Otago Regional Council & Industry Advisory Group

Otago's rural businesses and environmental actions for fresh water

Otago Regional Council

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Acknowledgements


Image 1: School bus shelter in Owaka Valley, Catlins.
Source: Emma Moran

All the farmers and growers who invested their time and supplied their data and knowledge, in some cases over several years.

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Reviewer: *Blair Keenan (Principal Economist, Waikato Regional Council)*

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Otago Regional Council Disclaimer: *This report was prepared as part of the process of developing the Land and Water Regional Plan. More specifically, the report will be used to inform the section 32 policy evaluation ORC is required to undertake to support the LWRP, but the report itself does not constitute that evaluation. Good management practices (GMPs) are complex and evolve over time. The suite of 'GMPs' and 'GMP+s' referred to in this report do not necessarily reflect those that may actually be required by the LWRP.*

Cover image: *A natural wetland area that is part of the Upper Taieri Scroll Plain. In this area seven hectares were fenced in spring 2022 and planted with natives.* ***Photo credit: Emma Crutchley.***
The upper reaches of the Taiari (Taieri) River provided an important travel way for mana whenua in the past, giving access to the rich mahika kai found inland. Mahika kai includes the species, places, practices, and knowledge associated with food and resource gathering, and is a significant source of identity for Kāi Tahu whānui. (Kate Timms-Dean, pers. comm., May 2023).

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The Industry Advisory Group

This report is the second of two main outputs from the Farmer and Grower Workstream within Otago Regional Council's Economic Work Programme – the first characterises farmers and growers in Otago and was completed in late 2022. To undertake the Farmer and Grower Workstream as robustly as possible, the Council formed a group of industry-good organisations in October 2021. These organisations are all actively involved in this work and collectively known as the Industry Advisory Group for the purposes of this work. The organisations and their representatives are as follows:

Beef + Lamb New Zealand (B+LNZ): Andrew Burtt (Chief Economist – Economic Service) and Jane Chrystal (Principal Science Advisor, Farm Systems & Environment – Economic Service)

Deer Industry New Zealand (DINZ): Tony Pearse (Producer Manager – retired) and Lindsay Fung (Producer Manager)

Foundation for Arable Research (FAR): Abie Horrocks (Research Manager - Environment)

DairyNZ: Carina Ross (Senior Regional Policy Advisor) and David Cooper (Principal Regional Policy Advisor)

Horticulture New Zealand (HortNZ): Leanne Roberts (Senior Environmental Policy Advisor)

Central Otago Wine Growers Association (COWA): Andy Wilkinson (Advocacy Lead / Owner and Director, Misha's Vineyard Wines)

Ministry for Primary Industries (MPI): Matthew Newman (Principal Economist, Farm Monitoring Team)

Executive Summary

Report Purpose and Scope

This is an in-depth economic[1] report that explores what environmental actions for fresh water may mean for rural businesses in Otago. In the context of the National Policy Statement for Freshwater Management 2020, the intent of the analysis is not to the weigh the impacts of change versus the status quo. Rather, it is to better understand how the impacts of change (that must happen) can occur as 'economically' as possible for individuals and communities. In this way, environmental issues are more likely to be resolved and reasonably foreseeable unintended consequences may be side-stepped. Ultimately, the 'system' we all live in is more balanced and resilient than otherwise may be the case.

Here rural businesses are those across the agriculture, horticulture, and viticulture sectors. Environmental actions are the avoidance, mitigation and remediation measures used to address water quantity issues (relating to how a waterway's flow reflects its natural behaviour) and/or water quality issues (concerning discharges of four priority contaminants: nitrogen, phosphorus, sediment, and micro-organisms as indicated by E. coli). The various tools or 'mechanisms' used to put each action in place are not considered, and nor is the success of their implementation. As a general rule, environmental actions rely on a set of non-regulatory mechanisms (e.g., education) and in some situations a form of regulation is needed as well.

The report's focus is the impacts of actions relevant to the development of the new Land and Water Regional Plan (LWRP), which is central to Otago Regional Council's (ORC) approach to implementing the National Policy Statement for Freshwater Management (NPS-FM) in this region. The actions relevant to the LWRP are those that may occur over the next ten years, rather than necessarily being those that may eventually be needed to achieve environmental outcomes. They are in addition to the actions stemming from recent policy changes that have already come into force but may not yet be fully in place on the ground, either through regional plan changes or national regulations.

In essence, this report is a series of research outputs by industry-good groups. The main body of this report is divided into six industry-specific chapters. Each output is based on a set of rural businesses in Otago using industry data sources developed either as part of the Ministry for Primary Industries (MPI) Farm Monitoring and Benchmarking Programme or an additional project funded by MPI and/or ORC. The report is the third output from ORC's Economic Work Programme and follows and draws from Report 1: *Farmers and Growers in Otago* and Report 2: *Otago Catchment Stories Summary Report*[2]. Reports 1 and 3 should be viewed as two halves of a whole. Together they represent a considerable investment in rural businesses in relation to freshwater management by all parties involved.

The general approach was that each industry group undertook responsibility for their own research (i.e., the modelling, analysis, and reporting) within a robust editorial process. Each industry group had different resources to draw on and ORC along with the Ministry for Primary Industries (MPI) supported their efforts as requested. Within the needs of the council, each industry group had the latitude to develop their own methodology tailored to suit the nature of their farmers or growers' businesses. This flexibility was more important than trying to achieve consistency because what made sense for one industry was, at times, an unnecessary constraint for the next.

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1 Here 'economics' is used in its fullest sense, across human, natural, built, and financial capitals. Economics is essentially the study of utility (use and non-use value) and differs from 'chrematistics', which is the study of wealth or exchange-value (i.e., money). In economics, an environmental effect is an 'externality' from activity and needs to be accounted for in calculations of efficiency.

2 An overview of ORC's Economic Work Programme is available on the council website. A brief description of the full set of reports in the Economic Work Programme was included in Report 1: *Farmers and Growers in Otago.*

The research is an application of microeconomics, which is economic analysis at the scale of the firm or individual. The quality of any analysis is reliant on the robustness of the data. In this case, there was the opportunity to use datasets for real farms and growing operations in Otago collected through the MPI Farm Monitoring and Benchmarking Programme. The main modelling tools used were FARMAX for pastoral farm systems (sheep and beef, deer, arable, and dairy), Excel spreadsheet analysis for viticulture and horticulture (orchards and vegetables), and to a lesser extent Overseer. Although Overseer modelling is valuable in economic analysis, it had a lower priority in the scope of this research (for reasons that are explained within this report).

Much of the research contained in this report was, by necessity, undertaken slightly ahead of policy development for the new LWRP. Consequently, the environmental actions tested in this report, while relevant (in one way or another) to freshwater management in Otago, will not necessarily be included in the proposed LWRP when it is notified in June 2024. Many of the environmental actions tested are also likely to be relevant to certified and audited Freshwater Farm Plans in the future. This research may become a useful resource for that process. Figure 1 shows, conceptually, the relationships between environmental actions tested for this report, those that will eventually be included in the new LWRP and/or audited Freshwater Farm Plans. The extent of overlap will depend on the development of the LWRP and its relationship with Freshwater Farm Plans.

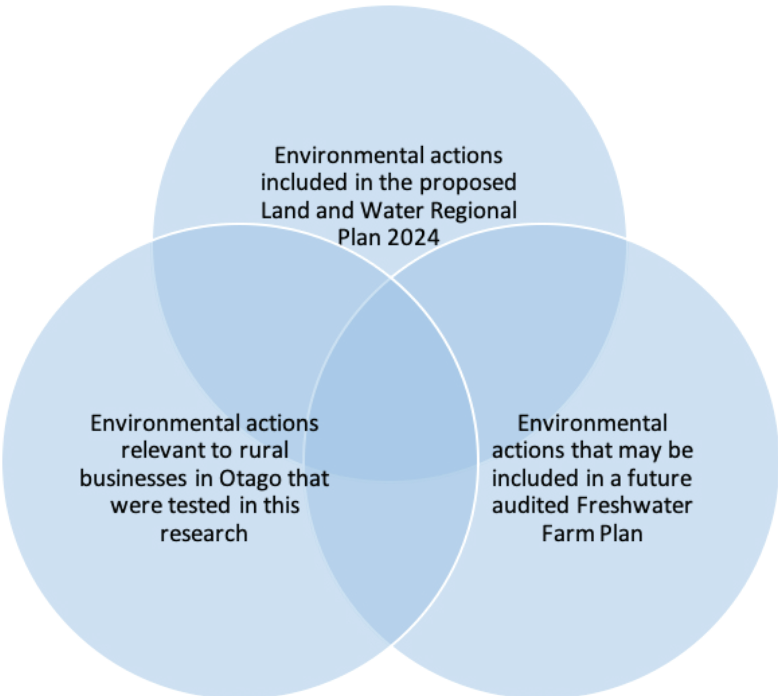

Figure 1: Conceptual relationships between environmental actions, the new LWRP, and Freshwater Farm Plans

Research Findings

The topics covered by the environmental actions tested in this research and a brief summary of the main research findings are included in Table 1. A more comprehensive summary of the industry-specific research is included at the start of each chapter and each chapter ends with an overview of the research findings. However, most of the understanding offered by this research is contained in the main body of each chapter. The length of this report is purely a reflection of the complexity of the subject, which is often underestimated, and it highlights the importance of understanding what we are managing in finding robust solutions.

Table 1: Summary of research findings for 56 rural businesses

Industry	Research	Topics covered by environmental actions	Summary of main research findings
Sheep and beef farms	16 case studies from a sample of 41 farms, which are also reported. The sample size is roughly 4.5% of the commercial sheep and beef farms in Otago.	Phosphorus fertiliser Waterway protection Biodiversity Irrigation Nitrogen fertiliser Tussock lands Farm system change	Almost all 41 Otago sheep and beef farms had a mixed topography of flat, rolling, and steep land, although the share of steep land varied. They also differed in size and access to water for pasture and crops (either as precipitation or irrigation). Most farms were generally low-input and low-intensity, and defining good management practices was only practical on a case-by-case basis. The environmental actions tested were based on potential risk. The main finding of this research was the disparate responses across farms to an environmental action. The same environmental action implemented on all farms, for which it was relevant, had a broad range of impacts and effectiveness. Some farms had less than a 1% reduction in profitability whilst others became financially unviable when the same environmental action was tested on them. Some actions tested had limited relevance and so are unlikely to be effective at scale (only 1 of 16 case study farms had suitable conditions for using RPR and its soil Olsen P level was 25). Actions resulting in removal of large areas of land from livestock farming, altered stock numbers, or the balance of sheep to cattle had the greatest impacts, particularly on larger farms with lower stocking rates. Reducing stocking rates on a drystock farm is impactful because a farm's livestock are its product (confirming earlier research for Southland). Sheep and beef farmers aim to match feed demand from livestock with supply of pasture (i.e., "farming to the grass curve"), with minimal inputs of nitrogen fertiliser, irrigation, and supplementary feed imported onto the farm. It was found that tailoring environmental actions to the individual farm (e.g., using an environmental farm plan tool) was an efficient way to contribute to environmental outcomes.
Deer farms	5 case studies from a sample of 17 farms, which are also reported. The sample size is roughly 8.5% of the deer farms in Otago.	Stock exclusion from gullies Wintering sheds Irrigation Intensive winter grazing Farm system change	Regular water quality tests and management options that include periodic exclusions are likely to provide the better outcomes in hill blocks that are very lightly stocked and in low rainfall areas compared with generic regulations. Wintering sheds are expensive to build but provide benefits for animal welfare and the improved condition of paddocks. They appear to be financially better for stags compared with hinds, based on both the high returns for velvet antler and the relocation of large mature stags off farm into sheds reducing environmental overwintering risks. The deer industry is particularly vulnerable to adaptive changes because relatively small numbers are run on many farms where expensive deer fencing is already in place. Where compliance requires an exclusion or shift, extra capital fencing costs are high. For farmers running multiple enterprises and stock classes, exiting deer altogether is a possible outcome. Breeding hind numbers are already under pressure as farmers consider the implications of meeting national stock exclusion regulations (rather than using targeted environmental actions that are better suited to deer farming).

