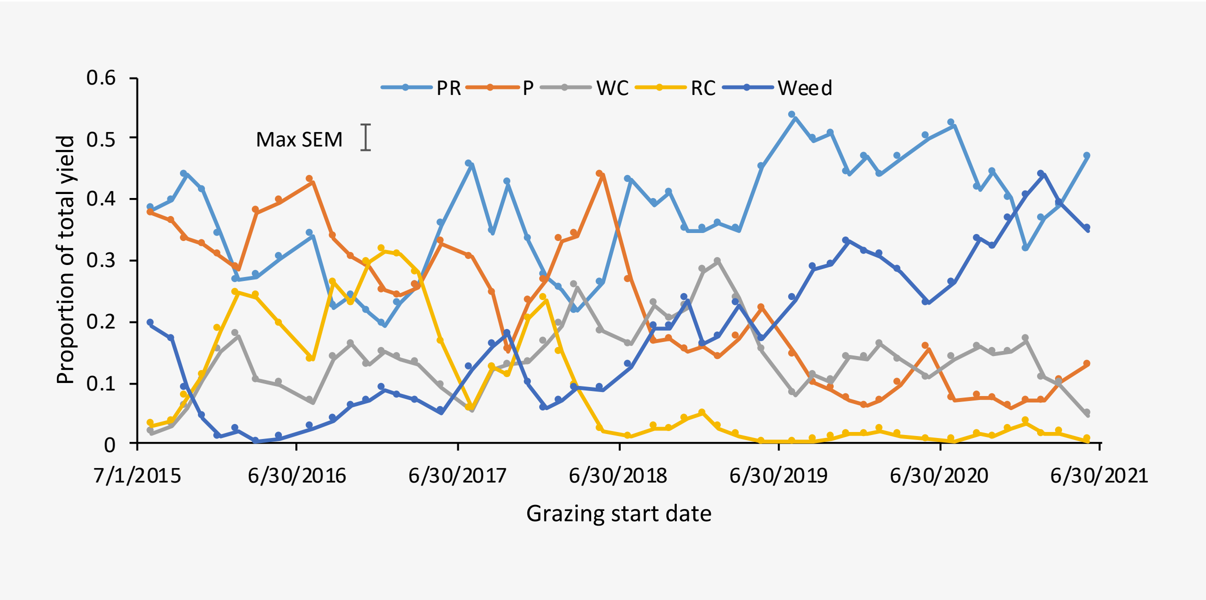

Figure 3: Pre-grazing pasture botanical composition of perennial ryegrass (PR), plantain (P), white clover (WC), red clover (RC) and unsown species (weed) averaged across monocultures and mixtures over six years at Lincoln University

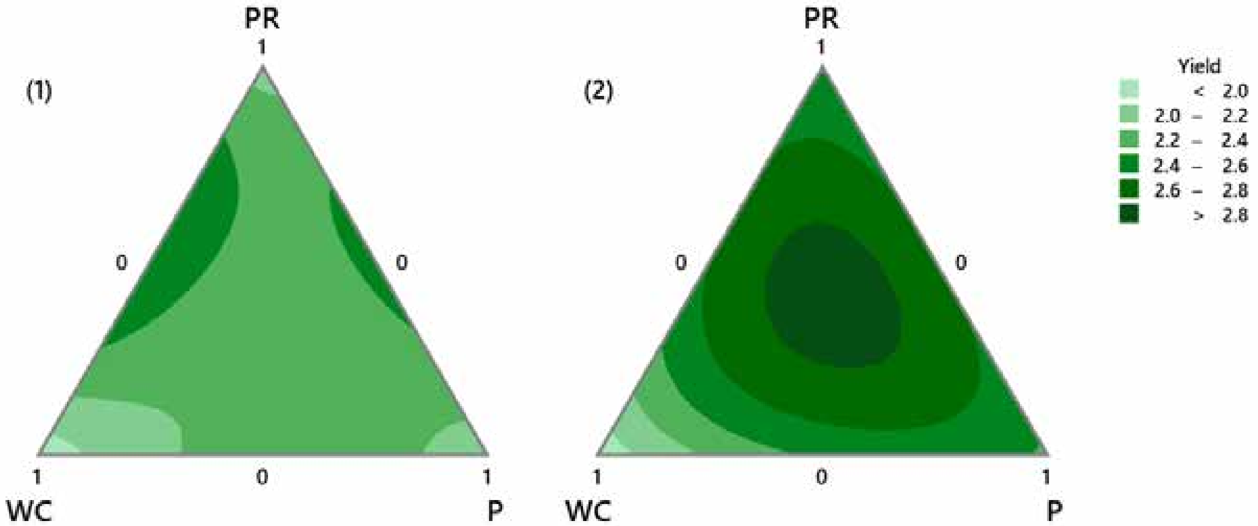

Figure 4: Contour plots of the relationship of pre-grazing pasture yield (t DM/ha) with sown proportions of perennial ryegrass (PR), white clover (WC) and plantain (P) without (1) and with (2) N fertiliser, averaged across 32 grazings over four years at Lincoln University

As a country, we need to accomplish significant reductions in nitrogen loading in over-allocated waterbodies in accordance with resource use limits set by regional councils.

three or four species can produce similar diversity effects and perform just as well.

The impact of multi-species swards on forage yield, weed suppression and quality was examined under sheep grazing and irrigation at Lincoln University. Sixty-nine mixtures of perennial ryegrass, cocksfoot, plantain, white clover, red clover and subterranean clover were sown in April 2018. After three years, the biomass-species richness relationships revealed that average pre-grazing pasture yield increased by 0.39 t DM/ha (3 t DM/ha/year), average weed yield decreased by 0.50 t DM/ha (from 44% to 7% of total yield), and average ME and crude protein did not change (10.9 MJ/kg DM and 21% of DM, respectively) with increased richness from one to six species.

However, there was substantial variation in each response between swards of equal richness, with several mixtures providing above-average total yield, ME and crude protein and below-average weed yield at two to four sown species. These highly productive swards included simple mixtures of perennial ryegrass and either white clover or red clover.

Conclusion

Sowing two to four legume and non-legume species together can increase pasture production compared with the production expected from the individual species. Any further increase in species number changes the botanical composition, but not the yield and quality of the pasture.

This diversity-production relationship is the result of pairwise interactions among legume and non-legume species. The strength of the interactions depends on the relative abundances of the species involved. If the species are not present in large enough abundance, the expression of the interaction is generally not strong enough to detect. Species relative abundances change substantially over time, with two or three species eventually dominating multi-species swards.

Acknowledgements

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Further reading

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CARLA MULLER, MATHIRIMANGALAM (MS) SRINIVASAN AND MARK NEAL

ESTIMATING VARIABLE IRRIGATION COSTS ON CANTERBURY DAIRY FARMS

This article presents an analysis of variable irrigation costs on Canterbury dairy farms (such as labour, repairs and maintenance, and electricity) for three seasons from 2015 to 2018. It explains the variability in these costs as linked to seasons and farms, and then highlights the current gaps in data availability and therefore knowledge.

Understanding the costs

Farm system and policy analysis is increasingly trying to estimate the economic impact of altering irrigation practices on-farm. There is limited information on the variable costs of irrigation on New Zealand dairy farms, making this type of analysis challenging and the results unreliable. Accurately understanding, analysing and forecasting the financial costs and benefits of irrigation is important for farm performance and sector analysis. Variable costs in operating on-farm irrigation infrastructure are considered (such as electricity, repairs and maintenance (R&M) and labour). Overall, these costs for irrigation averaged $1.55/mm/ha across these three seasons.

Improving the understanding of the cost of changing irrigation management will help ensure such farm system and policy analysis is grounded in robust data. Variable costs are those that vary with a level of output, in this case the use of the irrigator, either expressed in volume of water used or frequency and duration of the use of irrigation infrastructure. This includes some costs (such as electricity, supply charges, R&M and labour), but excludes the fixed cost components (such as depreciation, consents and the capital cost of infrastructure).

Other research in the area

Of the New Zealand studies that consider variable costs of irrigation, most use a figure of $2/mm/ha, based on a Foundation for Arable Research (FAR) study from 2010. This estimate was based on a study of five arable farms and considered operating costs (pumping, labour, R&M and water supply charges) and ownership costs (including depreciation, insurance and interest). There are also studies that consider the cost of irrigation water supply, which focused on the cost of delivering water to the farm gate, not the operational cost for managing water use on-farm. One 2016 study estimated that the water supply cost ranged from $0.02 to $0.43/m^3, with an average cost of water supplied of $0.14/m^3.

There are cost-benefit studies of irrigation in New Zealand, but these have tended to compare irrigation and non-irrigation. These studies therefore do not provide details on the variable costs of irrigation at a farm-scale,

but instead focus on differences in typical profit between irrigated versus non-irrigated farms. Some studies consider the costs and benefits of irrigation (versus no irrigation) at a macro (regional) level and then adjust down to a farm level. These studies often provide a summary of how they expect farm expenses on-farm to change as the farm moves from non-irrigated to irrigated. However, there is no explanation about what component of this is due to irrigation changes versus other farm system changes.

One such study carried out at Massey provided estimates for annual costs of irrigation for three dairy farms in the Manawatu. The annual estimates included both fixed and variable costs (but excluded capital costs) and varied from \$522/ha to \$1,295/ha. They also considered costs related to changing other aspects of the farm system resulting from a shift from dryland to irrigated farming. However, it is unclear from this study what component of their annual costs is fixed or variable, and what the relativities of each variable cost component are.

Another study that considered potential irrigation costs for farms in Taranaki found they ranged from \$0.10 m^3 to \$0.21 m^3. It was based on annualised irrigation costs (including annualised capital costs, electricity, overhead and maintenance and labour) and mean pumped volume. For labour and infrastructure maintenance costs, in the absence of any specific data available, this study made a series of assumptions for various types of irrigation systems but did not include an application rate. Data for cost categories were presented in \$/ha and it is not clear how many hectares or what application rate these are applied to in order to convert to a \$/m^3 value. It is useful to consider the relative proportion of each cost component, with electricity costs ranging from 14-30% of total irrigation expenses, overheads and maintenance from 16-24%, and labour from 5-15%.

A further in-depth analysis of 10 irrigated dairy farms in Canterbury between the 2004-05 and 2006-07 seasons provides an informative study on irrigation operating costs. This study gives a useful estimate of labour, based on case study interviews, which is not captured in other studies. However, it does not separate the irrigation operating costs into categories (such as electricity, labour and maintenance). In a number of cases the total irrigation water is back-calculated from application rates and number of applications rather than metered water use volumes. For farms with multiple irrigation systems, the study in Canterbury for the 2004-07 seasons did not attempt to differentiate the cost of operating individual systems:

- Two farms with mainly pivot systems had an operating cost of \$0.06/m^3
- Two others with mainly rotary systems had an operating cost of \$0.053/m^3
- Two with mainly border-dyke farms had an operating cost of \$0.007/m^3.

The rotary irrigation systems had the greatest labour requirement at 0.8 minute/ha/day of irrigation, with pivot irrigation approximately 0.2 minute/ha/day and border-dyke 0.45 minute/ha/day.

Methodology

DairyBase is a self-selected database of dairy farm data. It provides consistent benchmark and farm analysis data for both financial and physical indicators for individual farms.