Table 1: Summary of research findings for 56 rural businesses

Industry	Research	Topics covered by environmental actions	Summary of main research findings
Arable farms	4 case studies from a sample of 16 farms, which are also reported. The sample size is roughly 16% of the arable farms in Otago.	Nitrogen fertiliser Riparian fencing and critical source areas Variable rate fertiliser Intensive winter grazing	Otago's mixed arable farms tend to have extremely complex and flexible productions systems. The main finding was that matching the nature of these systems with a flexible approach to environmental actions (based on a risk assessment that fits actions to risks) had fewer impacts on the farm business than a fixed approach because it offered opportunities to customise those actions to the farming context. Crop rotations are unique to each farm and how they are utilised as a management tool (for both environmental and agronomic gains) varies from farm to farm. The benefits of robust risk assessments are that actions will be more effective in contributing to desired environmental outcomes than those not based on risk. In terms of impacts a fixed approach for overland flow on a case study farm resulted in a 10.8 per cent reduction in EBITR while a flexible approach resulted in a 3.5 per cent reduction in EBITR. As another example, a fixed approach for winter grazing for another case study farms showed a 35.7 per cent reduction in EBITR and the flexible approach meant a 3.5 per cent reduction in EBITR. These ratios will differ depending on the business in question. The impact of variable rate fertiliser capability was also shown to vary depending on economies of scale.
Dairy farms	10 case studies representing three dairying areas of Otago. The sample size is roughly 2.3% of the dairy farms in Otago.	Nitrogen use efficiency Phosphorus fertiliser Effluent management Irrigation Cropping (intensive winter grazing) Wintering barns Farm system change	Dairy farming characteristics vary across Otago, with the highest number of dairy cows and largest area of dairy land in the Clutha district. Waitaki and Central Otago districts have larger herd sizes and Waitaki the highest stocking rate, probably reflecting the use of irrigation on farms. The case study farms were selected to represent a spread of different variables: locations, soils, irrigation types, farm production systems and profitability. The modelling using case study farms tested the economic implications of achieving Good Management Practice (GMP) and environmental actions beyond GMP, so called GMP+. The key findings from this research are: - GMP leads to small profit and nitrogen leaching reductions, reflecting the farm's starting point. - Large nitrogen leaching reductions are costly since they can mainly be achieved with infrastructure changes e.g., baleage wintering, irrigation equipment upgrade and wintering barns (GMP+). The cost increase cannot be offset by increase in production if it increases GHG emissions (i.e., a pollution swap). - Using plantain pasture is cost effective but more research specific to Otago is needed to be sure its use as an environmental action is practically feasible for dairy farms in the region. - In some cases, nitrogen leaching is driven more by soil type and rainfall than on-farm N- use efficiency.

Table 1: Summary of research findings for 56 rural businesses

Industry	Research	Topics covered by environmental actions	Summary of main research findings
Commercial orchard and vegetable production	5 representative models based on 14 in-depth grower surveys. The 14 operations are a cross-section of crops grown and range of property and business sizes in Otago for each growing system (pipfruit, summerfruit and vegetables).	Good Management Practice + Reduction in fertiliser use and irrigation water availability Short vs long-term consents Provision of root stock survival water Innovations	Most surveyed growers are achieving good management practice at a minimum for irrigation and nutrient management. Representative financial models were constructed for outdoor vegetables and orcharding in Otago (based on production, revenue and financial performance) and used to a range of additional environmental actions. Each subsector has a different risk profile, and their profile influences the ways they assess and manage risk. For example, vegetable production involves a crop rotation on a single block of land, and across non-contiguous (owned and leased) fertile blocks in an FMU. Flexibility in response to changes in risk is crucial for growers to remain agile. To be profitable, growers need security and reliability of access to water for production and processing (washing) produce for market. In particular, water at specific times in the crop growth cycle is needed to achieve a 'marketable yield'. Restrictions in access to irrigation water cause a reduction in yield and a substantial loss in financial performance. Without rootstock survival water for orchards, the financial impacts ranged from 52 to 63 per cent reduction in net present value depending on fruit variety. Developing or purchasing horticultural operations is usually a large investment, and relatively large annual requirements to maintain that investment. Consent duration influences producer confidence, and the ability to invest in infrastructure, technology and innovations to improve productive efficiency.
Vineyards	3 representative models based on 7 growers. The sample size is roughly 3.2% of the vineyards in Otago.	Nutrient losses Reducing consented water Restrictions on access to frost protection Surety of consent conditions	The research undertaken identified three distinct economic models based on the size of vineyards. Otago has a prevalence of small and medium vineyards with limited capital and resilience to withstand fluctuations in vine yields. With yields directly related to irrigation and the ability to fight frost, the supply and surety of fresh water are challenging issues for the continued operations or future development of winegrowing in Otago. The nutrient losses and pollution risk from vineyards in general across New Zealand is very low, therefore the research focused on water quantity as the main economic concern for the sector. The research results indicate a considerable economic risk to winegrowers of restricted access to freshwater for irrigation and frost fighting, and short tenure of consents for freshwater. Central Otago has 234 vineyards, mostly small and family owned where the operating margins are small, returns low and reserves are limited. The economic and social impact of lower yields, crop loss or vine failure is high, even in a single year.

Note: The case studies (agriculture) and growing operations used in representative models (horticulture and viticulture) were specifically selected (i.e., not random) to cover the range of production systems that typifies each industry. Some of the sample sizes are sufficiently large to be statistically significant.

Research Themes

It has long been recognised that policy to manage fresh water in a region has considerable potential to impact rural businesses and other users of natural resources. They are, in essence, the 'receiving environments' for policy (to use a term from science). Impacts occur because policy, by design, acts to change people's use of water and the land it flows through (water and land are forms of 'natural capital'). Here the use of water captures water takes for a range of activities (e.g., for stock drinking water, storage, irrigation, wash down processes) and to absorb and/or transport waste (e.g., excess nutrients and sediment) from those or other activities. Three main themes relating to impacts were evident across the research for rural businesses in Otago:

1. A need to look beyond profitability;
2. Diversity in production systems and its implications; and
3. Showing progress and giving priorities.

Looking beyond operating profit

The basic purpose of a business is to be profitable. A business' profitability depends on its capacity to both earn revenue and limit expenditure, which stems from how the business uses its different forms of 'capital' (e.g., human, natural, built). In this report, the primary impact reported is the change in operating profit, measured using 'earnings before interest, tax, and rent' (EBITR). As the results still include the costs of land (interest and rent) and other considerations, they are not equivalent to the business owner's income. Profitability (including expectations of future profitability) is central to the market price of land and strongly influences a business owner's ability to use debt as a business management tool[3].

Most rural businesses (like those in the rest of the economy) were not originally set up to fully account for their 'use' of water within their production systems. Therefore, environmental actions that effectively constrain their use of natural capital tend to change their profitability by altering a business's revenue and/or its expenditure. Many impacts tend to occur through a transition phase, which may last for some time (e.g., the impacts of economic restructuring during the 1980s are still being felt). In some cases, actions also involve more investment in built capital (e.g., infrastructure, machinery, earthworks) at a scale that means borrowing, which in turn means improving profitability via further changes to the production system (e.g., higher intensity activities may be needed to justify investment in more efficient irrigation). Capital investment has a limited life span and is an ongoing expense, as indicated by depreciation as well as repairs and maintenance.

Changes in profitability are a useful indicator of the level of adjustment needed for a production system when putting in place a specific environmental action (or actions). However, profitability does not in itself fully capture the impacts for a business because there are many considerations or limiting factors (e.g., a business owner's skills and career stage, pasture or crop management). For example, constraining cattle or deer enterprises within a farm may lead to poor pasture management, breeding and growth

3 The tension between the stewardship of fresh water and a farm's financial position, particularly in relation to farm debt and land values, is of real concern for communities in regions around New Zealand. While farm debt is important in the context of freshwater management, the topic is complex, and our joint knowledge is limited. To shed some light, Environment Southland set up a research project in 2021 that centred on a panel of local experts, known as the Farm Debt Working Group, supported by a technical team of representatives from industry-good groups. The Farm Debt Working Group was comprised of seven professionals from agri-finance, agri-business, accountancy, land valuation, and rural support services. Collectively, they held just over 200 years' experience in their respective industries, almost all of which has been living and/or working in the south. The main output from this project is a report titled *Farm Debt, Farm Viability and Freshwater Management in Pastoral Southland* (Moran, McDonald, & McKay, 2022).

performance, livestock health over time, and increase workload. Conversely, a deer wintering shed or a dairy wintering barn may ultimately improve livestock health and the ability to retain labour. Changes in winter crop area affect the winter / summer feed balance on an arable farm or it may push the activity to areas less environmentally suitable (e.g., from slopes to heavy lowland soils). Insufficient water for perennial crops can threaten root stock survival. Where a business relies on leased land some actions may be beyond the control of the farmer or grower. Sediment is the loss of topsoil, which is a non-renewable resource.

Overall, the greatest impacts can be expected to occur when a rural business is unable to adjust to change, for whatever reason. The enterprises and production systems most at risk will vary by environmental action (type and magnitude) and a business' location. Examples of situations with elevated risk include (but are not limited to) deer enterprises within a drystock farm, seed production and winter forage crops on arable farms, sheep and beef farms with large cattle enterprises, small sheep and beef finishing farms, farms with border dyke irrigation, vegetable growers, and smaller vineyards – and any business without reliable access to water. This risk may flow through the value chain. For example, cropping supports many industries and was a key difference between farming and grazing in the 19th Century[4]. The scale of a rural business is influential in determining impacts at either end of the spectrum (i.e., small and large rural businesses). Over time the impacts may be a factor in the changing scale of rural businesses.

Consequences of diversity

Farmers and growers manage living production systems with all their vagaries and complexity. These systems are site-specific (i.e., tied to land and water where they are located) and operate as a whole (i.e., there is connectivity between all parts, whether actively managed or not). Consequently, each rural business has a unique combination of attributes, from location, soil types, topography, and microclimates, through to its production system (past and present). These attributes include the skill sets and other resources available to the business owner/manager – whether a farmer or a grower. The productive efficiency of each business depends on its mix of attributes (i.e., it is context-specific), including any externalities it may create.

In terms of characterising rural businesses, the most that can be said is that a production system is fairly typical of others in an industry for a particular locality. While averages can be calculated for individual attributes, to refer to 'average farms' or 'average growing operations' misrepresents reality because each system is a unique set of attributes. The diversity in production systems within an industry in Otago means the impacts of many environmental actions will vary strongly between businesses, as well as industries – confirming the findings of similar research in Southland (Moran (2017). In other words, diversity results in a discordant pattern of distributional impacts across the landscape.

Examples of actions that this variability of impacts applies to include (but are not limited to) irrigation, stock exclusion, riparian management, management of critical source areas, stocking rates, and feed pads. In the case of stocking rates, critical considerations are the level that is needed for efficient pasture management and the relationship with production, which varies between industries.

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4 The use of forage and fodder crops to 'carry' livestock over winter has its origins in Victorian 'high farming' (Horrocks, 2022, p. 111).

In Otago there is a considerable proportion of land in higher Land Use Capability Classes and consequently the usual delineation between what is ‘grazeable’ and ‘non-grazeable’ areas in pastoral systems is often blurred. This type of land also has fewer alternative land use options. The form of irrigation that is technically efficient can depend on the nature of a production system. Impacts occur where efficiency in the use of irrigation water and efficiency in the use of all resources in a production system do not align easily.

Where a resource user puts in place an environmental action that successfully contributes to managing a freshwater issue while minimising impacts then they are, in effect, internalising the ‘environmental externalities’ of the resource use. The result is a fuller or more complete accounting of productive efficiency. In this situation, the impact of the action is more akin to the end of a benefit that had previously been experienced than the imposition of a cost.

However, when the actions to be put in place are based on ‘averages' there can be a disconnect between resource use and a freshwater issue. An example for rural businesses is riparian planting in drier parts of Otago where both overland flow containing contaminants and access to water for plant survival is limited. In such circumstances, the impacts on the resource user may be either less or more than what is needed to manage a freshwater issue. Both circumstances are inefficient and create risks environmentally. Unintended consequences inevitably arise, highlighting the need to consider how land users will change their behaviour. The diversity in farms and growing operations means there may be more risk of such a disconnect in Otago than elsewhere.

The variability in impacts means it is not possible to scale-up to a district or regional economy in any meaningful way without a more complete understanding of the total population of rural businesses. This said, it is clear from this research that certain types of rural businesses may be particularly vulnerable, which additionally will flow through to others because the high level of diversity means some rural businesses are more limited than others and there can be strong interconnections between production systems (e.g., the breeding and finishing of livestock) (Moran, 2022).

Progress, priorities and planning

The need to better manage our activities that use fresh water, either as takes or to receive waste, is not new and is becoming more urgent as the impacts of climate change gather pace. The additional environmental actions in the new LWRP will be the latest step in a societal process that has now been playing out since at least the 1970s (e.g., Knight, 2017, p. 324), and they are unlikely to be the last. This process is, in effect, a continuous adaptation to an evolving operating environment.

The impacts on rural businesses of additional environmental actions for fresh water will be influenced by the impacts of actions to meet recent policy changes. Where farmers and growers have put in place actions to meet recent policy changes some of these impacts are already occurring. However, some farmers and growers still have work to do – either because they are not yet in a position to initiate it (for whatever reason) or because their ‘to do’ list is longer than others (e.g., they may have a higher proportion of waterways per hectare). This situation is likely to be exacerbated with any requirement for additional actions, which may be overwhelming for some. Although this research largely tested individual actions (rather than mixes of actions), there were some businesses for which multiple environmental actions were relevant while for some businesses a specific single action was a major change.

In some cases, there were obvious interconnections between actions (e.g., irrigation and nitrogen losses) and in other cases there were potential conflicts (e.g., irrigation and stock exclusion of deer), which is another potential cause of unintended consequences. The way that all impacts play out depends in part on how they are implemented, which influences the level of community support (Moran, McDonald, & McKay, 2022). Where the 'to do' list is long, the impacts may be minimised by giving farmers and growers priorities in return for showing progress in a timely manner. While there are always lessons to be learned from elsewhere, 'economical' environmental actions can also come from local grass roots where they are specifically tailored to fit a rural business. The impacts also highlight the importance of connecting farm plans to farm budgets.

Image 2: Winter grazing trials, Waitahuna, showing a critical source area uncultivated and ungrazed with a water monitoring station.
Source: Craig Simpson, Watershed Solutions

Limitations and Assumptions

The main constraint on this type of research is always the sheer scale of effort needed to survey sufficient rural businesses and test and analyse a comprehensive set of environmental actions, which demonstrates the complexity and diversity of the businesses and the 'environments' in which they operate. Generally, conducting a case study or developing and testing a representative model is the equivalent of at least a fortnight's work (if not more) from data collection through to reporting. The effort needed for each case study (agriculture) or model (horticulture and viticulture) meant it was not practical to cover the full diversity and complexity of farming across Otago. The 56 farms and growing operations in this report form a robust dataset but obviously do not reflect every rural business in Otago.

Although understanding their respective industry is each industry group's 'bread and butter', they all had different mixes of resources and tools to draw on – whether it was specialist expertise, local knowledge, or existing databases. In particular, Central Otago Winegrowers Association and the fruit and vegetable product groups operate on a voluntary basis even though they are supported by national organisations. At times this research had to accommodate bottlenecks within an industry, such as during harvest, Covid-19, and responses to adverse weather events (e.g., Cyclone Gabrielle).

The research of this scale would not have been possible without the existing MPI Farm Monitoring and Benchmarking Programme and ORC's additional support. It also benefitted from the existing capacity within some industry groups, particularly B+LNZ's Economic Service (and its Sheep and Beef Farm Survey), DairyNZ's DairyBase (including the Baseline Project) and Sustainable Winegrowing New Zealand. Equally important was the Industry Advisory Group, which was a collaborative process of technical expertise through which this research has occurred.

By necessity, the testing of environmental actions assumes rural businesses have full information. This assumption means that this research does not consider ORC's implementation process for the LWRP, including how it is communicated to resource users. This limitation, in addition to not considering the 'mechanisms' (e.g., peer support, written guidance, regulation) that put each action in place, will influence the actual impacts of environmental actions. In other words, the impacts also depend on ORC's choice of mechanisms and their implementation process, including communication and different types of support. Here, relevant considerations go beyond productive efficiency to both allocative and dynamic efficiency, particularly in relation to the timeframes and the tension between public and private costs.

This research primarily focused on efficiency of environmental actions rather than their effectiveness, the latter being more of a question for scientific research. However, some of the results of this research highlights that the two concepts are inextricably linked. For example, if the impacts of an environmental action are more than necessary to manage a freshwater issue then there may be less support for such an action 'on the ground'. In some cases, the extra impacts may unnecessarily limit the use of that action or other actions, and so change the overall calculus of effectiveness. To illustrate the point, requiring breeding hinds to be excluded from gullies meant the actual response was to remove hinds from the farm system because such gullies provide shelter during fawning – so the action may be effective but not in the way intended. Similarly, constraints on the efficiency of implementing an action may limit its effectiveness, such as with dissolved reactive phosphate (RPR). Further, if an action's effectiveness is less than what is needed to manage risk then it may be economically inefficient when externalities are considered. This is an important topic for further research.

Research of this type is often constrained by the ability of any computer software programme to accurately represent all farms and environmental actions. To a certain extent this limitation is unavoidable because no software can perfectly reflect reality. The research addressed this limitation in part by not confining the research to the set of environmental actions that were able to be successfully modelled in the Overseer software that was used. The environmental actions tested were still limited by modelling practicalities. For example, analysing constructed wetlands tends to need a lot of site specific information. Industry groups focused their efforts on some actions ahead of others (e.g., improving water use for irrigation was a focus rather than reducing water takes).

This research was undertaken to create a farm and grower dataset for Otago. As it stands, the dataset is a snapshot of the 2020-21 production year. It does not consider how farmers and growers will need to adapt over time, including implementation rates and adoption rates, particularly as climate change gathers pace. Nor does it reflect any technological change and new opportunities that will arise as Otago and other regions implement the National Policy Statement for Freshwater Management (2020). Consequently, care needs to be taken when interpreting the research.

Contents

A note on language: the terms 'effects' and 'impacts' are often used interchangeably. In this report, 'effects' is used to describe the changes in the environment that are caused by an economic activity; while 'impacts' is used to portray the socio-economic changes for individuals and communities that are result from managing the economic activity and/or its effects. Put simply, an economic activity can have effects on the environment and when an activity is managed for those effects it has impacts. Whether 'effects' and 'impacts' are positive or negative can be a matter of perspective. Also, 'effects' and 'impacts' do not usually occur in isolation, i.e., environmental effects can have socio-economic impacts and vice versa.

1 Introduction

Author: *Emma Moran (EM Consulting)*

Sufficient, clean fresh water is critical for life. Fresh water is also in finite supply. Never is this more evident than during a prolonged drought or when water is unsafe for drinking. Even in more settled times, the capacity of water to support life can be put under pressure as our demand for water outstrips its supply within a catchment. As this occurs, the 'system' that we all live in becomes increasingly out of kilter (i.e., it is not in balance or tending towards an equilibrium).

In addition to fresh water being critical for life and finite, it is also apparent that we manage our activities and their effects within the natural world, rather than being able to manage nature itself. The natural world is far bigger than the economy that sits within it and is dependent upon it. The tension is not between the economy and the environment, it is the quality of life we want now compared to later as we increasingly face the reality of having to live within our means. Recognition of these relationships is seen by some as being good for business, at least in the longer term[5], and is increasingly being reflected in environmental policy. It may be the latest chapter of what economist and historian Brian Easton recently described as New Zealand's history of attempting to improve its economic resilience (Easton, 2023: p. 8).

Image 3: Lake Wanaka, Queenstown Lakes District.
Source: Simon Moran

5 For example, the global trend for corporations to develop 'Environment, Social, and (Corporate) Governance' policies.

In the rural landscape, some of our 'demand' for fresh water comes from its use by businesses as an input in living production systems[6] for such things as stock drinking water, the irrigation of pasture and crops, and wash down processes. More 'demand' for water (even if unintentional) comes when we use it to absorb and/or transport waste from these production systems, such as excess nutrients, sediment, and microbes (as indicated by *E. coli*). Yet most rural businesses (like those in the rest of the economy) were not originally set up to fully account for their 'use' of water within their production systems (Moran, 2017; Moran, 2022)[7]. In other words, any assessment of their efficiency in producing products is, at best, only a partial view. However, a fuller accounting of productive efficiency is relevant to the efficient allocation of resources over time, and so sustainability.

This situation currently benefits (at least in the short-term) farmers and growers, as well as everyone else in their value chains, including the final consumers of their products in both domestic and export markets (Moran, 2017). However, where there is a gap between a catchment's demand for fresh water and its supply then it can also create adverse environmental effects[8] and impacts for local communities. Increasingly, such 'gaps' are being addressed by the adoption of environmental actions. These actions are intended to improve our water 'use' – either as an input or to receive waste products – and so dampen demand for it as a resource. The impacts of this change in situation tend to be borne by farmers and growers within their businesses because they usually have little influence to pass them on in the prices of their products.

Image 4: Arid conditions surrounding Butchers Dam, Central Otago District.
Source: Simon Moran

6 Farms and growing operations are not the only production systems in the rural landscape and were not the first. Other production systems occur in non-developed land, such as include mahinga kai in wetlands and manuka honey. An Otago example is Sinclair wetlands: Te Nukuroa o Matamata. https://www.tenohoaka.org.nz/get-involved/activities/

7 Although water is essential to production systems its value is not part of the calculus of a business' viability (i.e., there is no fee for the resource itself) even though some businesses pay considerable costs for its supply.

8 In economics, an environmental effect is a type of 'externality'. Dasgupta (2021, p. 189) describes externalities as "the unaccounted-for consequences for others, including future people, of actions taken by one or more persons. The qualifier 'unaccounted-for' means that the consequences in question follow without prior engagement with those who are affected." It is common to read externalities as market failure but that is merely to reword 'externalities'. Dasgupta contrasts two types of externalities: unidirectional and reciprocal. Ribaudo et al., (1998) point out that externalities exist when some of the consequences of production (e.g., pollution imposing costs on others) are not considered when production decisions are made. The result is a misallocation of resources from society's perspective.

1.1 Rural businesses in Otago

Rural businesses in Otago are influenced by the nature of the landscape, climate and soils, which marks the region out from the rest of New Zealand (Moran, 2022). Otago is dominated by strong metamorphic geology, which influences its topography, altitude and climate. Importantly, it has limited rainfall (away from the Southern Alps and the Catlins) and limited flat land. The differing combinations or mixes of characteristics in each locality create the patterns of land uses across the region, and the variable texture to the production systems within each land use, down to a property-scale. It is these differing mixes of characteristics, as well as the region's scale, that help make farming and growing in Otago diverse.

This section compares the eight Land Use Capability (LUC) Classes[9] in Otago with the four other regions with the most rural developed land in New Zealand: Canterbury, Waikato, Manawatu-Whanganui, and Southland[10]. The five regions also have large populations of rural businesses, which influences diversity in production systems. For the purposes of this analysis, rural developed land is that identified as grazed pastoral, cropping, orchards and vineyards from the New Zealand Land Use Map (source LUCAS)[11], and excludes urban land, forestry and conservation estate. However, for completeness, forestry land is included in the map in Figure 2 even though it is not a focus of this report.

The Land Use Capability System assesses the land's capability for sustained primary production, while taking into account its physical limitations and its versatility (Lynn, Manderson, Page, Harmsworth, Eyles, Douglas, MacKay, & Newsome, 2009). These limitations include susceptibility to erosion, steepness of slope, climate, susceptibility to flooding, liability to wetness or drought, salinity, and depth, texture, structure and nutrient supply of the soil.

> *LUC Classes 1 to 4 are suitable for arable cropping (including vegetable cropping), horticultural (including vineyards and berry fields), pastoral grazing, tree crop or production forestry use. Classes 5 to 7 are not suitable for arable cropping but are suitable for pastoral grazing, tree crop or production forestry use, and in some cases vineyards and berry fields. The limitations to use reach a maximum with LUC Class 8. Class 8 land is unsuitable for grazing or production forestry, and is best managed for catchment protection and/or conservation or biodiversity.*
>
> ***Lynn et. al. (2009: p9)***

While the analysis here focuses on the eight main LUC Classes, the LUC subclasses (Level 2) provide more information on the limitations of the landscape. The limitations considered in the LUC include susceptibility to erosion, steepness of slope, climate, susceptibility to flooding, liability to wetness or drought, salinity, and depth, texture, structure and nutrient supply of the soil. Importantly in the context of this report, limitations may be seasonal in effect, such as snow cover and seasonal waterlogging in some soils while others are limiting all year round (slope, soil depth, and stoniness). The third level of the classification is about the severity of the limitations identified at Level 2.