Anonymised individual data were extracted from DairyBase for Canterbury farms, with full physical data and profit and loss financial accounts entered for the 2015-16 to 2017-18 seasons. Farms were identified by ownership structure and other factors, and this affected exclusions from the sample:

- Those that were not Owner Operator (OO) or an Owner with a Variable Order Contract Milker (O+VOCM) were removed from the sample. This adjustment was made because for other business structures (e.g. sharemilkers) it is unclear from the financial accounts which financial costs each party covers in the business entity
- O+VOCM were maintained in the sample as it is likely that the owner covers most of the irrigation

costs, and this was checked by comparing key costs for OO and O+VOCM

- Labour costs were treated as an exception, as these are often covered in full or in part by the VOCM
- Farms with outlier data, incomplete or incorrect data (e.g. observations that could realistically indicate errors such as more than 100% of the platform being irrigated) were excluded from the sample, as were any observations that identify less than 50% of the milking platform being irrigated. DairyBase does not record information on irrigator type(s). If multiple irrigation systems are used in one farm, it is assumed that the data entered represents a weighted average across the systems, although there is no independent way of verifying this
- Outliers and data that appeared to have errors were removed from the sample because there is no way to retrospectively correct the data.

From DairyBase data this analysis was able to isolate irrigation electricity costs and irrigation R&M, along with various water use and irrigation system data (e.g. application and days irrigated). The dataset used also had irrigation 'other' costs, which were grouped with electricity (as some farms had 'irrigation other' costs but not irrigation electricity costs). All costs could be assessed on an irrigation volume, days or per hectare basis.

There is no irrigation labour cost, but it is possible to get an average hourly labour cost (wages divided by employee hours). However, there is no information on how many hours per day were spent on irrigation and this is likely to vary a great deal between irrigator types. A labour cost is therefore included based on an assumption of two hours/day spent on irrigation (for each day irrigated).

Research results

Table 1 provides descriptive data from the sample. The sample size was approximately 34 farms in each of the three seasons. The OO only sample is approximately 23, with the balance being O+VOCM.

Results included:

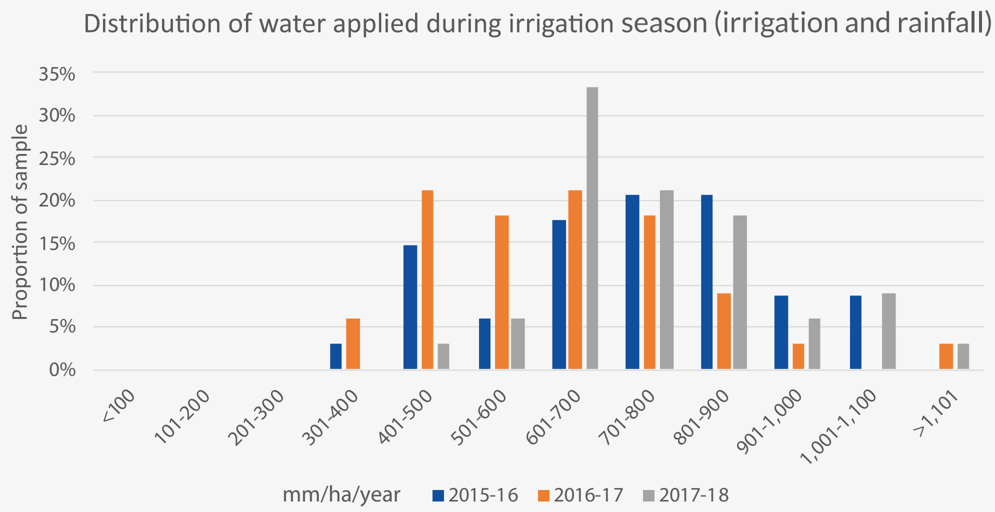
- The average proportion of the farm platform that is irrigated was about 95% across the three seasons
- The number of days irrigated varied a great deal between the three years, and the season (2015-16) with the most days irrigated had the lowest irrigation season rainfall
- Irrigation applied had a large range, from 50 mm/ha (2016-17) to 993 mm/ha (2016-17)
- Irrigation season rainfall ranged from 307 mm/ha (2017-18) to 1,189 mm/ha (2016-17). This range highlights the differences in irrigation practices across the Canterbury region in response to differences in rainfall. The rainfall through the irrigation season is not described by volume and frequency of events, which will also impact on irrigation responses
- Irrigation interval ranged from one day through to 30 days and is likely to be strongly correlated with irrigator type, but this relationship cannot be validated
- There is much variation between farms' average irrigation interval, from one day to 30 days across all seasons, but despite this variation there is a mean of approximately six days. A system with a faster irrigation return is likely to represent systems with more flexibility.

DairyBase provides rainfall for 'irrigation seasons', and while it is not clear which months the irrigation season was for each farm, the sum of irrigation season rainfall and irrigation applied provides a comparison of total water applied during the irrigation season. Figure 1 shows the distribution of water applied during the irrigation season for the three seasons in the sample.

Table 2 and Figure 2 provide estimated variable costs of irrigation across the three seasons. Note that electricity, other and R&M costs are based on the OO and O+VOCM samples, whereas labour and 'all costs' are only based on the OO sample.

Table 1: Description of data from the Canterbury dairy farms selected from DairyBase for this study

	2017-18	2016-17	2015-16
Number of Owner-Operator farms	25	23	21
Number of Owner with a Variable Order Contract Milker farms	8	11	13
Percentage of farm irrigated (average)	96%	94%	95%
Average irrigation interval (days)	6	6.6	6
Average times each area was irrigated per season	21	24	42
Average irrigation applied per season (mm/ha)	290	349	491
Irrigation season rainfall (mm/ha)	479	276	234



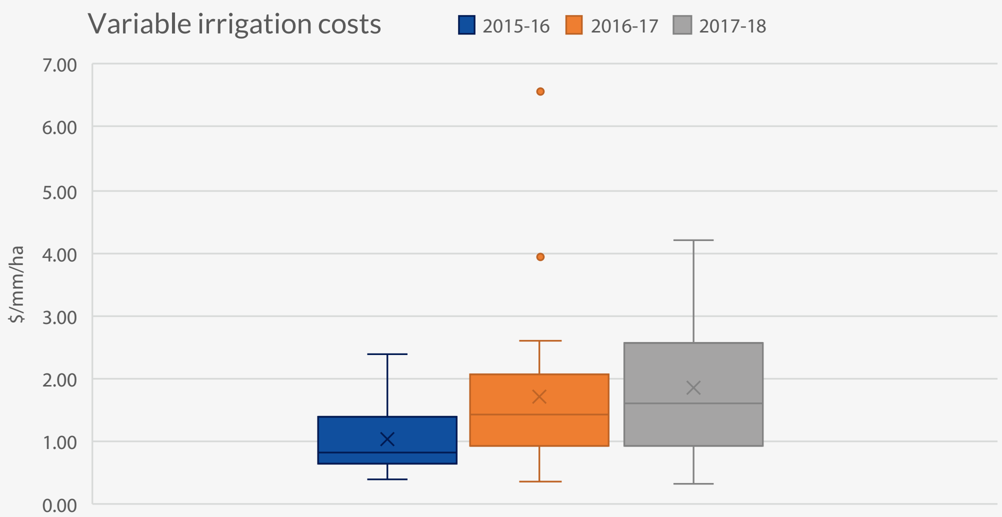


Figure 1: Distribution of water applied during irrigation season (irrigation and rainfall) mm/ha

Discussion

Electricity costs

Our analysis shows that electricity costs are on average about $0.06-$0.08/m³, representing about half of all variable costs, although with a large range (up to $0.31/m³). When electricity and 'other' costs are combined, they range from an average of $0.09 to $0.17/m³ ($0.88/mm/ha to $1.70/mm/ha) across the seasons, with a tendency to increase from 2015-16 to 2017-18.

R&M costs

The R&M costs are on average about $0.14-$0.30/mm/ha and their proportion in 2016-17 was much higher than in the other two seasons. This was also a season of a higher milk payout than the preceding two seasons, which may indicate that some R&M had been deferred from the previous seasons. It could be that the repair bill was higher due to weather damage, but a cursory assessment of wind data from NIWA showed that all three years had very similar maximum observed wind speeds and there is no obvious difference in the number of 'strong wind' events during this time.

There was one data observation which was considered an outlier in the 2016-17 data set. This farm had a R&M cost much higher than average on a cubic metre and mm/ha metric, but not for $/day. This highlights the importance of considering what units are used to consider costs. For example, a breakdown that took a while to fix would reduce the irrigation amount applied and increase the R&M bill, leading to this looking quite different to other data points. This also raises the question of whether it truly is R&M expenditure or capital expenditure marked as R&M.

Labour costs

An assumption was made that labour was on average two hours/day each day the irrigation was on. Based on this, labour appears to be a smaller cost component than electricity, 'other' and R&M. Unfortunately, no variation around this can be meaningfully extracted. Two hours seems to be a reasonable assumption based on one study that focused on irrigation labour requirements, but this does suggest that further investigation into irrigation system types and associated labour requirements would be useful.

Overall variable costs

Overall, the variable costs for irrigation averaged $1.05/mm/ha in 2015-16, $1.72/mm/ha in 2016-17, and $1.87/mm/ha in 2017-18. The most significant component was electricity and 'other' costs (79% of total OO cost), followed by R&M (14% of total OO cost) and then labour

Table 2: Analysis of variable costs

SEASON	2017-18			2016-17			2015-16		
VARIABLE AND UNITS	MIN	MIN	MIN	MIN	MEAN	MAX.	MIN[a]	MEAN	MAX.
Electricity costs ($/m^3)	0.00	0.08	0.31	0.00	0.08	0.27	0.00	0.06	0.22
Electricity costs ($/mm/ha)	0.00	0.77	3.13	0.00	0.81	2.69	0.00	0.57	2.20
Electricity & other costs ($/m^3)	0.01	0.17	0.62	0.00	0.14	0.46	0.01	0.09	0.28
Electricity & other costs ($/mm/ha)	0.13	1.70	6.21	0.00	1.45	4.56	0.08	0.88	2.79
Repairs & maintenance ($/m^3)	0.00	0.03	0.23	0.00	0.03	0.10	0.00	0.01	0.06
Repairs & maintenance ($/mm/ha)	0.00	0.3	2.28	0.00	0.27	0.99	0.00	0.14	0.60
Repairs & maintenance ($/day of irrigation)	0.00	182	703	0.00	145	606	0.00	108	623
Labour[b] ($/m^3) (2hrs/day)	0.00	0.01	0.03	0.00	0.01	0.17	0.00	0.01	0.05
Labour[b] ($/mm/ha) (2hrs/day)	0.03	0.10	0.27	0.02	0.14	1.03	0.01	0.12	0.53
All costs ($/m^3) (OO only, 2hrs/day)	0.03	0.19	0.42	0.04	0.17	0.66	0.04	0.10	0.24
All costs ($/mm/ha) (OO only, 2hrs/day)	0.33	1.87	4.21	0.38	1.72	6.58	0.39	1.05	2.40

[a] Where the minimum equals zero, the farm has no irrigation electricity listed and it is likely this is included in the 'other' cost category, so the 'electricity & other cost' category is included in the analysis
[b] Labour is based on OO sample only

(7% of total OO cost based on the labour assumption of two hours for every day irrigated). On average, irrigation costs appear to be increasing across the three years in the sample, although it is too short a period to generate a meaningful trend. This increase is mainly driven by the increase in electricity and 'other' costs.