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9 The Land Use Capability (LUC) system has been used in New Zealand since 1952. The system has two key components: 1) a Land Resource Inventory is compiled as an assessment of physical factors considered to be critical for long-term land use and management, and 2) the inventory is used for LUC Classification, whereby land is categorised into eight classes according to its long-term capability to sustain one or more productive uses. The Land Use Capability Survey Handbook was first produced in 1969 and was prepared to provide national standards, which were used at the time as the basis for central government's financial assistance to farmers for erosion control works. *https://www.tupu.nz/media/jzbjrpy4/land-use-capability-luc-survey-handbook-3rd-edition.pdf*

10 The area of farmland in each of these five regions is over 1 million hectares. Bay of Plenty and Northland also have relatively large populations of farms but smaller area of farmland (*https://www.stats.govt.nz/indicators/farm-numbers-and-size*).

11 *https://environment.govt.nz/facts-and-science/science-and-data/new-zealand-land-use-map/*

The analysis of rural developed land (excluding forestry) shows the limitations in Otago in comparison to the other four regions (Figures 3 and 4). Just 2.4 per cent of rural land in Otago (less than 4,600 km^2) is highly versatile land, being classified as LUC Classes 1 and 2 land. In other words, proportionally fewer rural businesses in Otago occur on LUC Classes 1 and 2 land than in any of the four other regions. The more versatile rural land in Otago is typically LUC Classes 3 and 4 (rather than LUC Classes 1 and 2), which has some biophysical limitations for arable cropping and, to a lesser extent, pastoral grazing. By comparison, the range in share of rural land classified as LUC Classes 1 and 2 in the other four regions is between 11 per cent and 21 per cent (average just under 22,800 km^2).

At the other end of the classification scale, more than 60 per cent of the rural land in Otago is classified as LUC Classes 6-8 (just over 117,000 km^2). This share is proportionally similar to Manawatu-Whanganui and the extent is second only to Canterbury, which has 126,000 km^2. In contrast to Otago, Southland stands out with just over one-quarter of its rural land in LUC Classes 6-8. Both Southland and Waikato have relatively small shares of LUC 7 and 8 land (roughly 6% for both regions), while the share is sizeable in Otago (27%).

Image 5: Looking north from the Whale Fossil Lockout towards Lake Waihola and Sinclair Wetlands on the lower Taieri. Source: Emma Moran

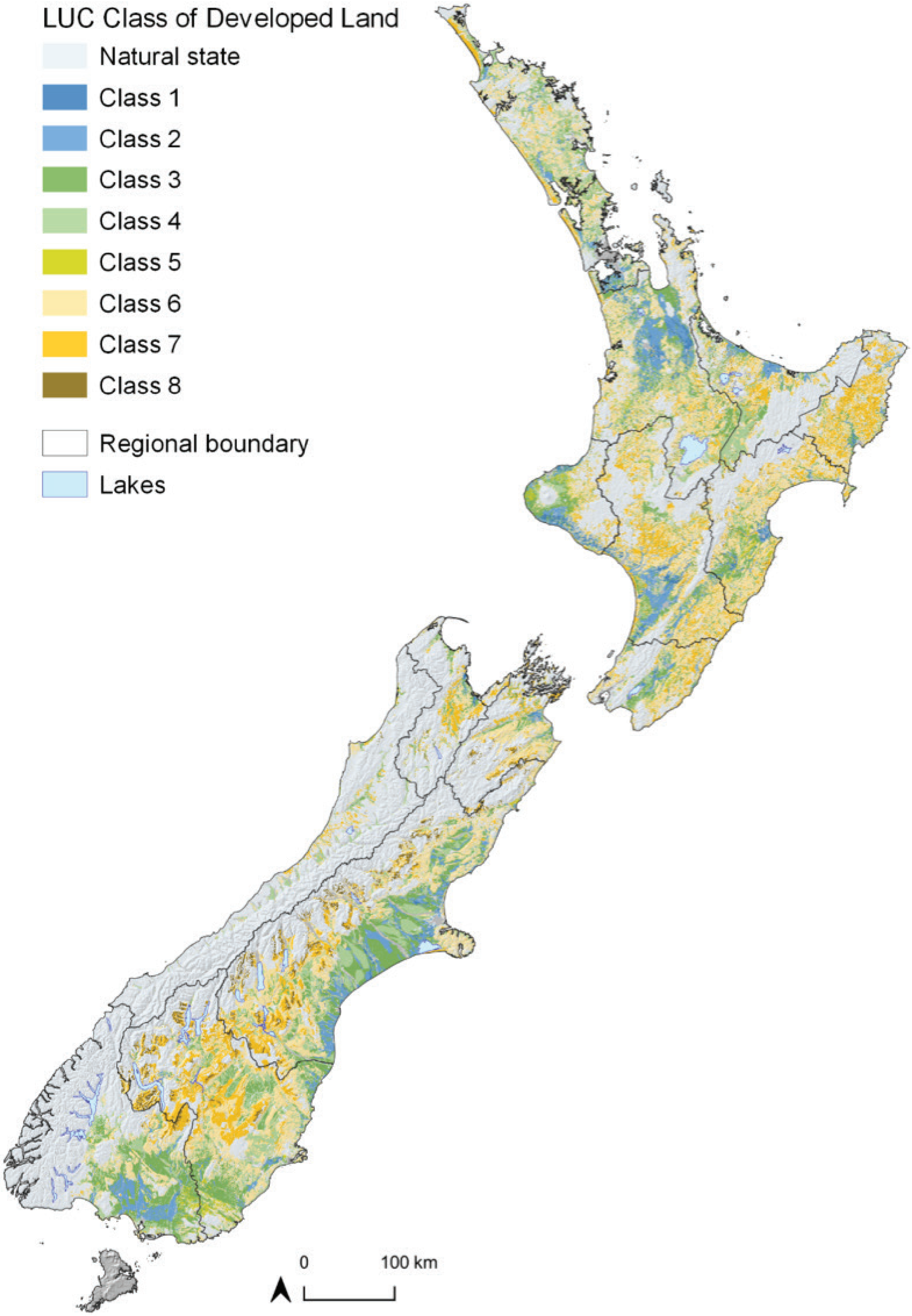

Figure 2: Distribution of Land Use Capability Classes across rural developed land in New Zealand
*Note: The map shows all rural developed land (i.e., grazed pastoral, cropping, orchards and vineyards **plus** forestry).*

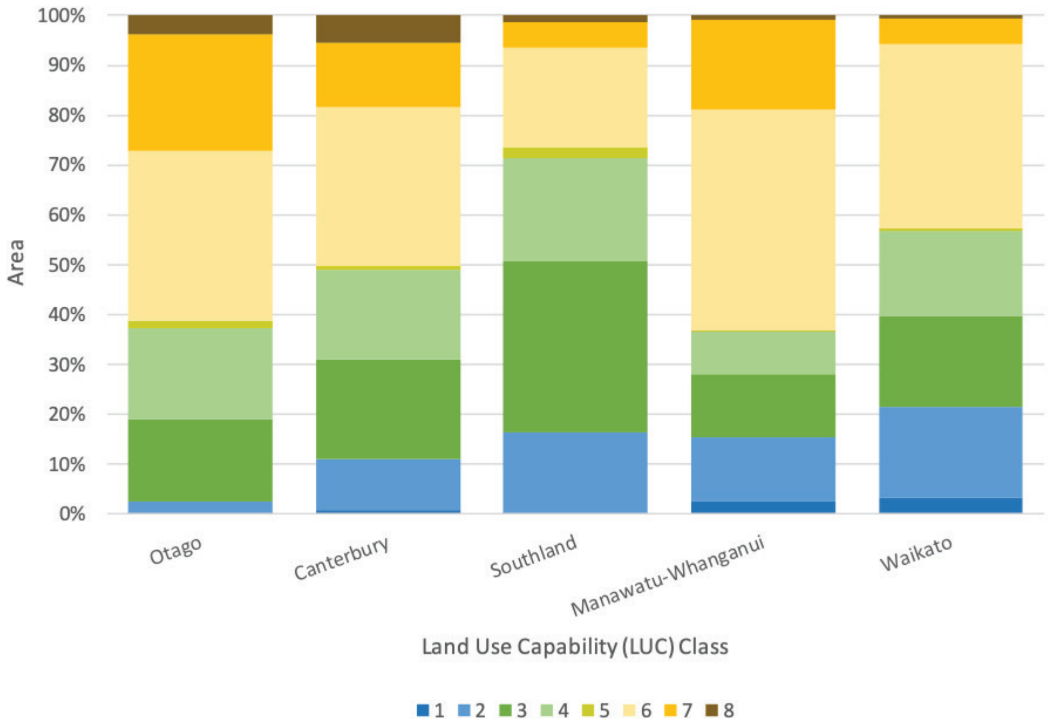

Figure 3: Distribution of Land Use Capability across rural land for five regions with the most rural land in New Zealand

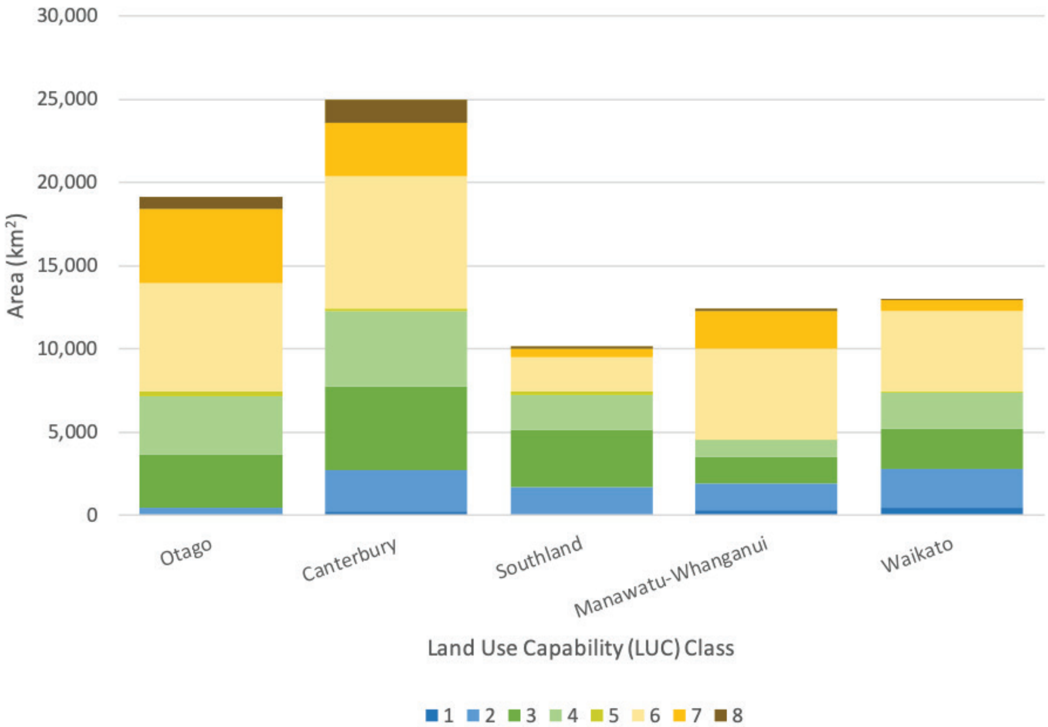

Figure 4: Areal distribution of Land Use Capability across rural land for five regions with the most rural land in New Zealand
Note: A km^2 is 100 hectares and thus 1,000 km^2 = 100,000 hectares.

Recognising New Zealand's geology and topography is complex, agricultural businesses tend to have a mix of topography, with any LUC 1-4 land usually being central to the farming system. In horticulture, vegetable growing tends to focus on LUC 1 and 2 while the free-draining properties of the soils on the higher LUC classes are well suited to orchard crops. For viticulture, prime grape growing soils are typically less fertile soils, often falling into the higher bands of the LUC classification system.

> *Otago has a predominance of hill and high country and limited flat land, particularly at low altitude, contrasting with the expansive plains of Southland and Canterbury. The region is, however, strongly connected to farming and growing in those neighbouring regions as well as related economic activities – particularly for processing and manufacturing. With limited flat land there is competition, as different land uses jostle for position, which tends to translate into higher land prices and more pressure on production systems. The development of irrigation has created more opportunities and certainty, but fresh water too is limited. The result appears to be more interdependence within land uses across different topographies as well as more complexity and diversity in production systems than elsewhere. Where variability occurs it likely improves the region's resilience.*
>
> ***Farmers and Growers in Otago (2022: p4)***

While the LUC system assesses the land's versatility and limitations for production, it does not factor the environmental susceptibility of the landscape for contaminant losses from the productive farm system. Susceptibility is the inherent risk of the land to contaminant losses through nutrient leaching (nitrate and dissolved reactive phosphorus) and particulate contaminant (sediment, sediment-bound nitrogen and phosphorus, and pathogens) loss through runoff. For example, the landscape is more susceptible to nitrate leaching where the soils are well drained, and the underlying aquifer is oxic (i.e., oxygen-rich). Particulate losses are highly susceptible where the soils are fine textured, poorly permeable, the land is sloping, and the underlying geology is weak. While susceptibility to erosion is considered as a limitation in the LUC it is mapped from evidence of active erosion type (e.g., landslides, slips, and streambank erosion etc) and severity rather than the potential for sediment and sediment bound contaminant loss (mudstones are highly susceptible due to weak strength and small particle size).

Physiographic Environments of New Zealand (PENZ) is a classification specifically designed to explain the inherent risk of the landscape to contaminant loss[12]. It considers both the hydrological pathway contaminants take to leave the land and how the landscape regulates water quality contaminants through dilution, resistance to erosion, filtration and adsorption, and attenuation of both nitrogen and phosphorus. Each environment has distinct properties that can be used to predict the susceptibility of a contaminant for loss independently of land use (source). The two classification systems can be used together to understand both the productive capacity of the landscape and the inherent susceptibility for contaminant loss from the productive system. A map of PENZ for Otago is in Figure 5.

12 An explanation of the classification system is available at *https://www.landscapedna.org/science/physiographic-environments/*

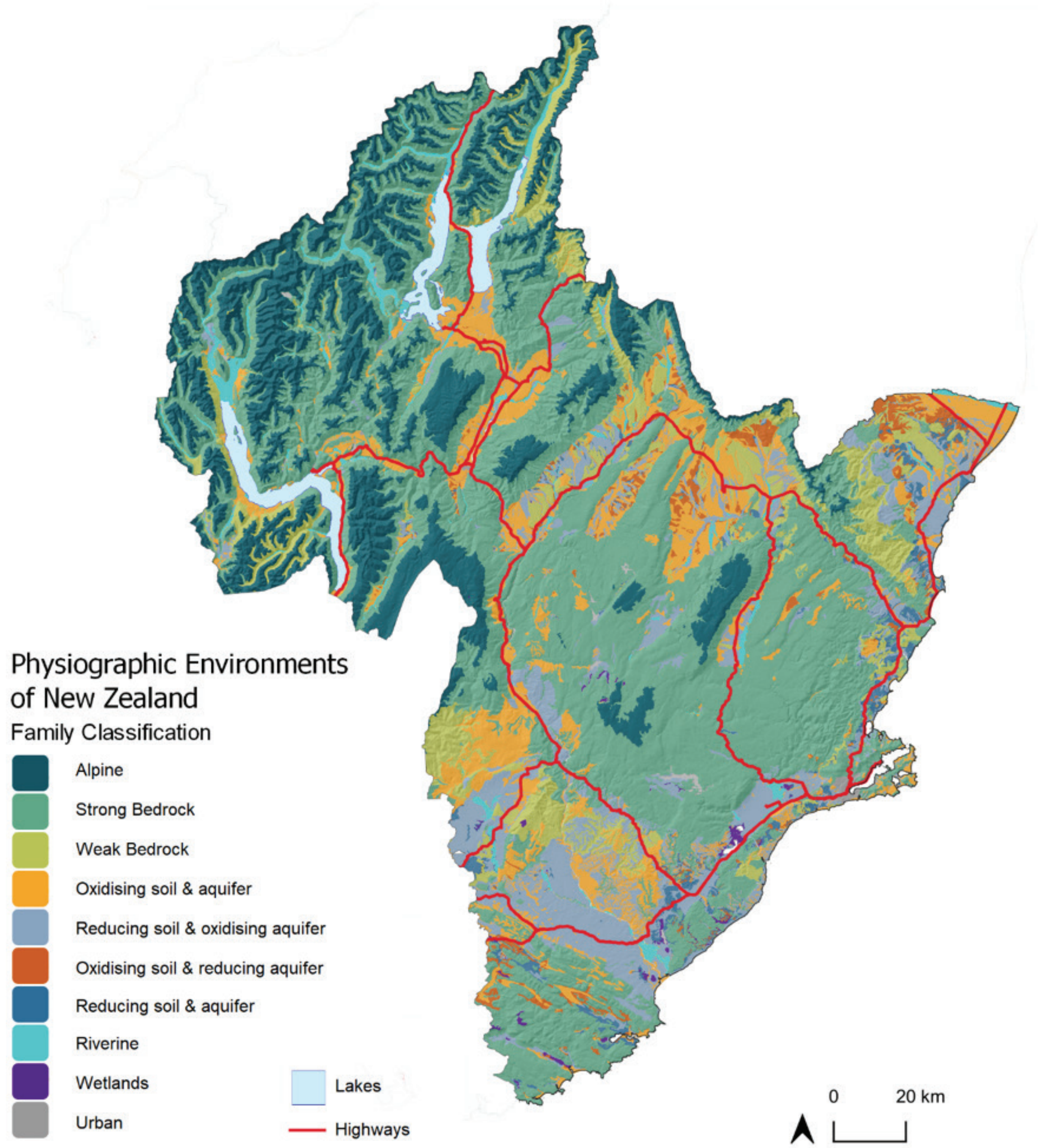

Figure 5: Physiographic Environments of New Zealand (PENZ) in Otago
Source: Landscape DNA

Analysis of LUC in Otago is developed further in the *Otago Economic Profile for Land and Water* Report (Yang & Cardwell, 2023). Land use maps showing the geographical extent of each industry in Otago are included in the *Farmers and Growers in Otago* Report (Moran, 2022).

1.2 Policy context

Numerous efforts are now occurring across Otago and the rest of New Zealand to better manage how people, through their activities, use water for the future. The statutory backdrop for these efforts is the *National Policy Statement for Freshwater Management 2020*[13] (NPS-FM) and the fundamental concept of Te Mana o te Wai[14]. The NPS-FM applies to all fresh water (surface water and groundwater) and its 'receiving environments', which includes rivers, lakes, wetlands, aquifers, estuaries, and the wider coastal marine area (and is influenced by fresh water). Its objective is for natural and physical resources to be managed in a way that prioritises (in this order):

- The health and well-being of water bodies and freshwater ecosystems;
- The health needs of people (such as drinking water); and
- The ability of people and communities to provide for their social, economic, and cultural well-being, now and in the future[15].

Each regional council is currently developing its approach for implementing the NPS-FM in their region. In general, such an approach will include science and mātauranga Māori to understand issues, and possible steps to address them, changes to statutory planning documents, as well as action plans (where appropriate)[16]. Once completed, there is an equally important process to put it all into practice 'on the ground'. Once in place, the approach will both guide and be part of the community's 'package' of solutions for fresh water.

A central role in Otago's approach to the NPS-FM is played by Otago Regional Council (ORC)'s new L*and and Water Regional Plan*[17] *(LWRP)*, which will set limits and targets for fresh water, as well as controlling a host of activities relevant to both rural and urban communities when it is finalised. ORC will notify a proposed LWRP by the end of June 2024. When the appropriate planning processes are completed, the new LWRP will replace the *Regional Plan Water: for Otago*[18], which has been operative since 2004. In doing so, the new plan will manage Otago's land and water alongside two iwi management plans: *Kāi Tahu ki Otago Natural Resource Management Plan (2005)* and *The Cry of the People Te Tangi a Tauira (2008)*[19]. As discussed below, some of what will be incorporated in the LWRP is already required in one way or another (at least for a limited period) and some will be new as part of putting into practice the NPS-FM.

Otago's proposed LWRP will carry forward provisions (i.e., objectives, policies, and rules) from a series of recent plan changes to the existing regional plan[20]. It will also incorporate the *National Environmental Standards for Freshwater 2020*[21], and additional regulations relating to stock exclusion[22] and water takes[23],

13 The National Policy Statement 2020 was most recently amended in December 2022: *https://environment.govt.nz/acts-and-regulations/national-policy-statements/national-policy-statement-freshwater-management/*

14 The first National Policy Statement for Freshwater Management was in 2011 and it was amended to introduce Te Mana o te Wai and the National Objectives Framework in 2014.

15 This prioritisation is known as the 'hierarchy of obligations' and it is part of Te Mana o te Wai. To support the Objective, the NPS-FM also includes National Bottom Lines. Achieving national bottom lines does not necessarily equate to a healthy ecosystem. For example, the description of the 'state' of suspended fine sediment in rivers that meets the National Bottom Line (i.e., the 'C-band') is "moderate to high impact of suspended sediment on instream biota" (NPS-FM, 2020: p50). Sensitive fish species may be lost.

16 Action plans are important for transparent decision-making (NPS-FM, Section 3.6) and, in some cases, are compulsory (NPS-FM, Section 3:12 and Appendix 2B). An action plan effectively draws a 'line of sight' in a spatial way between the set of steps being put in place, the target attribute state(s) and, in turn, the environmental outcome(s).

17 *https://www.orc.govt.nz/plans-policies-reports/developing-a-new-land-and-water-regional-plan-for-otago*

18 *https://www.orc.govt.nz/plans-policies-reports/regional-plans-and-policies/water*

19 As well, the *Otago Catchment Stories Summary Report* (2023) noted many catchment groups emphasised the importance of having a coordinated strategy and plan, aligned with both short-term and long-term goals and visions.

20 *https://www.orc.govt.nz/plans-policies-reports/regional-plans-and-policies/water*

21 *https://www.legislation.govt.nz/regulation/public/2020/0174/latest/LMS364099.html*

22 *https://environment.govt.nz/acts-and-regulations/regulations/stock-exclusion-regulations/*

23 *https://environment.govt.nz/acts-and-regulations/regulations/measurement-reporting-water-takes-regulations/*

while also considering Freshwater Farm Plans[24]. In contrast to the regionally specific approaches being developed around the country for the NPS-FM, this suite of regulations applies nationally and is already legally in force – although the environmental actions stemming from them are not yet fully in place 'on the ground'.

1.3 Report purpose

It has long been recognised that the introduction of policy for managing fresh water has considerable potential to impact rural businesses and other users of natural resources. Impacts occur because, by design, new policy acts to alter the incentives that these businesses face in their use of water and the land it flows through (e.g., Doole, 2013). There is also clear evidence that it can have markedly differing impacts on rural businesses within an industry and between industries (Moran, 2017).

Put simply, the purpose of this report is to explore what additional environmental actions for fresh water may mean for rural businesses in Otago. The analysis looks at businesses across the agriculture, horticulture, and viticulture sectors, and builds general understanding. Where possible, it identifies how the impacts of policy may be managed while still achieving policy objectives in a timely manner (i.e., within the time available for change to occur). It is hoped that the analysis may also help farmers think through changing circumstances.

The report also considers how rural businesses' current situation may change because of recent regional plan changes to the *Regional Plan Water: for Otago* and the introduction of national regulations relevant to fresh water. As a whole, this report is an important step in developing a region-specific approach to freshwater management, and the planning process for the new *LWRP* that sits at its centre.

In essence, this report is a series of research outputs by industry-good groups. Each output looks at a set of businesses in Otago using data sources developed either as part of the MPI Farm Monitoring and Benchmarking Programme or an additional project funded by MPI and/or ORC. It is Report 3 of ORC's Economic Work Programme and follows directly on from Report 1: *Farmers and Growers in Otago* and Report 2: *Otago Catchment Stories Summary Report*[25]. Reports 1 and 3 are intended to be viewed as two halves of a whole. Together they represent a considerable investment in rural businesses in relation to freshwater management by all parties involved.

The primary intent of economic analysis where there is a prescriptive context, such as the National Policy Statement for Freshwater Management 2020, is not to weigh the impacts of change versus the status quo. Rather, it is to better understand how the potential impacts of change can occur as 'economically' as possible for individuals and communities. Here 'economics' is used in its fullest sense, across human, natural, built, and financial capitals[26]; and 'economically' means minimising the impacts, as far as possible, of more fully accounting for the uses of fresh water within production systems (i.e., moving closer towards actual productive efficiency). In this way, environmental issues are more likely to be resolved, and reasonably foreseeable unintended consequences may be side-stepped. Ultimately, the 'system' we live may be restored to a more natural balance.

24 https://environment.govt.nz/acts-and-regulations/freshwater-implementation-guidance/freshwater-farm-plans/

25 An overview of ORC's Economic Work Programme, including its outputs as they are completed, will be available on the Council's website (the link was being developed at time of publication). A brief description of the full set of reports in the Economic Work Programme was included in Report 1: *Farmers and Growers in Otago.*

26 'Economics' is essentially the study of utility and differs from 'chrematistics', which is the study of wealth or exchange-value (i.e., money). A more fulsome discussion on the nature of economic analysis for resource management is available in Moran (2023).