While the $2/mm/ha cost widely used in the literature so far is similar to our results (mean of $1.05/mm/ha 2015-16, $1.72/mm/ha 2016-17 and $1.87/mm/ha in 2017-18), none of these studies are directly comparable due to the different cost components included and the methodologies used. This analysis was limited to dairy farms. Also, because the costs only consider the variable costs of irrigation, and not the changes in a farm system associated with changes in irrigation, the results should only be extrapolated to other irrigated land uses provided the irrigation systems are similar. For instance, it would not be sensible to extrapolate the results to sub-surface or micro-drip irrigation systems.

The intent of our research was to explore variable costs and, as such, only costs that are likely to vary with irrigation management were considered. It was not possible to verify what was included in the irrigation 'other' costs in addition. Some farms had no electricity costs, but had recorded 'other' costs, so these were considered together for most of the analysis. This creates a risk that some fixed costs have been included in the analysis due to a lack of clarity about what is included by accountants in the 'other' section in the accounts, which could include water supply charges or consent costs etc. It will be unlikely to include capital costs, as it is a sub-category in operating expenses, but it is not clear if it is all variable costs or if some fixed costs have been included.

Variation in milk payout or extreme weather events can impact these results, such as R&M (i.e. deferred maintenance in low payout years or increased repairs as a result of damaging storms) and electricity (as a result of droughts and water availability). The results are suitable for extrapolation to other 'average' seasons. However, consideration should be given to how some factors (such as payout and weather) might affect the results in individual contexts, especially when using the results in this study to support decisions on-farm.

Conclusion

While individual farms may track their own variable irrigation costs there is limited published information on these costs to support farm system and policy analysis. We suggest that:

- At a farm level, understanding variable irrigation costs will support operational and investment decisions on-farm
- At an industry level, understanding these costs will help farmers evaluate their systems against their peers and use this to inform decision-making
- At a regional and national level, understanding these costs will help inform policy discussions about environmental regulation.

While this article has been unable to analyse some features (such as how these costs vary by irrigator type), it does provide a robust starting point to better assess the variable costs of irrigation. This study should therefore contribute to the literature available on the costs and benefits related to irrigation and help inform discussions from the farm through to policy levels.

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VIRGINIA SERRA

WINTERING SYSTEMS IN CANTERBURY – THE PAST, THE PRESENT AND THE FUTURE

Wintering systems have been changing and adapting, responding to internal and external risks, new options and opportunities provided by science and technology, as well as to external demands from regulators and the community. This article provides an overview of the changes seen in wintering systems in Canterbury, including some predictions for the future.

Winter a critical time

Winter (June-July) is a critical period for the success of a dairy farm business. Achieving body condition score (BCS) targets pre-calving has a significant influence over the success of the whole production season. Winter grazing is a considerable expense (accounting for around 10-15% of farm working expenses), and availability and price variability can present a significant business risk.

The risk of nutrient loss to the environment and animal welfare issues are also crucial considerations for this period. Wintering systems have constantly been changing and adapting in response to internal and external factors and will continue to evolve in the future.

How cows are wintered

There is no recent data on where, how or what practices are implemented over winter. The best description of current practices is a survey conducted in Canterbury by DairyNZ in 2016. In this study, 238 dairy farmers (20% of the 1,208 farms in the region) were surveyed to determine where and how cows were wintered. The survey found that most of the cows (93%) were wintered off the milking platform, with only a small percentage (7%) wintered on the milking platform.

Of the cows wintered off the milking platform, 72% were wintered on support blocks owned or leased by the dairy farmers (58% owned, 36% leased and 6% unknown), and 28% managed by graziers (mainly arable farmers). Most farmers wintered their cows on forage crops supplemented with grass/cereal silage, baleage or straw. Kale (46%) and fodder beet (40%) were the most common winter crops fed to cows.

Evolving wintering systems

Wintering systems and practices have constantly evolved in response to several factors:

- The availability and cost of wintering
- Higher expectations by farmers of animal performance (e.g. achieving BCS targets)
- New options and opportunities provided by science (e.g. cropping practices, catch crops)
- The need to comply with external pressures from regulators and the community about environmental impact and animal welfare.

Over the last 20 years, the demand for winter feed has increased sharply with the rapid expansion of dairy farming in the South Island (mainly in Canterbury, Otago and Southland). Cow numbers increased from ~560,000 in the 1999-2000 season to ~1,835,000 in the 2019-2020

Cows eating kale crop

Over the last 20 years, the demand for winter feed has increased sharply with the rapid expansion of dairy farming in the South Island (mainly in Canterbury, Otago and Southland).

season, generating significant demand for winter feed. As mixed livestock and arable land was converted to dairy farming, winter feed has been sourced from further afield, potentially increasing cost.

In the 1990s, a successful wintering system was about securing enough feed at a reasonable price and with both cows and people having a winter holiday. In the early 2000s, there was an increased focus on crop utilisation and feed quality, with a stronger emphasis on cows achieving BCS targets. The increased focus on animal performance led to herd owners wanting more control over management and higher expectations of BCS outcomes.

Over the last 10 years, there has been an increased focus on the environmental impact of wintering. The stocking density used to harvest the high-yielding crops during the winter feeding period can result in large nitrogen (N) leaching loss relative to the total farm footprint. In Canterbury (mainly light soils), N leaching is a significant issue, but phosphorus (P) and sediment loss to waterways are also risks.

Currently, a successful wintering system needs to consider achieving animal welfare needs. Looking after the welfare of animals is much more than healthy animals achieving their BCS targets at calving. There is abundant evidence that wet and muddy conditions have adverse effects on the welfare, health and productivity of cows, including severely reduced lying times (which can lead to chronic stress and immunosuppression), reduction of quantity and quality of sleep, and reduced production. When given a choice, cattle avoid wet and muddy surfaces to the extent that they will choose to lie down on concrete (a surface they also find aversive) rather than in mud. The changes in behaviour seem to be primarily driven by the moisture content of the surface.

The outbreak of *Mycoplasma bovis* brought biosecurity to the forefront as another significant consideration when sending animals off-farm for winter grazing. Environmental considerations have also extended to greenhouse gas (GHG) emissions and in the digital world we live in public scrutiny is widespread.

Current systems in Canterbury

The most common wintering system in Canterbury is for cows to winter on forage crops grazed in situ and supplemented with conserved feed. For a long time, kale was the dominant winter crop. It is a low-risk crop to feed, but achieving pre-calving BCS targets (as well as high crop utilisation) has historically been a challenge.

When fodder beet (FB) emerged 15 years ago, high yields of consistent quality (ME/kg DM) delivered good BCS gain.

Table 1: Environmental footprint FB vs kale over winter

FOOTPRINT	% REDUCTION	COMPARISON
Methane emissions	18%	Cows eating FB + ryegrass dominated pasture silage vs eating kale & barley straw
Nitrous oxide from urine patches	39%	Cows eating FB vs cows eating kale
N leaching/ha	45-50%	Cows eating FB vs cows eating kale
N leaching /cow	35%	Cows eating FB vs cows eating kale

Published research data has demonstrated water quality and GHG benefits from feeding fodder beet compared to kale over winter (Table 1). The benefit for water quality comes from the lower N content of FB that can reduce urinary N excretion, and consequently nitrate leaching and nitrous oxide emissions. Methane emissions from cows eating a diet of FB has also been measured to be lower than cows eating one of kale. The reason for the lower methane emission from FB is likely to be the high readily available carbohydrate content affecting rumen fermentation, which reduces enteric methane emissions.

It is well known that FB comes with nutritional risks that need to be managed, but FB can be a polarising feed for farmers and experts. Some farmers have successfully incorporated FB into their wintering system, which has become a critical element of its success. Others have stopped or reduced FB use as it created too many issues with animal health and became too stressful to manage for the people involved. In 2018, a telephone survey of 508 dairy farmers was completed to better understand the range of FB use and feeding practices within South Island dairy systems (Table 2).

Contradictory advice or misinterpretation of recommendations has contributed to poor decision-making and mistakes when feeding FB. To capitalise on the environmental advantages of FB as a low N crop, we need to ensure the management of the crop is adequate, including accurate allocation, adequate transition and mineral supplementation.

Management needs to follow the known science to avoid animal health and welfare issues. FB is a crop that requires good planning and attention to detail. If the management systems are not in place to achieve that, FB may be too much of a risk for the system and stressful for everyone involved.

Catch crops to reduce N leaching after winter grazing

Catch crops are not new and are being used widely by arable farmers. However, research conducted under the P21 programme showed that a catch crop established as soon as possible after winter forage crop grazing has the potential to take up nutrients deposited over the winter, reducing the risk of loss of these nutrients to the environment.

Also, research carried out under the FRNL research programme estimated that a winter-sown cereal catch crop can reduce soil mineral N and reduce N leaching by 22-40%. The reduction of N leaching risk by growing catch crops varies from year-to-year, depending on weather conditions, particularly before and during catch crop establishment.

Catch crops are an excellent tool to reduce unnecessary nutrient losses. However, there are a few practical limitations. For instance:

- The paddock is too wet to get onto to sow
- Difficulty fitting them into the rotation (short timeframe to establish a catch crop and/or pressure to re-sow permanent pasture in the spring)
- They use the soil moisture needed for the next crop to be planted in dryland conditions
- They provide feed at a time when it may be less required.

The future

This section describes what wintering in Canterbury could look like based on the changes described above, as well as future influences, combined with discussions with farmers, rural professionals and researchers.

It is unlikely that winter grazing demand will increase due to limitations to future dairy expansion in Canterbury. However, the increased scrutiny on winter practices and proposed wintering rules may still create challenges for dairy farmers as graziers and arable farmers who are offering winter grazing now may find wintering of dairy cows too risky. This situation could increase the cost of winter feed.

Wintering on crops is likely to remain the most common wintering practice and a viable and sustainable option in Canterbury. Kale, FB and to a lesser extent swedes (starting to gain popularity in Canterbury), fed in situ with baleage, grass silage and straw, is likely to still be the main wintering system. Wintering on kale and swedes is likely to be the preferred option for some farmers (for the whole herd or part of the herd) for ease of management, despite the environmental benefits of FB. Establishing catch crops after the winter crop is considered good management practice (GMP), but presents its challenges. However, as with other challenges, farmers with the support of trusted rural professionals can develop solutions.

Table 2: FB use in the South Island (survey results)

DESCRIPTION	PERCENTAGE OF FARMERS (508 TOTAL FARMERS)
% farmers feeding FB	69%
% farmers never fed FB	24%
% farmers stopped feeding FB	8% (most frequent reasons for stopping were animal health issues, cost and management challenges)
% herds with metabolic issues (>5% of the herd affected)	41% of herds fed FB 23% of herds not fed FB
Feed allocation	
• 82% of the respondents feeding FB determined allocation by yield and break area • 98% of the respondents feeding FB transitioned cattle onto FB over an average of three weeks • Of those that fed FB to non-lactating cows in winter, the mean allocation was 10.3 kg DM/cow/day (66% of the diet) and 12% fed FB ad libitum	

Research carried out under the FRNL research programme estimated that a winter-sown cereal catch crop can reduce soil mineral N and reduce N leaching by 22-40%.

The use of off-paddock infrastructure is not likely to be the default option for wintering in Canterbury, as lighter soils and drier conditions than Southland makes wintering on crops in Canterbury less challenging. However, there would be some conditions (location, soil types and weather events) where cows may need to be taken off-paddock for the whole winter period or part of it. If this is the case, a low-cost wintering specific infrastructure that meets animal welfare and environmental outcomes could be a good option. Current research led by DairyNZ in Southland is looking into some low-cost off-paddock infrastructure that could provide options for this purpose.

Careful analysis is required before investing in expensive infrastructure (e.g. barns) to accommodate the winter period. Case studies in Southland have shown that investing in wintering infrastructure could lead to an overhaul of the production system and to a higher environmental footprint due to linked intensifications (increased DM intake leading to increased N eating and methane emissions).

After the M. bovis outbreak, wintering cows at grazier properties required very tight biosecurity practices and a good working relationship between the dairy farmer and the graziers to ensure adequate practices were being implemented to minimise risks. We have not seen a significant move from dairy farmers to winter cows on the milking platform after M. bovis, but we have seen an increased awareness of biosecurity practices from both farmers and graziers.

Essential freshwater policy and the intensive winter grazing rules will require a documented winter management plan from winter 2022. The documented wintering plan should include a Plan B to provide dairy cattle with a comfortable, drier lying surface during adverse weather events. Wet conditions reduce lying times on most soil types, so removing cows from crop paddocks might be the only Plan B to achieve a more suitable lying area.

Crop or paddock-based wintering has garnered much interest from the Government and the public in the last few years, so adopting good animal welfare and environmental wintering practices must become a priority for our farming operations. Southland is leading the way in implementing GMPs for wintering due to intense scrutiny in recent years. Farmers, researchers and other stakeholders have therefore been working together to identify practical solutions to address all the requirements for successful crop-based wintering.

In Canterbury, more favourable conditions (lighter soil and drier conditions) have created a sense of complacency. However, the risk of not adhering to GMPs is that we continue to come under increased scrutiny from our consumers and the public with possible international trading implications. Local and central governments will react with unnecessarily stringent and prescriptive regulations, and farmers risk losing their social licence to farm the way they want.

Final thoughts

A sustainable wintering system should be cost-effective and support achieving BCS targets without compromising animal health (e.g. metabolic disorders in early lactation). It needs to minimise nutrient (N and P), sediment and E. coli losses to waterways and consider GHG emissions. It must consider any impacts on animal welfare, including providing a comfortable surface for cows to lay down. Finally, it needs to be well documented and demonstrate that robust systems are being implemented to achieve


Loose housed barn with woodchip and sawdust bedding

good wintering outcomes and have a Plan B in place to deal with adverse weather events. Increasing scrutiny on wintering practices have transformed wintering into a challenging time for farmers with no room for mistakes. Gone are the winter holidays for many.

The role of the rural professionals working alongside farmers is likely to change. In addition to the support advisors are currently providing, an increased level of support will be required to help farmers create their tailored wintering plan and implement it. There is also a role in facilitating farmer access to the suite of resources developed based on the research carried out over the last few years. These templates and resources, developed by industry bodies and other organisations, are available for farmers to use to create these plans. These resources have been based on science and practical experiences and incorporate the GMP concepts.

Acknowledgements

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Further information

www. dairynz.co.nz/feed/crops/wintering/
www.dairynz.co.nz/about-us/research/pastoral-21/
www.dairynz.co.nz/about-us/research/forages-for-reduced-nitrate-leaching-programme/

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MORTEZA GHAHREMANI, PETER TOZER AND SVETLA SOFKOVA-BOBCHEVA

ROBOTIC APPLE HARVESTERS – THE ANSWER TO LABOUR SHORTAGES?

The New Zealand apple industry is largely export-oriented and relies on manual labour throughout the year, but recently labour shortages for harvesting have been jeopardising its profitability. One way to address this challenge is to use new technologies (such as robotic harvesters) and this article outlines the results of research on this topic.

Current labour shortages

In a perfect world for apple growers there would be no issues sourcing enough high-quality skilled labour, but shortages exist (particularly for harvesting) and this is a serious challenge. Apples must be harvested within a short harvesting window. Any unharvested or late harvested fruit are considered waste and may not be suitable for the export market, which can adversely impact on the profitability and growth of the apple industry.

This is of concern, given the apple industry is one of the major players in the New Zealand horticulture sector, which generated exports of over $900 million in 2020. Until now apple growers have been dependent on labour from local workers, international backpackers and recognised seasonal employer (RSE) scheme workers who come mainly from the Pacific islands. It is estimated that up to 80% of New Zealand's apples are harvested by RSE workers.

The ongoing labour shortages have also been compounded by the COVID-19 pandemic, which has caused significant disruption to the availability of seasonal labour. The associated travel restrictions have prevented overseas workers (backpackers and RSE workers) from entering New Zealand. The apple sector is therefore faced with large labour shortages until COVID-19 is under control and the borders can be reopened.

Robotic harvesting technology as a solution

This has led the apple industry to consider robotic harvesting technology as an alternative to reduce the dependency on harvesting labour. The idea of using automation or a mechanical harvesting system is not new to the industry, as mechanical harvesting technology is already being used by apple growers, mainly for the processed market. However, due to the fruit damage caused by the shake-and-catch technology, apples harvested in this way are not suited for the fresh export market. Several robotic technologies more suited to harvesting apples for this market have been developed and trialed around the world. As yet, these technologies are not commercially available and their cost-effectiveness has not been evaluated.

The robotic harvesting technology uses a pick-and-place mechanism, which mimics the human picking action. This uses a combination of precision and automation technologies, which includes sensory computer vision, artificial intelligence (AI), and a vacuum or gripper mechanism to pick the fruit off trees without damaging it (see first photo). The robot uses a computer vision system

The robotic harvesting technology uses a pick-and-place mechanism, which mimics the human picking action.

to scan apples for ripeness and harvestability. Then a vacuum or gripper mechanism picks the fruit and places it into a designated place, or on a conveyor belt, which moves the harvested fruit to a bin.

Given these robots are still in the trial phase, no technical information about their performance has been published. Also, no commercial launch date has been announced by the robot developers and the reasons for this could be technical, horticultural and economic. A fully commercialised robotic apple harvester should be able to pick fruit faster than or equal to manual pickers, with fruit quality equal or better than manual picking, and it should be economically viable.

Cost-effectiveness

A recent study was undertaken at Massey University to evaluate the cost-effectiveness of robotic apple harvesting. The study used a modelling approach and looked at different orchard types and sizes. The model could change inputs (such as planting system, and orchard types and sizes). This makes the model adaptable to various apple varieties, or even crops such as kiwifruit, given that fruit yield/ha is a function of tree density/ha, fruit yield/tree and fruit size.

It was assumed that apple trees were planted in a two-dimensional (2D) tree structure at a tree density of 2,400 trees/ha and that a robot can harvest fruit at a speed of 1 second per fruit and at an efficiency of 80%. It was also assumed that at the current harvesting speed and efficiency, robots would not completely replace pickers, so pickers can complement robotic harvesting.

The study found that the robotic harvesting of orchards that had low-value varieties and achieved low yield/ha was financially less viable compared to those with relatively higher-value varieties and achieving high yield/ha. The technology was therefore not suitable for orchards growing relatively lower-valued and yielding varieties.

Of the three apple varieties studied in a single-varietal orchard (Envy, Jazz and Royal Gala):

- The Envy orchard generated the highest net income when it was mainly harvested by robot. The relative profitability of Envy is higher than other varieties because of its relatively higher value and size
- Jazz and Royal Gala are relatively more expensive to harvest as they are relatively lower-valued and yielding varieties compared to Envy
- It is more profitable to have a bi-varietal orchard planted with Jazz and Royal Gala (or a multi-varietal orchard planted with Envy, Jazz and Royal Gala) than a single-varietal orchard planted with either Jazz or Royal Gala when an orchard is mainly harvested by robot.

A robotic apple harvester in action identifying ripe fruit using computer vision and picking it by a vacuum mechanism. Photo courtesy of Hawke's Bay Today

For example, harvesting 10 ha of a single-varietal orchard by robot generated a net income of $7.27 million for Envy compared to $0.28 million for Jazz or $0.48 million for Royal Gala for an investment of 25 years. In a bi-varietal and multi-varietal orchard of the same size, there was a net income of $0.96 and $3.70 million, respectively. However, given the current picking wage rates and technological performance of the robot the manual picking is more profitable.

Number of robots and pickers required

Based on our model, each variety requires a different number of robots for harvest because of differences in fruit size and number. For instance, as the Envy apple is larger, fewer robots are required for harvesting the same weight to the smaller Jazz and Royal Gala apples. So, harvesting 10 ha of Envy required four robots compared to five robots for each of Jazz and Royal Gala, and 10 ha of bi-varietal and multi-varietal required three and two robots, respectively, because of the extended harvest window.

The use of robots reduced the number of pickers required when compared to harvesting the orchard completely manually. For example, for 10 ha of Envy, using robots reduced pickers by 52% (26.52 to 12.76 full-time equivalent or FTEs), for Jazz by 44% (24.40 to 13.72 FTEs) and for Royal Gala by 44% (25.03 to 13.98 FTEs). Similarly, for bi-varietal and multi-varietal orchards of the same size, the number of pickers required reduced to 9.91 FTEs and 9.08 FTEs, respectively.

Having a bi-varietal or multi-varietal orchard did not significantly reduce the dependencies associated with pickers compared to a single-varietal orchard. Because of the assumed harvesting efficiency and speed, there is unharvested fruit left over by robots that need to be picked by pickers, regardless of the orchard type. Also, growers will still need an operator to operate each robot.

Robot adoption requirements

The process of mechanising and automating tree fruit production for the fresh export market requires changes at the farm and industry levels:

- At the farm level, many of the growers will need to change their cultivar and rootstock selection, traditional orchard practices, orchard design, tree planting density, tree shape and training, labour dynamics, harvesting logistics and operating systems. So, orchards that are best suited to robotic harvesting need to use modern high-density planting and training systems with narrow row and tree width, and uniform plant size and fruit position (such as a 2D tree structure – see second photo), and grow high value and size apple varieties. These changes can influence the entire fruit production system leading to the better management of inputs, while meeting the quality requirements of harvested fruit for the fresh export market. Such changes require considerable investment and are more suited to new apple plantings.
- At the industry level, if robotic harvesting is to be a feasible alternative, a new support industry will be required to service these technologies for both their software and hardware requirements. Such services will need to be available on a regional basis. It is important that the industry participants, including government and agribusinesses, play an active role in attracting agri-tech companies and venture capitalists to invest in this sector. Without sufficient support, the robotic harvesting system can be more of a liability than an asset for potential adopters.

Farmer adoption of robotic apple harvesting requires an automation system with comparable performance to human pickers. The system needs to be capable of harvesting ready-to-pick fruit from trees quickly and efficiently without causing damage to the harvested fruit on the tree. The robot's harvesting performance will therefore need to be similar to human pickers. This will comprise its harvesting speed (the time the robot takes to remove an apple) and harvesting efficiency (the percentage of fruit identified to be of harvestable quality and that is harvested). How much the robot is substituting human pickers becomes important, considering the relative price and yield of harvesting different varieties based on harvesting speed and efficiency.