The need to be economical while achieving necessary change was highlighted in the recent *Otago Catchment Stories Summary Report (Reilly, 2023):*

> *Significant concerns were noted around the volume and pace of regulatory pressures from both central and local government, with a general sentiment that the 'negative' is now overpowering the 'positive', with the focus being on what cannot be done, rather than on opportunities.*

The value of understanding economic impacts of environmental issues to better inform decisions by government, businesses, communities, and households was recently underlined in the *Ngā Kōrero Āhuarangi Me Te Ōhanga: Climate Economic and Fiscal Assessment (2023)*. The report noted that there are material economic implications of both the environmental issue and how New Zealand responds to the risks and opportunities it presents. The same thinking equally applies to fresh water.

1.4 Report structure

In reading this report it is important to consider the scope of this research and the general approach, which are both the focus of the remainder of this introductory chapter (Sections 1.3 and 1.4). The main body of this report is divided into six industry-specific chapters:

Chapter 2: Sheep and Beef Cattle Farming
Chapter 3: Deer Farming
Chapter 4: Arable Farming
Chapter 5: Dairy Farming
Chapter 6: Horticulture
Chapter 7: Viticulture

The unique nature of each industry shaped the research and is reflected in the structure and content of each industry chapter. This said, each chapter is broadly consistent and follows a general pattern of methodology, wider farm sample (in the case of sheep and beef, deer, and arable), specific case studies, and research findings. Each chapter starts with a summary of what is contained within that chapter.

1.5 Research Scope

1.5.1 Environmental Actions

The scope of the research contained in this report is focused on testing the impacts of additional environmental actions[27] for rural businesses that are relevant to the development of the new LWRP (which has a lifetime of at least 10 years). They are not necessarily what may eventually be needed to achieve the environmental outcomes. In this context, environmental actions are the avoidance, mitigation and remediation measures used to address water quantity issues and/or water quality issues. Water quantity issues tend to relate to how much a waterway's flow regime reflects its natural flow behaviour. Water quality issues are usually concerned with discharges of four priority contaminants: nitrogen, phosphorus, sediment, and micro-organisms, as indicated by *E. coli*. These actions are often referred to simply as 'mitigations', however this term is not used here because 'mitigating' (or abating) implies a narrower set of actions than those that may be relevant.

27 A useful 'library' of actions, which describes many of those used in New Zealand, is available at: https://landscapedna.org/actions/

As already noted, this report is one step in Otago's approach to implementing the NPS-FM and it is intended (in the first instance) to inform the planning process, rather than assess its outputs. This means the research was undertaken concurrently with the shaping on the new LWRP and, by necessity, ran slightly ahead of its drafting. The general methodology is explained in more detail further on in this Chapter (Section 1.6).

The timing of this research highlights that policymaking, of which 'planning' is one aspect, is not simply a binary choice (in this first instance) between a 'regulatory' or a 'non-regulatory' approach[28]. Such a view belies the multi-disciplinary effort involved to be able to reach the point where the role, whether leading or supporting, that regulation may play in the wider policy approach can reasonably be determined. In reality, a package of solutions is usually needed to address an issue.

1.5.2 Mechanisms

While this report focuses on the impacts of environmental actions relevant to the new LWRP, it does not explicitly consider the various tools or 'mechanisms' that might be used to put each action in place 'on the ground'[29]. Examples of the types of mechanisms that exist are statutory provisions (e.g., policies and rules[30]), written guidance, peer support[31], expert advice, compliance monitoring and enforcement, and market forces (e.g., processor supply agreements, banking client risk profiles). Some mechanisms are within the direct control of a regional council, but others may be in its sphere of influence. It is the combination of an action and a mechanism that creates a planning 'method'[32].

Statutory policies and rules are specific forms of regulation. Within them, environmental actions tend to be expressed as the conditions on an activity, with the activity usually either being 'permitted'[33] or needing a 'consent'[34]. The differences in impacts of a permitted activity and a consent largely relate to the distributions of public and private costs. Another mechanism now available for requiring environmental actions is via certified and audited Freshwater Farm Plans[35], which started coming into effect from mid-2023, and will be implemented progressively.

Whether regulatory or non-regulatory, it is almost always the case that more than one mechanism is needed to put in place an environmental action at scale. Just as a package of solutions is needed to address an issue, so an integrated set of mechanisms is needed to implement an environmental action (or actions). As a general rule, environmental actions all rely on non-regulatory mechanisms (e.g., education) and the choice, if there is one, is whether some form of regulation is needed as well.

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28 Similarly, regulation is not just a question of either targeting the inputs to a production system or its outputs (i.e., its environmental effects or 'externalities'). In reality, there is no silver bullet to 'wicked problems' (i.e., one that is challenging to solve), of which achieving the desired outcomes for fresh water is a prime example, and the successful solutions are as necessarily intricate and nuanced as the issues themselves.

29 In resource management, the technical term used for the combination of an action and a mechanism is a 'method'.

30 In general terms, rules are used in district plans and regional plans by local government while regulations are used by central government in National Environmental Standards and under Section 360 of the Resource Management Act 1991. Both central and local government use objectives and policies. Although in the past farm environment plans have been a non-regulatory mechanism, audited *Freshwater Farm Plan*s are now a specific type of regulation.

31 An example of peer support is the deer industry's Advance Parties: *https://www.deernz.org/deer-hub/support-services/advance-parties/*

32 A method is the means by which the policies in a regional policy statement or regional plan are implemented *https://www.qualityplanning.org.nz/node/613* . Internationally and in New Zealand, there is evidence of a freshwater policy implementation gap whereby jurisdictions struggle to move from policy development to on-the-ground action (Kirk et al., 2020). Kirk et al., (2020) identify potential barriers to local government implementation of central government freshwater policy in New Zealand and make recommendations on how to overcome these barriers in a New Zealand policy context.

33 An option where the effects of an activity are less than minor when the conditions relating to it are met.

34 The activity status of a rule is dependent on the risk of environmental effects (e.g., the effects of a permitted activity are 'less then minor').

35 Freshwater Farm Plans will contain a description of the catchment context, a risk and impact assessment, and actions to reduce risks. *https://environment.govt.nz/acts-and-regulations/freshwater-implementation-guidance/freshwater-farm-plans/*

Some actions may be better suited to particular mechanisms because of their specific characteristics, such as their scale. For example, large native plantings or wetland restoration usually work well as a voluntary collective because project time, effort and resources. Otago examples of such collectives include (but are in no way limited to) the Thomsons Catchment Project[36] and Tiaki Māniatoto - Protection Māniatoto Project[37].

The research in this report, for the most part, assumed that the environmental actions tested must be achieved (in one way or another). However, the set of mechanisms and the way they are applied is critical in driving the impacts of an environmental action and, ultimately, its success (measured by effectiveness and efficiency). For example, the specific set of mechanisms, including how well they are understood, will influence how resource users respond to an environmental action. It will also partly determine the distribution of direct impacts across society (i.e., whether 'first order' impacts occur as private cost and benefits or public costs and benefits).

Image 6: A catchment fieldday held on 3 March 2023 in the partly constructed wetland, which is an important part of the farmer-led Thomsons Catchment Project in the Manuherekia Catchment to improve water quality.
Source: Thomsons Catchment Project

36 https://www.facebook.com/ThomsonsCatchmentProject
37 https://www.facebook.com/pages/category/Community-Service/Tiaki-Māniatoto-102630655237340/

1.5.3 Timeframes

In addition to the focus on environmental actions (and not mechanisms), attention was directed to testing those actions that are most likely to be relevant to rural businesses during the life of the new LWRP (i.e., ten years) or shows potential. Consequently, the research is unlikely to capture the scale of change that may be needed to fully achieve environmental outcomes within the timeframes specified in Otago's proposed *Regional Policy Statement (RPS)*, with the decisions version of the RPS still in the future. In some localities, the life of the new LWRP and the timeframes for environmental outcomes will be similar but in others there may be more of a gap between the two.

For some rural businesses (and other water users) the scale of the task longer-term may change the calculus of their response in the short-term. An adaptive management approach can be economical except where it creates additional uncertainty (i.e., there are different types of uncertainty, and adaptive management may increase some while it decreases others). It highlights how clear information (and understanding) helps minimise impacts and avoid unintended consequences. Where change will take some time, clear pathways (i.e., steps and timeframes) are set out towards that change from the beginning.

Beyond the various policy timeframes, the research does not consider rates of adoption[38] or innovation and technological change, all of which are influenced by a complex range of factors (including the choice of mechanisms). Rates of change (whether fast or slow) are a key determinant of the impacts of freshwater management on all who are reliant on water's capacity to support life (including rural businesses). 'Time to adjust' has been central to freshwater management in New Zealand for at least a decade (e.g., Ministry for the Environment, 2013)[39]. Impacts are already being felt by farmers and growers where they have put in place environmental actions (e.g. stock exclusion, improved effluent management systems, improved intensive winter grazing). Some farmers and growers still have more work to do to keep pace – either because they are not yet in a position to initiate change (for whatever reason) or because their 'to do' list is longer than others (e.g., they may have a higher proportion of waterways per hectare).

When considering 'time', economic impacts are influenced (both positively and negatively) by time lags in the policy process (i.e., its development and implementation) as well as time lags in the response of the economy and the environment. Where there is intensification, time lags can also constrain the range of potential options available. All of these factors are not independent of one another. However, with climate change gathering pace, the impacts of environmental actions for freshwater management will depend in part on how much time there is available to change and the extent to which it fits with our capacity[40]:

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38 Kaine and Wright (2015 and 2016) provide a useful starting point for thinking about rates of adoption. They proposed that the adoption of more complex innovations by farmers requires greater motivation, time and effort than does the adoption of simple innovations. The adoption of more complex innovations takes longer simply because they are inherently more difficult to understand and to integrate into the farm system. The greater time and effort involved in adopting them means that their adoption involves greater overall costs and risks and is thus more sensitive to the strength of the motivation to adopt them.

39 The National Government enacted the first NPS-FM in 2011 and introduced Te Mana o te Wai and the National Objectives Framework as amendments in 2014, with further strengthening amendments (including clarification of Te Mana o te Wai), in 2017. The Labour Government revised the NPS-FM in 2020, including making it more explicit that the health and well-being of waterbodies and freshwater ecosystems takes first priority in Te Mana o te Wai.

40 The critical relationship between climate change and freshwater management internationally was recently highlighted in the journal *Science* by Yao, Livneh, Rajagopalan, Wang, Crétaux, Wada, and Berge-Nguyen (2023).

Climate change is accelerating, and its effects are being felt more and more by New Zealanders. We are experiencing more severe and frequent droughts, floods and storms, higher temperatures and rising sea levels. Large impacts from future warming are already locked in, driven by historic global emissions. The future trajectory of global emissions will affect how much more temperatures rise beyond this level. Assuming policies are unchanged globally, studies have shown that mean temperatures in New Zealand in 2090 could be as much as 4.6°C higher than pre-2005 levels. An increase of this size could cause catastrophic damage to our economy and society.

Ngā Kōrero Āhuarangi Me Te Ōhanga: Climate Economic and Fiscal Assessment (2023)

Scarcity of freshwater resources, which are affected by both droughts and floods, is likely to increase with climate change – as are the impacts of improving freshwater management because of the disruption caused by weather events.

1.5.4 Efficiency

Efficiency, together with effectiveness, are the two main criteria for assessing policy[41] (effectiveness is discussed in the next section). Essential to any economic analysis for freshwater management is the efficiency criterion. Efficiency, or more correctly 'economic efficiency', is one of those terms where its usage is so commonplace that few people may ever pause to think about what it actually means[42].

In broad terms, economic efficiency is about how well limited resources[43] (human, financial, natural and built) are 'utilised' (or managed) within an economy. Economic efficiency is about the 'utility' or 'welfare' gained from the resources available, although utility does not necessarily imply resources are used in a consumptive sense[44]. It consists of three main dimensions: productive efficiency (which includes technical considerations), allocative efficiency, and dynamic efficiency[45]. Needless to say, efficiency is a highly complex topic, especially in environmental policy[46].

The focus of the research in this report is on the productive efficiency of rural businesses, although the allocative and dynamic dimensions are also relevant. For example, the relevance of climate change highlighted in the previous section is a matter of dynamic efficiency (i.e., present and future generations). Questions around the distribution of impacts on individuals and society concern allocative efficiency,

41 41 Under section 32 of the Resource Management Act 1991. "The issue of whether s32 of the RMA requires a strict economic theory of efficiency or a more holistic approach was raised before Woodhouse J in Contact Energy Limited versus Waikato Regional Council [2011] NZEnvC 380 … while economic evidence can be useful, a s32 evaluation requires a wider exercise of judgement. This reflects that it is simply not possible to express some benefits or costs in economic terms … in this situation it is necessary for the consent authority to weigh market and non-market impacts as part of its broad overall judgement under Part 2 of the RMA." In its decision the Court appears to have misunderstood the nature of economics, which consists of both market and non-market components (e.g., Total Economic Value). New Zealand's economy is based on the flows from its stocks of natural, built, human and financial capital (e.g., Makhlouf, 2018).

42 The Australian Productivity Commission (2013) stated that in economics, efficiency is not always defined nor interpreted consistently within and across disciplines and its use in everyday language is often casual (Anon, 2013). To many economists, efficiency has a clear and distinct meaning, and misapplications are at best imprecise, and at worst misleading (Anon, 2013).

43 Resources are 'limited' in the sense that there is only ever a finite amount.

44 Paul Krugman (Laureate of the 2008 Nobel Memorial Prize for Economic Cciences for his work on international trade and economic geography) recently noted that what an economy is for is "to serve human needs, not generate favorable statistics" (Krugman, 2023). It is through 'utility' that efficiency and effectiveness are interconnected.

45 The Australian Productivity Commission produced a valuable explainer on the topics of efficiency and effectiveness (Anon, 2013). Ribaudo et al., (1999) discusses the efficiency as part of outlining the economic characteristics of instruments that can be used to reduce agricultural nonpoint source pollution and empirical research related to the use of these instruments.

46 To illustrate the point, biodiversity has been found to be a determinant of the efficiency with which an ecosystem uses limiting resources (e.g., nitrogen and phosphorus) (Dasgupta, 2021). Experiments on grasslands have found that biodiversity improves the ability of ecosystems to resist invasive species via lower soil nitrate, greater abundance of neighbouring plants, and lower abundance of light.

which is about how well resources are used across all the goods and services produced, consumed and exchanged in the economy (whether via markets or not). While this report is about rural businesses, productive efficiency is a policy consideration for all economic agents (including local government). Productive efficiency depends on context – environmental actions that are efficient for one economic agent and locality may not be in the next. Efficiency also depends on a society's existing institutional arrangements, which can work against environmental outcomes (e.g., land drainage and clearance being treated as 'improvements' in the tax system, or the time and resourcing needed to gain consents for some voluntary environmental actions)[47].

Where a resource user puts in place an environmental action that successfully contributes to managing a freshwater issue while minimising impacts then they are, in effect, internalising the 'environmental externalities' of their resource use. The result is a fuller or more complete accounting of productive efficiency (i.e., externalities indicate inefficiencies). In this situation, the impact of the action is more akin to the end of a benefit that had previously been experienced than the imposition of a cost. Environmental externalities are important because they can cause both damage costs (i.e., costs arising from a deteriorated environment) and remediation costs (i.e., costs of fixing this environment so that the costs do not continue to occur) (Moran, 2019). In some cases, actions are more obviously efficient (often with some public investment) once the damage and remediation costs of an activity are considered[48].

1.5.5 Effectiveness

The final consideration in the scope of this report is effectiveness, which has already been touched on (to some extent) in the previous sections.

Economic analysis for freshwater management at the business-scale (i.e., microeconomics) often relies, in part, on Overseer[49] modelling. Overseer is a software tool used to show how an environmental action may change estimates of nitrogen loss and the risk of phosphorus loss for an individual farm. Such changes indicate the potential effectiveness of an environmental action, which is a measure of how well it contributes to achieving desired outcomes. Although Overseer modelling is valuable in economic analysis, it had a lower priority in the scope of this research for three main reasons.

First, the effectiveness of an individual environmental action or set of actions is primarily a question for science (including mātauranga Māori)[50]. The reason Overseer modelling was originally included in economic analysis was because it allowed for a 'system' approach to testing environmental actions,

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47 This is a common challenge the world over and across environmental issues. It was recently specifically highlighted in *The Economic Report of the President* (2023: p273). "The design of climate adaptation policies must recognize that actors across the United States … already face incentives to adapt to climate change. But they also face informational, financial, and legal constraints that may limit their ability to adapt. Targeting adaptation policies to alleviate these constraints and address related market failures should be most effective in supporting private action."

48 An example is Scion's new technology for processing forestry slash on site following Cyclone Gabrielle. https://www.rnz.co.nz/news/country/485544/processing-forestry-slash-on-site-an-immediate-solution-scion-chief-executive

49 OverseerFM is computer software that gives a way of estimating nutrient flows on-farm and is used to assess the relative risk of various management options (i.e., one option compared to another option). It allows the user to understand a farm's annual average nutrient requirements and how different practices may change its nutrient inputs and outputs: https://www.overseer.org.nz/

50 The effectiveness of an environmental action is not necessarily the same as the effectiveness of a planning method that includes that action. Also, effective at a paddock or property scale does not necessarily translate to effective at a catchment scale because it depends on the frequency of situations to which it is relevant. Additional considerations are 1) the effectiveness of the mechanisms being used to implement the action in question, and 2) how an action's 'fit' within a production system (i.e., its impact on efficiency) influences its implementation. An action's effectiveness is part of a broader question about policy effectiveness: *Policy Effectiveness = Method x Monitoring x Enforcement x Sanction* (B. Keenan, pers. comm., April 2023), with method being a function of an action and the mechanisms used to put it in place. If any of the variables are particularly low, the effectiveness is commensurately low, even if all the others are high.

which suited farms with a higher level of inputs. For example, it is common to use step targets of ten per cent reductions in nutrient loss for the modelling to aim to achieve (where multiple inputs are adjusted until each step is reached) rather than environmental actions for a particular input (e.g., stocking rates or fertiliser usage).

Second, the purpose of the economics here is to test environmental actions that are most relevant, because of policy or issues or both, to a farming or growing business. As such, it was important that a fuller set of actions were available for testing, and the analysis was not unnecessarily constrained to only those actions that can be modelled reasonably accurately in Overseer. This was particularly the case for the industries for which Overseer is less well suited because it gave them more flexibility in their modelling approach[51]. This said, farmers and growers' understanding of an action's potential to contribute to better outcomes for fresh water is a crucial factor in their uptake of it (i.e., the adoption rate) (Reilly, 2022). Many industries appear to prefer a risk-based approach.

Third, base Overseer files were available for most of the farms through the MPI Farm Monitoring and Benchmarking Programme. These files meant current nitrogen leaching and risk of phosphorus loss can be reported, as well as greenhouse gas emissions to air for some industries. Knowing these start points is likely to be sufficient in many cases to indicate an action's likely effectiveness, especially given the quantum of existing research on the topic. Moreover, this research broadly considers environmental actions relevant to water quantity and water quality (nitrogen, phosphorus, sediment, and *E. coli*) – not just nutrients. The lower priority given to Overseer in this research allowed more effort to be invested in the economic analysis.

The 'benefit' of an environmental action is determined not only by its effectiveness in managing activities that 'use' fresh water, but also the context of that use: the values of waterbodies – the groundwater, streams, rivers, lakes, and estuaries – and their sensitivity to use. Similarly, the effects of a water take or a discharge of contaminants in one location are unlikely to be equivalent to similar uses of water in another location. The benefits of an environmental action depend on where the water use occurs within a catchment as well as the positioning of the action itself[52]. In general, there tends to be more gained from an action either at source or as close as possible.

1.6 Research approach

This section describes the general approach used in this research into the impacts of environmental actions for rural businesses. Specific methodologies used by each industry are summarised in Chapters 2 to 7.

The general approach used was each industry group undertook responsibility for the research (i.e., the modelling, analysis, and reporting) into their industry, and Otago Regional Council supported their efforts as requested. Within the needs of the council, each industry group had the latitude to develop their own methodology tailored to suit the nature of their farmers or growers' businesses. This flexibility in approach was more important than trying to achieve consistency because what made sense for one industry was an unnecessary constraint for the next. The reporting of the research has occurred within a robust editorial and review process to ensure the outputs are as fit for purpose as possible.

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51 There are other models available e.g., APSIM *https://www.apsim.info/*

52 For example, constructed wetlands are particularly effective on hydric soils, where natural wetlands would have been located in the past. Hydric soils include mineral soils as well as peat (organic soils). *https://www.envirolink.govt.nz/assets/R13-5-Hydric-soils-field-identification-guide.pdf*

In most cases, the industry group sub-contracted the technical work to a consultant of their choice and then used the outputs as the basis for each chapter. Importantly, each industry group had different resources to draw on – whether it was specialist expertise, local knowledge, or existing databases. Each industry group scoped its research in consultation with staff in the ORC Strategy Team, which is where the economic capabilities sit within the council. Initial results and findings were presented to ORC staff during an online Industry Advisory Group workshop on February 22, 2023.

The industry groups were asked to develop case studies, based on actual rural businesses in Otago. The use of case studies is a well-established approach for this type of research, given its complexities, and it is particularly appropriate for Otago's distinct environments. Each industry group selected a range of businesses and then were asked to follow a basic two-step methodology:

Step 1: Consider a rural businesses' current issues and actions and, where necessary, adjust the business to meet recent policy changes (via national regulations and regional plan changes); and

Step 2: Use the outputs from the previous step to test what additional environmental actions for fresh water (covering both water quantity and water quality (reducing discharges of nitrogen, phosphorus, sediment and *E.coli)*) may mean for these rural businesses.

The rural businesses used for the case studies were largely selected from the MPI Farm Monitoring and Benchmarking Programme (described in the next section). Instead of case studies, Horticulture New Zealand and Central Otago Winegrowers Association chose to develop 'representative models', each one based on several growers' businesses in Otago. The industry groups were asked to report the results from each step separately, as well as noting all key assumptions. They were also encouraged to test alternatives or variations on an environmental action (where possible) to show how impacts on a business may be minimised.

A crucial question in this type of research is the choice of metrics to summarise business impacts. There is a complex economic equation that, in simplistic terms, travels from gross revenue through various steps to end (after interest, tax, rent, and drawings) at a business' surplus. With any metric, it is a matter of knowing what you are looking at (i.e., what items are included or excluded) and understanding how to interpret it, including what it is not telling you. Preferably, more than one measure is needed to give some depth perception on impacts.

Each industry group was encouraged to look beyond changes in profitability[53] to consider in their analysis what each environmental action is likely to mean (in reality) for the farm business (e.g., changes in production, labour, practicalities). While remaining profitable is essential for the viability of any business, it is not necessarily the sole driver for farmers and growers. All industry groups were asked to use 'Earnings before Interest, Tax and Rent' (EBITR) as the key profitability measure. The rationale for preferring EBITR is because rent, like interest, is a cost of capital and it is important to treat both interest and rent in the same way[54]. The horticulture and viticulture analyses used EBIT rather than EBITR.

Both profitability measures give a business' longer term 'steady state' position and account for depreciation, which is important because the use of capital embedded as equipment ('plant and machinery') is an economic cost. Cashflow within a production season is also highly relevant. Its frequency and timing differ markedly between industries within agriculture, viticulture, and horticulture. For example, some businesses receive regular cash payments while for others they are few and far between.

53 The 'profit motive' is a core feature of a capitalist economy.

54 If EBIT was used rather than EBITR then a farm will appear more profitable if it is leased rather than owned (A. Burtt, pers. comm., January 2023). From a business perspective, non-cash items like the change in the value of the livestock (i.e., inventory) and depreciation matters as much as its cash position.

The research process, from the initial data collection (which occurred largely through the MPI Farm Monitoring and Benchmarking Programme) through to modelling, analysis, and reporting, was undertaken from 2020 up to March 2023. During this time, ORC continued to build its scientific understanding of fresh water across the region (water quantity and water quality), ran community and stakeholder consultation processes, and (from later 2022) developed 'Issues and Options' council papers for specific topics (e.g., dams and diversions, farming activities). To help guide the research, the ORC Science Team gave the Industry Advisory Group regular updates, which included information on potential over-allocation for water quantity and water quality across the region.

Understanding this timeline is crucial because much of the research contained in this report was, by necessity, undertaken alongside the development of the science and slightly ahead of policy development for the new LWRP. More specifically, the environmental actions tested in this report were selected by the industry groups in late 2022 / early 2023. This time period followed the ORC Science Team's development of good management practice 'bundles'[55] but ahead of the ORC Policy Team's series of regional stakeholder workshops and the drafting of provisions for the new LWRP, which did not begin in earnest until early 2023. In the absence of firm policy direction, some guidance was provided by the ORC Policy Team on the environmental actions for rural businesses that might be considered in the development of the new LWRP.