Robot harvesting performance and financial viability

The study also looked at the impact of the robot's relative harvesting performance on financial viability. It was found that both harvesting speed and efficiency are key factors that can positively affect the profitability of using the robot and its long-term investment. The analysis found that at the technology's current development stage, it is more important that robots operate faster but not necessarily more efficiently, so that they can substitute for as many pickers as possible and make their use more profitable (Figure 1).

For example, in 10 ha of Envy orchard, a 25% reduction in time from 1 second per apple to 0.75 second per apple (and with the efficiency at 80%) lifted the net income by 7% ($7.27 to $7.76 million). It reduced the number of pickers by 8% (12.76 to 11.76 FTEs), and dropped the number of robots from four to three, as robots spend less time harvesting each tree (therefore covering more area of the orchard or harvesting more trees/ha). This reduced the number of robots and pickers required to harvest the same area. Operating the robot at the fastest speed assumed (0.70 second per apple), while maintaining the efficiency at 80%, lifted the net income by 10% ($7.27 million to $7.97 million) using three robots and 18% less pickers (12.76 to 10.49 FTEs).

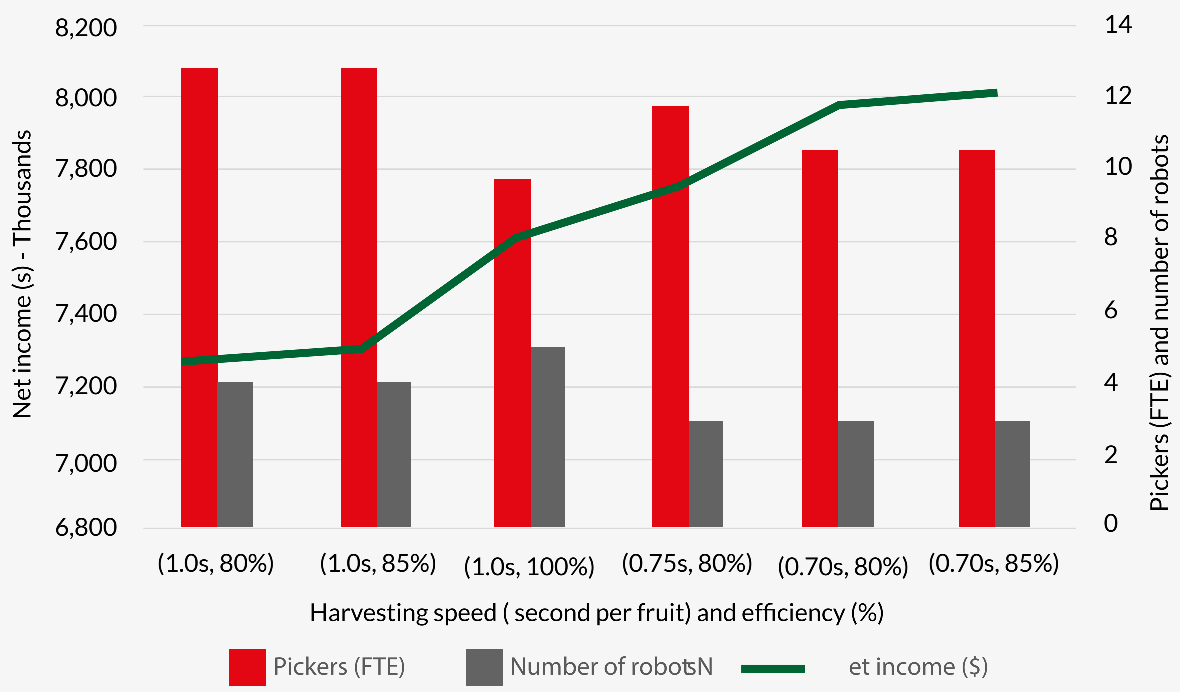

***Figure 1:** Impacts of different combinations of harvesting speed (second per fruit) and efficiency (%) on the net income ($), pickers (FTE), and number of and robots (10 ha of Envy orchard in full production per 18 days of harvest window)*

For 10 ha of Envy, using robots reduced pickers by 52% (26.52 to 12.76 full-time equivalent or FTEs), for Jazz by 44% (24.40 to 13.72 FTEs) and for Royal Gala by 44% (25.03 to 13.98 FTEs).

Increasing harvesting efficiency slows down robots as it takes longer to harvest each tree. For example, if a robot harvests a tree with 100 apples at 80% efficiency, and 1 second per fruit, the robot will take 80 seconds per tree. If the efficiency increases to 85%, then the robot will take 5 seconds longer. Assuming a tree density of 2,400/ha, this increases harvesting time per hectare by 3.33 hours. So, running robots more efficiently may not be the most ideal strategy, even though they can harvest more apples per tree.

The above results in covering less area of the orchard, which has to be compensated for by buying more robots or hiring more pickers, which can work well on the block that the robots harvest. However, because of the harvest window constraint it would be problematic as fruit have to be harvested within a limited harvest window. Otherwise, late harvested or unharvested fruit may not be suitable for the fresh export market and could become waste.

The study also looked at running the robot at its full efficiency rate of 100% and speed of 1 second per fruit. It reduced the number of pickers required by 24% (12.76 to 9.66 FTEs) using five robots and generated a net income of $7.62 million (Figure 1). In reality it may not be possible for the robot to harvest 100% of the identified apples on trees.

Considering the trade-off between harvesting speed and efficiency in relation to the net income and labour substitution, the study found that increasing both the speed and efficiency would make the robot harvest more area as well as more fruit per tree, making it more profitable. For example, by running the robot at the fastest speed assumed (0.70 second per apple), but not fully efficient (85%), growers can substitute 17% more pickers (12.76 to 10.58 FTEs) with a lower capital requirement using a lower number of robots (four to three robots). They can then generate 10% more net income ($7.27 million to $8 million) compared to the case of 1 second per fruit and 80% efficiency (Figure 1). This would also allow robots to harvest the block faster in the limited harvest window than if they were to harvest faster and fully efficient.

So, each one of the combinations shown in Figure 1 may be considered as the best combination on its own merit (depending on what is important to potential adopters), substituting as many pickers as possible or capital requirement. Speed or efficiency could be the key parameter in harvesting the orchard by robot. For growers who have trouble sourcing pickers due to labour shortages, substituting as many pickers as possible with the highest possible number of robots could be an option. For growers

Example of 2D apple tree structure at Plant & Food Research in Hawke's Bay – a planar cordon vertical design on 'Scifresh' tree

who may not be financially stable, and who do not have difficulty sourcing pickers, then saving up to buy more robots while hiring more pickers could be appealing.

Robot adoption relative costs

Even though the adoption of robots can significantly reduce the number of pickers, it also hugely increases the capital cost due to their cost. Consequently, the adoption of robots becomes less profitable compared to manual harvesting across all varieties. This could be a demotivating factor for growers who are already in debt and not financially stable, and might hinder potential adoption until robots become more affordable.

Another important aspect in the current development stage of robotic harvesters is that the capital and operating costs of commercial harvesters are unknown. Given the complexity of their operation and their embedded technologies (such as vision systems and AI), robotic harvesters will likely be expensive pieces of equipment, at least during the initial commercial phase. This was the case with automated milking systems (AMSs) when they were first commercialised, and resulted in some of the potential adopters delaying their investment for a few years until it became more affordable.

Given the high costs involved in purchasing and operating the robots, larger growers who usually supply most of the production in the industry are the most likely to invest in robotic harvesting technology. For these growers, a large fixed investment can be spread over more area. When robotic harvesters become commercially available, it is likely that the costs for early adopters may be higher than for other available alternatives (e.g. platform harvesting systems) until the infrastructure is in place to support the sale and maintenance of the equipment.

Given the expected initial high cost of robotic harvesters, this may see the development of contract harvesting or ownership of the technology by a grower cooperative. This would enable smaller growers and less financially viable growers to use robots in their orchards without having to outlay a large sum of capital. A cooperative business model has been well practised and recognised in the New Zealand agricultural industry. A grower cooperative could own shares in a set of robotic harvesters and their use and costs could be shared across the members.

Different labour demographic

Using a robotic harvester would also create requirements for a different labour skillset. A much smaller workforce of pickers will be required to pick the apples not harvested by the robots, so it will be important how the outflow of labour is managed to prevent unemployment problems. The use of a robotic harvester will free up harvesting labour to perform other tasks (such as supervisory and packing roles). However, labour will need to be trained to operate and maintain the robotic harvester, which will require a much higher level of knowledge, so workers will move from lower to higher-skilled tasks, creating a new demographic in the labour force in the industry.

Conclusion

We are entering a new phase for the New Zealand apple industry, with a greater focus on labour management and ethics alongside profitable and sustainable production. Apple growers have rapidly adopted new varieties and growing methods to meet customer preferences and capture value. To continue along this path they will need the support of industry and government organisations, in particular, in dealing with skilled labour shortages and considering alternative approaches. It is clear that tackling labour shortages can be achieved through the adoption of robotic harvesting technology when it is commercially viable and available. However, major infrastructure changes, industry support, economic factors and mindset changes also have to be considered.

Acknowledgements

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TIM PAYN

Planted totara

TREES ON FARMS – THINGS TO THINK ABOUT

This article looks at what to consider when planting trees on farms – and the opportunities and challenges. It covers decision-making to get the right tree in the right place, carbon sequestration by native and exotic tree species, some of the other ecosystem services trees provide, weaving trees into the farm landscape, and sources of information and advice.

Changing operating environment

Tree planting in Aotearoa New Zealand is very topical as it is a focus of the current government and is seen as one response to mitigate the challenge of climate change. The New Zealand Climate Change Commission has recommended that significant new areas of tree planting be undertaken to aid New Zealand meet its 2050 greenhouse gas (GHG) emission reduction targets. The recommendations are for the establishment of 380,000 ha of new exotic and 300,000 ha of new indigenous forests. These new forests will help mitigate emissions through carbon sequestration.

Climate change commitments are not the only driver of tree planting. Other motivators include:

- Growing forests for erosion control on steep erodible country
- Improving water quality through a reduction in nutrient leaching
- Providing habitat for flora and fauna
- Native biodiversity enhancement
- Economic returns from timber.

These drivers are known broadly as ecosystem services and all forests provide a mix of these. Unlike the mid-1990s (the last time there was a big increase in new plantings mainly by investors looking for good economic returns) the current drivers are more environmental with economic returns secondary. Trees can contribute significantly to the National Policy Statement for Freshwater Management, the developing National Policy Statement for Indigenous Biodiversity and climate change goals.

The purpose of tree planting

Right Tree, Right Place, Right Purpose (RTRPRP) is a common mantra globally and in New Zealand. We tend to put purpose first as this will then drive what sort of trees to plant, where to plant them based on environmental and socio-economic conditions, and also (most importantly) how to manage them to best meet the purpose.

There have been a number of RTRPRP projects undertaken in New Zealand recently. The largest example is the Hawke's Bay Regional Council/One Billion Tree study that looked at siting carbon plantings on erodible farmland in the region, with an evaluation of a range of native and exotic species that might be suitable. This project gave rise to a series of regional maps of possible options for discussion.

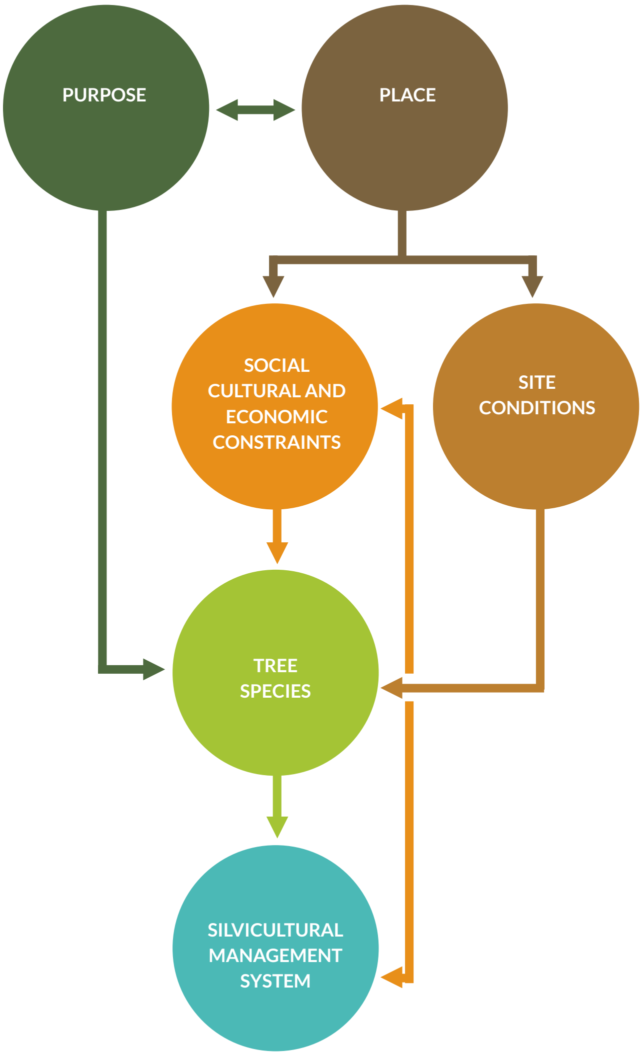

Figure 1. Framework for making tree planting choices that include purpose, siting, tree species selection and silvicultural management regime

Tararua District has just completed a similar study. The Hawke's Bay project also worked on a number of case studies at the farm-scale to evaluate how to weave trees into the agricultural landscape. This demonstrated the potential for mixed agriculture and forestry benefits on a range of individual properties. The Soils and Land Use Initiative (SLUI) is another example of an RTRPRP project, but which focuses on erosion control as the primary purpose. This project has carried out over 36,000 ha of erosion control plantings within the Horizons region since the programme started in 2006.

Types of forests

New Zealanders often categorise forests into just two types – indigenous conservation forests and exotic production forests. This is quite simplistic and there are many other options and approaches that can be taken. In a recent paper in the *New Zealand Journal of Forestry*, we identified a broad range of forest types developed for a range of purposes or the provision of ecosystem services. Most relevant for farms are:

- The many potential types of agroforestry systems
- Pole planting for erosion control and fodder
- Riparian forests for improved water quality
- Retirement of very steep erodible land into native bush
- Enhancement planting of native remnants on-farm
- Small woodlots.

The design and management of these types of forests is quite different to the typical exotic plantation forest and can be tailored to suit the main purpose for the planting.

Focusing on carbon

The hot topic of the day for trees on farms is revenue from carbon. The Climate Change Commission has

There is a very strong social and cultural value to native species, and if the aim of planting is not purely economic return (but more environmental and social) then there is a very good case for native plantings.

identified the need for a significant area of new forest planting and the vast bulk of the land these plantings can go on is currently under agriculture. This is creating both opportunities and concerns. Opportunities for a landowner are from the ability to register with the Emission Trading Scheme (ETS) and to earn a passive carbon income from trees for a period of time until the area planted reaches a steady state and stable carbon stock. This income is available for use on-farm or investment elsewhere.

The concerns are mainly around loss of land to permanent carbon forests that limit future agricultural opportunities and may also adversely affect rural communities through, for example, loss of employment opportunities. These concerns have manifested in significant anti-forestry sentiment and could be limiting the potential for farmers and other landowners to realise some of the benefits from the carbon opportunities from planting trees on their land.

The carbon topic is complex and often seen as 'too hard' from a range of perspectives. Forest carbon advice is getting easier to access, but there is definitely still a need to address lack of knowledge, misunderstandings and misperceptions on the topic.

The ETS is the main vehicle to recognise carbon benefits through the registration of eligible areas, and thus access to carbon credits from the trees planted, but there are limits to the scheme. The area planted must be more than 1 ha and 30 m wide, trees must reach more than 5 m tall, and the canopy cover must be more than 30%. Also, the trees must have been planted onto land that was not forested before 1990 or had been cleared by 2008. This means smaller areas on the farm (such as windbreaks or riparian plantings and areas of remnant native bush that may be sequestering carbon) are not eligible. There have also been concerns about the difficulty of proving that the land was not forested prior to 1990, the complexity of the scheme and risks from future carbon price increases.

Voluntary carbon schemes operating in parallel to the ETS that allow monetisation of the carbon stored have been proposed, most recently by Motu, and are a potential future option for landowners not wishing to enter the ETS. He Waka Eke Noa is also developing a pricing mechanism for on-farm emissions that should be able to incorporate offsets from trees not eligible for the ETS.

He Waka Eke Noa is a five-year programme developed in partnership between government and the primary sector 'that will empower farmers and growers to measure, manage and reduce on-farm emissions; recognise, maintain or increase integrated sequestration on farms; and adapt to a changing climate' (see https://hewakaekenoa.nz/). In February 2022, a pricing scheme for emissions will be presented to Ministers and the target is to have the scheme up and running in 2025.

Exotics or natives?

For those who have decided they would like to take up the opportunity from trees planted for carbon there are multiple things to consider before taking the plunge. The main question that we hear is should we plant exotic or native species, and this is a large topic in its own right.

In a nutshell, the exotic species commonly planted for timber in New Zealand will sequester carbon at a faster rate than native species. However, managed plantings of some native species (such as tōtara or kauri) can sequester carbon at a much faster rate than in their natural state. A growth model developed for planted kauri showed 12-20 times greater productivity at age 60 than natural stands.

Indigenous trees are commonly slow starters and consequently sequester carbon at a much lower rate in the early years than exotics. Rates will increase over time, and in the long term (hundreds of years) they are likely to build up larger carbon stocks than most exotics. So, if the aim is carbon revenue in the short term (30-50 years) then exotics are the answer.

However, there is a very strong social and cultural value to native species, and if the aim of planting is not purely economic return (but more environmental and social) then there is a very good case for native plantings. These species, as with exotics, can provide many additional ecosystem services than an unforested site:

- Enhanced native biodiversity
- Better water quality and stream ecological function
- Reduced nitrogen leaching
- Enhanced carbon stocks
- Potentially more valuable timbers.

The Climate Change Commission recognised the longer-term value of indigenous species planted now for their ability to be sequestering carbon post-2050 that can offset some of New Zealand's very hard-to-reduce emissions from processes such as cement production.

Approaches to siting and establishing the main exotic species are pretty straightforward and build on many years of research for the commercial forestry sector and farm foresters. The establishment of new indigenous plantings is less well understood, with comparatively little research or operational experience. RTRPRP projects to date have only really considered mānuka and tōtara and there is much more work to do on optimal raising, siting and establishment of indigenous species.

Little is known about the genetic diversity, and matching seed source to site (eco-sourcing) is likely to be important. Understanding what the climatic conditions may be in the future will also need to be considered when siting very long-lived trees.

There are also cultural considerations relating to indigenous species. Cultural affinity and whakapapa to all aspects of the forest is an integral part of Te Ao Māori. These relationships were reflected in the wording of Te Tiriti o Waitangi and in the intent behind the Wai 262 Treaty claim. New planted indigenous forests might not only help mitigate climate change and provide additional ecosystem services, but might also provide an opportunity for deep cultural enrichment of our country.

Practically, the cost of establishment is a major challenge as seedling costs are several times greater compared to exotics and often many more plants per hectare need to be established to shade-out weeds and ensure survivability of seedlings. Costs of establishment can be of the order of NZ$15,000 to NZ$20,000/ha, with additional follow-up weed and pest control of NZ$2,000 to NZ$3,000/ha/year for three to five years. These costs can be highly variable, depending on the site and species to be planted. There is currently a large research effort towards reducing these costs with a goal to get to the range of NZ$4,000 to NZ$8,000/ha. This will be mainly through decreased cost of plants and effectiveness of weed and pest control.

Availability of plants will also be a challenge as the area established ramps up. National nursery capacity will need to be expanded to cope with demand and seedling quality will need to be a focus to ensure good survival and early growth. Planting is just the start – ongoing weed control to remove competition (and also pest control to protect the plants from grazing by herbivores) is essential to ensure successful establishment.

Integrating trees within farm systems

There are an increasing number of case studies where the integration of trees into an existing farm have been evaluated. AgFirst, as part of the Hawke's Bay Regional Council RTRPRP project, analysed a number of properties on the East Coast and looked at scenarios incorporating trees into hill country sheep and beef properties. They found that land carrying less than seven stock units was more attractive financially if converted to forestry, and 13 stock units if carbon was incorporated at NZ$25/tonne.

All case studies showed that incorporating trees could be achieved without a significant adverse impact on agricultural returns and with the added benefits of returns from the trees, either as carbon or timber or opportunities for improved animal welfare. One example showed that converting the least productive 500 ha of a 1,250 ha property to production forestry and focusing on improving the remaining land led to an overall lift in Earnings Before Interest and Tax (EBIT) of NZ$20,000 p.a. Adding forestry to the mix also strengthened cashflow and farm resilience to severe storms.

The additional ecosystem service benefits were not quantified, but increased soil stability from afforesting the steeper poorer land was one significant potential benefit. PF Olsen, a forest management company, has also been undertaking such analyses outside the Hawke's Bay with similar positive results.

The integration of trees into existing landscapes is feasible – a rule of thumb suggests around 15% of a hill country property could effectively be put into trees without too much change to agricultural returns through efficiencies on the smaller productive area. Work by AgFirst and Scion has shown the benefits of using forestry as an offset to farming emissions, particularly if significant reductions are required.

Working out options for weaving trees into the landscape will:

- Allay fears about 'blanket pines' and the loss of good agricultural land through the conversion of entire farms to trees
- Provide carbon and timber returns to farmers and diversify income streams
- In the context of emission reductions plans being developed through He Waka Eke Noa, give direct emission offsetting options on-farm.

Advice and information

Farmers tend to specialise in their core business and will often know less about trees and forests. Forestry has quite a different language to farming and advice from professionals needs to be couched in 'farmer-friendly' language and the economics translated into the common terminology. As trees are a long-term crop the way foresters treat economics tends to be different to farmers, and recent expression of forestry returns as annuities (NZ$EBIT/ha/year) is simplifying the comparison of financial benefits between agricultural and forest options.

There are a number of resources available for people interested in planting trees on farms:

- The NZ Farm Forestry Association has an excellent website that covers all aspects of the topic
- Te Uru Rākau – New Zealand Forest Service is developing resources on their new Canopy website
- For erosion control plantings, the Poplar and Willow Trust is a very comprehensive resource
- Regional councils have a range of information
- Industry groups (such as Dairy NZ, and Beef + Lamb New Zealand) also have resources to support trees on farms
- There are many catchment groups (such as the King Country River Care group) actively planting trees for various reasons, and building a very large local

knowledge base on what works, and they are happy to share knowledge

- Other groups (such as Tane's Tree Trust and Trees that Count) focus on indigenous species
- Trees for Survival work closely with schools to promote waterway restoration with trees and have a wealth of experience
- He Waka Eke Noa, the primary sector programme, is also developing extension mechanisms that incorporate trees into on-farm emission reduction plans.

Rural professionals provide an avenue for information and knowledge transfer, but may be focused only on agriculture or on commercial forestry advice, or particularly erosion control (e.g. Council staff). There is a need to develop these avenues and add in other types of advice that is not currently readily accessible. Te Uru Rākau – New Zealand Forest Service is increasing its regional advisor capacity so this may be a good route for the new information.

In the longer term there is a need to integrate trees and forestry education into agricultural and horticultural courses at wananga, polytechnics and universities. The subjects have historically been taught separately and have limited the access to on-farm advice on trees and forestry as agricultural and forestry advisors have tended to be different individuals.

Summary

Weaving trees into farm landscapes is possible and provides many benefits (environmental, social and economic), and can assist New Zealand meet its climate goals with little impact on agricultural production. Carbon can supply cashflow to expand tree planting activities on-farm and offset loss of agricultural production and revenue. Exotic species provide fast carbon revenues. Indigenous species provide smaller short-term revenues, but a longer-term and potentially bigger carbon sink with additional ecosystem services and cultural benefits.

There is a great deal of enthusiasm for establishing new indigenous tree plantings. Many efforts are underway to overcome the challenges around successfully establishing new plantings – seedling availability, siting, establishment costs, ongoing pest and weed control, and to improve access to information and advice

Further information

For more information on the Hawke's Bay Regional Council RTRPRP project see: www.hbrc.govt.nz/assets/Uploads/Summary-report-Right-Tree-Right-Place-Dec-2019.pdf

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THOMAS CRESWELL

CAN STRATEGIC ALLIANCES BENEFIT THE AGRICULTURE INDUSTRY?

Applied correctly, strategic alliances are a powerful tool that could hugely benefit the agriculture sector. This article explores the benefits and risks associated with partnership agreements. It looks at important steps during the implementation process to improve the ongoing management and overall success of a partnership agreement.

Future-proofing agriculture industry

Businesses in New Zealand are often constrained by the small domestic market, distance from major markets and access to capital. There is also a high percentage of small-to-medium enterprises in this country.

Many business consultants have described the future as volatile, uncertain, complex and ambiguous. Technology advancement has increased the speed of change and this is not slowing down. We know the future is uncertain and the agriculture industry needs to future-proof itself.

The New Zealand economy is greatly dependent on primary production and international trade. This, coupled with a growing world population and people living longer, means New Zealand farmers should be well positioned to capitalise on the increasing world protein demand.

COVID-19 has highlighted how important the agriculture industry is to the New Zealand economy, with many leaders making statements that there is a real opportunity for the sector to capitalise on our clean and safe reputation.

Many business consultants have described the future as volatile, uncertain, complex and ambiguous.

Issues facing the sector

New Zealand farmers are also facing numerous challenges. Essentially, farmers are aiming to produce more while simultaneously reducing their environmental impact. According to the findings of the FMG *Future of Farming and Growing in New Zealand* report (2019), issues facing the sector going forward include:

- Trade is getting difficult
- Global economies are slowing down
- Technology will disrupt food production
- Ethics are driving pressure on factories and traditional farming methods
- The uncertainty over retail business models caused by disruption and global domination by a few
- Increasing new legislation, regulation and compliance aimed at farming.

Our farmers must compete in international markets, often against heavily subsidised competitors. New Zealand production is driven like any other commercial business model where decisions on-farm are responding to potential returns and domestic and overseas market expectations. Sales depend on meeting customer expectations on price, quality, animal welfare and sustainability.

Strategic alliances a powerful tool

One approach to respond to this rapidly changing environment is business-to-business collaboration using strategic alliances. Applied correctly, these alliances are a powerful tool that can benefit the industry.

A strategic alliance, also called a strategic partnership, refers to an agreement between two or more companies/partners to reach objectives of common interest. They each remain independent, and each company/partner hopes that the benefits from the alliance will be greater than those from individual efforts.

Typically, two companies/partners form a strategic alliance when each possesses one or more business assets or have expertise that will help the other by enhancing their businesses. They may each provide the alliance with resources such as products, distribution channels, manufacturing capability, funding, capital equipment, knowledge, expertise or intellectual property.

The most common forms of collaboration used are non-equity/contractual partnerships, equity-based partnerships and joint ventures.

Traditionally, companies have opted for mergers or acquisitions when entering new markets to gain economies of scale or access new capabilities. Mergers and acquisitions are not considered strategic alliances because the two partners do not remain independent.

Partnership objectives

The top five benefits that businesses can derive from establishing a new strategic alliance are:

1. Acquiring new customers

Essentially, this is focused on market share and market access. The organic growth of a company on its own may not be sufficient. Using the partner's distribution or client base, in combination with taking advantage of a good brand image, can help a company to grow faster than it would on its own.

An example of this is the partnership between Apple (a technology company) and AT&T (a large telecommunications company). This partnership enabled AT&T to be the sole US carrier of the iPhone between 2007 and 2011 and has resulted in huge success for AT&T. The company had 3.6 million activations of iPhones in just the first three months of 2011, with 23% being new subscribers to AT&T.

2. Expand geographic reach

Expanding distribution is among the top three benefits sought by businesses entering a partnership, with 32% of executives naming expanding geographic reach as a primary goal of their partnerships.

A good example within the industry of companies collaborating to expand their own geographic reach is the creation of Primary Collaboration New Zealand (PCNZ). In 2014, PCNZ was established to help New Zealand primary industries access Chinese markets. The collaboration includes New Zealand companies Synlait, Silver Fern Farms, Sealord, Rockit Apple, Villa Maria Estate and Pacific Pace.

3. Extend product lines

Product diversification is another objective for entering a strategic alliance. When a company rolls out a new product that carries slight differences from its existing product lines, it is part of a product line extension. Businesses with a successful product line in one arena can employ a product line extension to reach new geographic areas, appeal to different audiences or meet specific price points.

The collaboration between Doritos (who make tortilla chips) and Taco Bell (a fast-food chain) is a good example of this. They have a very similar target audience, but serve that audience in two different ways. By partnering they created one co-branded product named the Doritos Locos Taco. This is a taco with a shell made from Doritos chips. The result speaks for itself. In the first year that the Doritos Locos Taco was announced, over one billion units were sold and Taco Bell had to hire an additional 15,000 workers to keep up with demand.

Partners in a strategic alliance can help each other by providing access to resources, including personnel, finances and technology.

4. Access new technologies and knowledge

Partners will look to create an alliance to access technology or knowledge. Sharing skills, market knowledge, technical know-how and assets can mutually benefit both parties greater than attempting to do it alone.

An example of this is the strategic alliance launched in April 2011 between Microsoft Corporation and Toyota Motor Corp. This partnership was established to build a global platform for Toyota's next-generation telematics services using the Windows Azure platform. Telematics is the fusing of telecommunications and information technologies in vehicles, and it can encompass GPS systems, energy management and other multimedia technologies.

Toyota are reliant on Microsoft to provide the technology to be installed in their electric vehicles in the future. Microsoft benefits through extending its product line, delivering products and services into the automotive industry.

5. Sharing resources

Partners in a strategic alliance can help each other by providing access to resources, including personnel, finances and technology. This access to resources enables the partner to produce its products to a higher quality or in a more cost-efficient way than otherwise achieved alone.

The alliance between Starbucks and Barnes & Noble is a good example of pooling resources. Barnes & Noble has a retail presence in every state in the US, with over 600 bookstores, while Starbucks are large players in the coffee industry. This partnership resulted in in-house coffee shops within the bookstores, an alliance which allows both companies to do what they do best while sharing the costs of space.

What's the catch?

Yes, there is a catch. It is crucial to approach new alliance agreements with caution, as partnership management is not easy and case studies show high failure rates to support this concern.

Alliance Best Practice, a UK-based research and benchmarking firm, have research showing that 40% of alliances fail to comprehensively address commercial, strategic, operational, cultural and technical practices.

A survey conducted in 2001 by the consulting firm Accenture found that 50% of alliances drift into a suspended state of underperformance, while 20% are successful and 30% fail outright. Acknowledging this concern, the next step is to understand the cause of partnership failure. The three key areas are listed below:

1. Poor or damaged relationships
2. Poor strategy and business planning
3. Bad legal and financial terms and conditions.

On its own, poor or damaged relationships account for 52% of all failed alliances (see Figure 1). Together, poor business strategy and poor or damaged relationships account for a staggering 89% of them.

Does size and scale matter?

Well-managed small businesses have long proven themselves to be very adept at anticipating market trends, capitalising on new technologies, being innovative and using their lean structures to outpace larger players. They avoid multiple management layers and clunky processes – making them fast, responsive and nimble. However, small companies are also limited by certain realities that can be easily addressed by big firms, and these barriers are often highlighted if the small firm hopes to expand internationally.

A small business can quickly see the benefits of aligning with a larger business, but often the larger business does not have the same level of appetite or motivation. Alliances between large companies are still more prevalent, and many large firms continue to swallow up smaller enterprises via acquisition.

We are surrounded by examples of businesses in partnership today, all varying in size and scale. Regardless of scale, the same principles apply – you must understand what you can realistically offer and how this will directly impact the partnership's tangible and intangible objectives.

Terry Copeland, Federated Farmers CEO, notes that, 'It is difficult to have an alliance that delivers equal value to both partners. This is especially difficult in the short term compared to a long-term partnership. That is why it is important that the aims and goals of each partner are well aligned.'

Key actions

Strategic alliances can hugely benefit a business partner, achieving more than they could going in alone. Leaders and decision-makers are catching on, and the research from literature reviews supports this, showing that the use of business-to-business strategic alliances is increasing. The more complex and uncertain environments become, the more appealing a partnership becomes.

Doing your homework is required, and it is strongly recommend having a checklist or process in place, with particular attention to the three key areas listed below:

FOREMOST CAUSE OF PARTNERSHIP FAILURE

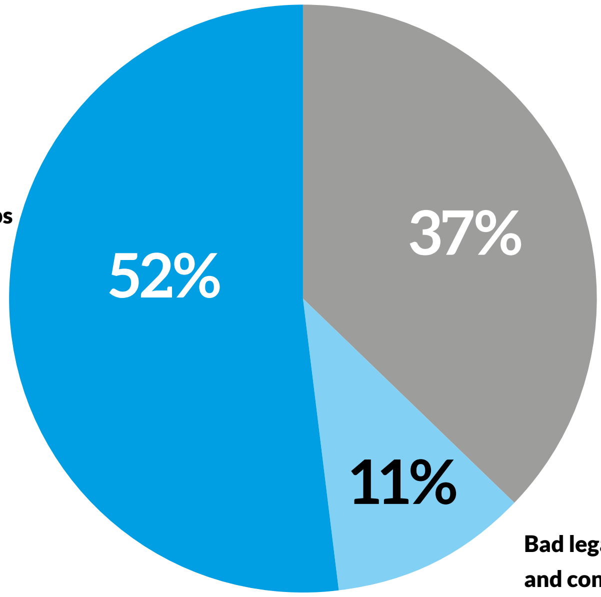

Figure 2: Distribution of all variable costs by season, OO only

One of the common mistakes businesses make when looking for possible partners is to consider only a few options instead of looking at the whole industry or outside the industry.

1. Getting the right partner

It all starts here. One of the common mistakes businesses make when looking for possible partners is to consider only a few options instead of looking at the whole industry or outside the industry. Companies should use a variety of mechanisms in their search for possible partnership opportunities.

2. Have real clarity about your purpose

You must have real clarity about your purpose for entering a strategic alliance. A clear objective is not to simply add value or to increase profit. The reason these are not objectives is they do not identify an action and they are hard to measure and track.

You must have clear and mutually understood objectives, and you need to understand your company's capabilities and what you can commit and contribute to as a partner. Honestly assess the strengths and weaknesses you bring to the table.

To adequately measure partnership success you need a measurement framework to generate a progress report. The measurement criteria can be whatever you think is important, but you must have a process in place that can track the relationship.

3. Have a sound business plan

You need a detailed business plan, which includes a flexible operating model. It needs to include the right team, as well as the governance and infrastructure to make the alliance work.

The reality is that ongoing success between partners doesn't just happen because you agreed on a good idea and signed a contract. Establishing a new partnership is only the beginning, To avoid it failing altogether, or to just maximise success, partners need to commit to and maintain the agreement. Once established, the focus then needs to be around ongoing maintenance. Maintenance will encompass communication, trust, teamwork, culture and resources.

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KEITH WOODFORD

This profile looks at the life and work of Keith Woodford, currently Professor of Agrifood Systems at Lincoln University.

Lincoln and Ministry of Agriculture

Keith Woodford was a city boy who yearned for the outdoors. When he completed secondary education at Wellington College in 1965 it therefore seemed natural to head to Canterbury and Lincoln College, not only to learn something about agriculture, but also to partake in mountain activities. The following four years were spent juggling lectures, farm practical work, climbing mountains and learning to ski.

On completing his B. Agr. Sci. degree in 1969, Keith joined the Ministry of Agriculture as a fresh-faced 22-year-old farm advisor, where he was tutored at Darfield by Les Bennetts. That was also when he first joined the New Zealand Society of Farm Management, which many years later became the New Zealand Institute of Primary Industry Management.

After 15 months at Darfield, Keith returned to Lincoln for an M. Agr. Sci. A key motivation for the move was that he figured that it would give more opportunities for mountaineering. Those were the days when study could be supported by no fees and good scholarships, with summer work at Mt Cook as an alpine guide providing additional funds plus adventure.

In 1973, Keith went back to the Ministry of Agriculture, this time based in Dunedin where he had a regional role across Otago specialising in agricultural economics. One

One of his more interesting projects was wrestling with the economics of apricot orcharding in Central Otago, where the best land was subsequently flooded by the Clyde Dam.

of his more interesting projects was wrestling with the economics of apricot orcharding in Central Otago, where the best land was subsequently flooded by the Clyde Dam.

South America and Nepal

By early 1974, the thirst for adventure was growing again, so Keith took off to South America for a year of mountain activities. This was combined with some exploring in the headwaters of the Amazon, and followed later by some disagreements with the authoritarian governments of both Argentina and Chile. The original destination was Peru with a group of eight mountaineers from New Zealand, Australia, Canada and England. This allowed them to take on the somewhat grandiose title of the '1974 Commonwealth Andean Expedition', but known more colloquially as BELCH, which stood for British Empire Large Climbing Herd. Later, Keith teamed with Kiwi Gary Ball for some wanderings in Tierra del Fuego, some virgin ascents in Patagonia, and a second ascent of the 7,000 m Aconcagua by the Polish Glacier Direct.

On returning to New Zealand, Keith worked for the Agricultural Economics Research Unit at Lincoln for two years before heading to Nepal as leader of the 1977 New Zealand Everest Expedition, this time as a party of seven Kiwis plus a Canadian to whom they gave honorary Kiwi status. They attempted Everest as a lightweight expedition using Sherpas only to Base Camp. The group failed to reach the summit but all returned alive. One of the climbing party was Catholic priest Mike Mahoney, but it is not clear whether his religious calling played a part in ensuring that they all returned safely. Two of that team subsequently went back to Everest and succeeded, including Nick Banks who was the second Kiwi to climb Everest, some 25 years after Ed Hillary. For many years Keith had thoughts of returning to Everest, but it did not happen.

Antarctica

In 1978, he took a position lecturing at Lincoln in the Farm Management Department, teaching techniques such as linear programming and investment appraisal to Agricultural Science and Agricultural Commerce students. Fortunately, both Barry Dent as Professor of Farm Management and Professor Jim Stewart as the boss at Lincoln were tolerant of Keith's non–scholastic interests and agreed to him taking four months of leave in 1979–80 to go to the Antarctic. This meant approval was also required for air transport to Antarctica of exam papers for marking.

In Antarctica, Keith together with colleagues Hugh Logan and Daryll Thompson, comprised a three–person team with responsibility for training scientists in Antarctica survival. They also assisted field parties in remote areas of the Antarctic, and carried out ground search and rescue for all Kiwis and Americans there. Keith and his two colleagues were therefore the first people onto the DC10 crash site on Mt Erebus to ascertain whether there were survivors, followed by crash site investigations and recovery operations working with investigators and police. Less than 24 hours after finally leaving the crash site, and following a desperately needed shower plus sleep, he was whisked some hundreds of kilometres by helicopter to more than 2,000 m up on the edge of the Polar Plateau for several weeks of geologising with two Australian geologists.

Fiji and Queensland

In 1982, Keith was seconded for a year to Fiji College of Agriculture and the Fiji Ministry of Agriculture as part of a long–term project there involving many of the Lincoln farm management lecturers. By then he was married to Annette, who spent the year in Fiji teaching at the International School in Suva.

The plan had been to return to Lincoln the following year, but in the meantime he was headhunted for a position as Principal Lecturer in Farm Management at Queensland Agricultural College (QAC). QAC was run by Mac Morrison, who had previously made his mark at Lincoln as Professor of Horticulture. Mac Morrison sought out various Lincoln staff who he thought could contribute in the Queensland environment.

So, with the Fiji experience having whetted Keith's interest for tropical agriculture and Annette's enthusiasm to try the Queensland sun–based lifestyle, the Woodfords headed across to Gatton, about 100 km west of Brisbane. This became their base for the next 18 years, with their two daughters Erin and Kiri born and brought up there. It was while based at Gatton that Keith came to understand that he was an explorer by nature, in both a physical and intellectual sense. Accordingly, he was interested in 'big picture' research, pushing back the boundaries rather than crossing the t's and dotting the i's within already dominant paradigms. For him it made life exciting, creating many friends, but also a few enemies along the way when people felt threatened by the prospect of new pathways.

In 1984, Keith received approval for a major project on one of the QAC farms. This included some horticulture plus arable crops, but most importantly from his perspective was the permission to establish deer herds (red, rusa and chital) and then subsequently blackbuck antelope. The aim was to figure out how to farm these animals in tropical and sub–tropical environments. He found this great fun, working both with the College herds and alongside commercial farmers. Much of the time they learnt by trial and error about what worked and didn't work, rather than from formal trials. This also led to international travel for deer and wildlife ranching conferences and some consultancy work in Asia.

Keith became increasingly involved in overseas rural development, often in countries coming out of war or other forms of turmoil. He travelled to more than 20 countries on work assignments during this time. The biggest was a project in Cambodia run by Australian Catholic Relief (ACR), but with support from the UN Development Programme (UNDP) and AusAID. Keith ran the education part of the project from Gatton and made about 20 visits to Cambodia between 1993 and 1999.

The 1990s were an interesting time as QAC was subsumed into the University of Queensland. By that time Keith had been Head of the Department of Management Studies for several years, which prior to the University of Queensland amalgamation had restructured as a School of Natural and Rural Systems Management. It took a few years for Queensland University to work out how to manage the Gatton team and during the interregnum they were able to create a strong transdisciplinary philosophy. Keith says it was a great mix, with farm management, agribusiness, conservation, ecology and rural extension all in together, trying to solve transdisciplinary problems of the 'real world'. He says that eventually Queensland University imposed its authority and they were restructured into component disciplinary parts.

Lincoln role

In 1999, Keith was approached as to whether he would apply for the position of Professor of Farm Management. He declined, because he did not think Lincoln at that time had figured out how farm management needed to link to both agribusiness and agricultural systems, with too many territorial issues. However, some months later he was asked again, with the position now restructured to include farm management and agribusiness, so he applied and was appointed.

Keith considers the first two decades of this century to have been challenging times for Lincoln. Initially, Lincoln was trying to figure out where as a university it fitted in the greater scheme of things, with much of the funding relating to commerce students, but with philosophical leanings to the primary industries. Also, at the internal level there were strong issues of territory, which became more intractable consequent to the new faculty structures of Commerce and Life Sciences introduced in 2004. This created challenges as to where farm management and

Colombian Highlands, South America in 2014 at guinea pig meal

agribusiness fitted. When he first came back to Lincoln, farm management and agribusiness were part of the Applied Management Division. Then they became part of the Agriculture and Life Sciences Faculty, and then they were shifted again, this time to the Commerce Faculty. Keith says the changes were imposed rather than sought by the group.

A key part of the challenge was that Lincoln's farm management strengths related to an integrative framework of problem solving, drawing on all the biological, physical and social sciences, plus economic, business and farming systems to pull it all together. Similarly, it is the biological context that gives agribusiness its unique characteristics which need to be understood. Keith observes that universities all over the world struggle with system–based problem–solving approaches within institutions in which specialised disciplinary expertise is the dominant paradigm.

Looking back at his Lincoln years, he takes some pride in the eventual introduction of the highly successful Bachelor of Agribusiness and Food Marketing degree in 2014 after more than 10 years of beavering away with colleagues to get the concept approved. He also takes considerable satisfaction from seeing many of his postgraduate students, both PhD and Masters graduates, now contributing across

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the world. During those Lincoln years, he also spent a satisfying decade on *The Journal* Editorial Committee for NZIPIM. Keith was made a Fellow of NZIPIM in 2012 in recognition of his contribution to the primary industry.

Recent work

Keith continued at Lincoln in his role as Professor of Farm Management and Agribusiness through to December 2014 when he decided it was time to move on. Since that time, he has kept busy through his own niche consulting company AgriFood Systems Ltd, but has retained an honorary position and an office at Lincoln as Professor of AgriFood Systems.

Keith continues to work on a range of consultancies, both in New Zealand and overseas. He writes articles on a fortnightly basis for *Farmers Weekly*, and also online at interest.co.nz. These can all be accessed at https://keithwoodford.wordpress.com.

Current consultancy projects relate to 'composting mootels' and 'composting shelters' and the associated farming systems, plus the health issues of food-derived opioids, including both A1 beta-casein and opioid peptides from gluten. He is also linked to A2 milk projects with various groups in New Zealand, Japan, Russia, Indonesia and Chile. This year he has also been involved in a meat industry modernisation project in Mongolia, that huge grassland and mountain country squeezed between Russia and China.

Keith says that, alas, his mountaineering days are now behind him. However, the boss at AgriFood Systems Ltd still gives him and Annette considerable time to ski each year (both in New Zealand and Canada), albeit somewhat constrained recently by COVID-19.

As for the future, Keith thinks that the pathway for New Zealand agriculture is both challenging and exciting. He believes that New Zealand cannot be prosperous without a prosperous agribusiness sector, but lots of transformation will be necessary. If starting out again, he would still head to agriculture and the outdoors.

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