In addition to science and policy advice, the industry groups had early access to outputs from the Catchment Stories Workstream, which identified some key areas of current progress in Otago, and where success is being seen on the ground. These areas included projects and practice changes around:

- Riparian protection;
- Stock exclusion;
- Biodiversity maintenance, restoration, and protection;
- Better endeavours to monitor water quality;
- Investment in more efficient water use;
- On-farm water storage;
- Changes to cropping and high-risk activities like intensive winter grazing;
- Weed and pest control;
- Investment in catchment management plans, and individual farm environmental plans;
- A greater focus on soil health; and
- Improved waste management.

A consequence of where this research sat within the timeline is that the environmental actions tested in this report, while relevant (in one way or another) to freshwater management in Otago, will not necessarily be those included in the proposed LWRP when it is notified in June 2024. In some cases, environmental actions in this report may have been considered and disregarded, and in other cases there will be environmental actions in the LWRP that were not tested here because they became apparent

55 These bundles were relevant to dairy farming and sheep and beef farming. They were designed to show, at a catchment scale, the level of effort that was likely to be needed to achieve environmental outcomes. Under the NPS-FM (2020), an environmental outcome means a desired outcome that a regional council identifies and then includes as an objective in its regional plan. An environmental outcome is in relation to a value that applies to an FMU or part of an FMU. There are four compulsory values (1. ecosystem health, 2. human contact, 3. mahinga kai, and 4. threatened species) and nine other values that must be considered when determining those that apply to an FMU (1. natural form and character, 2. drinking water supply, 3. wai tapu, 4. transport and tauranga waka, 5. fishing, 6. hydro-electric power generation, 7. animal drinking water, 8. irrigation, cultivation, and production of food and beverages, and 9. commercial and industrial use).

later. At the time of writing, the environmental actions for rural businesses that will be the focus of provisions in the LWRP was still unknown. Many of the environmental actions tested are also likely to be relevant to audited Freshwater Farm Plans in the future and this research may become a useful resource for that process.

Figure 6 shows, conceptually, the relationships between environmental actions tested for this report, those that will eventually be included in the new LWRP and/or audited Freshwater Farm Plans. It shows that a subset of the environmental actions tested in this research may be in the new LWRP and some may in a Freshwater Farm Plan, or both. It also shows that there is a subset of the environmental actions in the new LWRP that will not have been tested in this research.

In some cases, an industry group chose to focus their efforts on specific aspects of freshwater management (i.e., water quantity and water quality (nitrogen, phosphorus, sediment and *E.coli*) rather than investigate the topic as a whole. It may be that they considered certain aspects to be more relevant to their industry than others and/or they had to prioritise the resources available to them. Importantly, each case study or representative model is the equivalent of at least a fortnight's work (if not more) from data collection through to reporting. Arable farming was the most extreme, as it involves both cropping and livestock rotations, with a full case study taking at least a month. The effort involved in this research is an indication of the complex decision-making across multiple topics currently facing many rural business owners.

Figure 6: Conceptual relationships between environmental actions, the new LWRP, and Freshwater Farm Plans
Note: In reality, the extent of the environmental actions in each circle will vary.

1.6.1 MPI Farm Monitoring and Benchmarking Programme

This research is an application of microeconomics, which is economic analysis at the scale of the firm or individual. The quality of any analysis is reliant on the robustness of the data, and in this case, there was the opportunity to use datasets for real farms and growing operations in Otago collected through the MPI Farm Monitoring and Benchmarking Programme.

The Farm Monitoring Programme has existed since the late 1980s, first at the Ministry for Agriculture and Forestry and more recently at the Ministry for Primary Industries (MPI). Its original purpose was to create a short-term overview of the status of a range of farm and orchard types throughout New Zealand. Physical and financial data was collected from a sample of farms and used to inform the development of regional model budgets and to complement farmer and industry expectations. However, following the establishment of MPI in 2012, the programme and its funding was reduced considerably.

In 2020, a Farm Monitoring team was re-established following a successful funding bid through the Ministry's *Productive and Sustainable Land Use* programme[56]. The team's function was to collect detailed farm-level data to provide a baseline of farm performance across different sectors. MPI is working together with industry groups Beef + Lamb New Zealand (B+LNZ), Deer Industry NZ (DINZ), DairyNZ, Foundation for Arable Research (FAR), Horticulture New Zealand (HortNZ) and Apiculture New Zealand (APINZ), to build on sector knowledge, existing farmer relationships, and data collection and storage systems, while making sure individual industry projects are tailored to farmer and grower needs.

The Farm Monitoring Programme keeps production and financial performance at its core but now also includes environmental information for up to 1,600 individual businesses via the creation of farm environment plans and nutrient budgets in Overseer. It also assists industry in developing benchmarks, including environmental key performance indicators so farmers can determine how they are performing relative to similar farms and to improve knowledge on the range of performance. Overall, farm monitoring enables sound economic and farm system analysis, which is essential to improving understanding and policy outcomes.

There are opportunities, while protecting privacy, to use the information to develop analysis across the entire farm system's performance (production, environmental and financial). Its use in this research for the development of ORC's new LWRP is an early example of its potential. Through the Farm Monitoring Programme, MPI was able to support the agricultural and horticulture sectors in developing sufficient base farm and grower data for the industries to undertake modelling and analysis. A summary of the results for each industry is presented in this report. Ultimately, one hundred Otago farms and orchards will be engaged in the programme.

56 https://www.mpi.govt.nz/funding-rural-support/farming-funds-and-programmes/productive-and-sustainable-land-use/

2 Sheep and Beef Cattle Farming

This chapter was produced by the B+LNZ Economic Service.

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2.1 Summary

This chapter uses a two-step research methodology to understand the impacts of environmental actions on commercial sheep and beef farm businesses. In doing so, it builds on a recently completed overview of the industry in Otago, which was based on an analysis of B+LNZ Farm Classes[58] (Fisher & Burtt, 2022).

In the first step, an analysis was carried out for 41 Otago sheep and beef farms. In Otago, few (if any) sheep and beef farms are on a single soil type or slope or are limited to one livestock class. The most populous farm class in the region is Farm Class 6: South Island Finishing and Breeding. In locations where natural rainfall limits pasture growth, the difference between a farm classified as Farm Class 6 and one classified as a Farm Class 2 farm is sometimes the presence of irrigation, at least on part of the farm.

In the second step, 16 Otago sheep and beef farms were developed as case studies to test the impacts of different environmental actions on the farming business. These farms were specifically selected to cover both the four B+LNZ Farm Classes present in Otago (of the eight developed by B+LNZ to classify farms across New Zealand) and a geographical spread. Farms that were running production systems that were deemed to be relatively uncommon were not selected.

Given the different sources, levels, and ranges of risk, the following environmental actions were selected to be tested on the case study farms across seven topics: phosphorus loss, waterway protection, winter forage crops, irrigation, nitrogen fertiliser, tussock lands, farm system and land use change.

This research found:

- The range of impacts of the same environmental action between individual sheep and beef farm businesses is extremely wide. While an action (e.g., fencing off all waterways) may result in less than one per cent reduction in profit on one farm, it can make another financially unviable. This theme was seen throughout all the case study farms and all the environmental actions investigated for this chapter. It is a direct response to the diversity and complexity of sheep and beef farms and reflects the physical environments they operate in.

57 All Beef + Lamb New Zealand (B+LNZ) staff.
58 Refer to Appendix 1 at the end of this chapter.

- Sheep and beef farms in Otago usually have a relatively low nitrogen leaching footprint compared to other land uses. Their stocking rates are low, and they are generally stocked for optimal pasture management[59]. The case study farms range between 0.5 and 17.1 stock units (SU[60]/grazed ha) and had low rainfall (between 530 and 1,200 mm/yr with three of the 16 case study farms over 1,000 mm/yr). Their nitrogen leaching losses ranged from 2 to 15 kg N/ha/yr and phosphorus losses from less than <0.1 to 2.2 kg P/ha/yr.

- The majority of the 16 case study farms have either completed, or are working towards completing, fencing of all waterways that the national stock exclusion regulations apply to. Anecdotal evidence suggests that they are prioritising the most at risk locations and fencing as time and budget allow. The size, topography, and length of waterways on sheep and beef farms means many will be highly impacted (both financially and in terms of farm system options) if stock exclusion regulations are more stringent than they are currently.

- Pasture production on sheep and beef farms in Otago is low, which is due to rainfall and temperature limitations of those areas where sheep and beef farms are located. Farmers aim to match demand from livestock with supply of pasture (i.e., 'farming to the grass curve'), with minimal inputs of nitrogen fertiliser, irrigation, and supplementary feed that is imported onto the farm. Uses of inputs are tactical, to provide additional feed during a pinch period (e.g., drought or winter), rather than strategic so the farm can carry more livestock.

- High Country (Farm Class 1) sheep and beef farms have sizeable areas of tussock or brown top pastures, which have extremely low annual carrying capacities (0.3-1.6 SU/ha for the case study farms). Three of the four case study high country farms have small areas of irrigation (<1% to 9% of farm area) to provide a reliable source of feed when pasture supply is compromised.

- Irrigation schemes on sheep and beef farms in Otago are often older, using a mix of border dyke, flood irrigation, and K-line systems. Modelling changing irrigation systems to more efficient systems, even to increase the irrigated area without changing the volume of water used, reduced profitability (measured as EBITR[61]) by between one per cent and 316 per cent. This action reduced nitrogen leaching losses by between one and two kg N/ha/yr from what was a low base. The costs per hectare of upgrades tend to be expensive because the scale is fairly limited and more piecemeal.

- The topography within a farm tends to be mixed and the range in pasture growth rates across different blocks influence the farm system adopted. Farm management is complex as each block has specific pasture production, challenges and opportunities (e.g., altitude, exposure to elements/shelter available). The farm system is usually carefully balanced to run a viable farming business over time. Changes in one area of the farm can have implications across the whole farm business.

59 In earlier research for Southland (Moran 2017), it was found that reducing a drystock farm's stock numbers by 10% had little effect on nutrient losses because most farms already had lower stocking rates. It resulted in relatively small reductions in nitrogen loss on most farms with little or no reductions in phosphorus loss, but it had a considerable impact on profitability. Average profitability decreased by 24% on the sheep and beef farms and by 33% on the deer farms. In drystock farming there is a strong relationship between stock numbers and profitability because, at least in terms of meat production, a farm's livestock are its product. As well, farmers spend little on imported feed so there were limited cost savings from lower stock numbers.

60 SU = stock unit

61 Earnings before interest, tax and rent

- There is a high degree of interconnectedness between farms in Otago. Breeding properties in the hill and high country provide lambs and calves for finishing farms. Thus, when there is an occurrence that impacts breeding farms, it tends to flow-on across the industry. Breeding farms that are sold and converted to forestry no longer provide young livestock to be finished on the Farm Class 6 Finishing and Breeding farms and Farm Class 7 Finishing farms.
- Tussocks are a vital component of many sheep and beef farms in Otago. They provide animal shelter at certain times of year, particularly during lambing and snow events. Livestock grazing of areas with tussocks can help prevent invasive species of pasture from smothering and overtaking the tussock. Constraints on access to these tussock areas, for whatever reason, can have serious implications for animal welfare and control of invasive species. Careful management of stock grazing intensity ensures tussock cover is maintained in the long term.
- Sheep and beef farms have multiple income streams so environmental actions that result in reduction or elimination of an income stream (e.g., replacing cattle with sheep) will mean a farm is more exposed to volatility of prices for their outputs (e.g., by becoming more reliant on lamb prices). In addition, cattle provide vital roles in the mixed system (e.g., pasture quality control) that improve the efficiency of other components (e.g., lamb production).
- In this research, environmental actions were tested singularly. In reality, many environmental actions may be relevant for a farm, or a farm may face requirements for many actions. It is the compounding impacts that can result in inaction due to uncertainty and fear, financial unviability, and ultimately farm sales. A tailored environmental farm plan helps farmers to identify their areas of risk, identify priorities, and build it into their farm budget. Having a plan of action with time and cost estimates helps farmers make progress in a timely and efficient way.
- The financial viability of environmental actions depends on farm profitability, farmers' ability to borrow and the willingness from banks[62] to lend.

The farms most at risk of being impacted by the environmental actions tested in this research were:

- Those that have multiple challenges and face multiple regulations, e.g., many waterways to fence, an irrigation scheme to upgrade, winter crop restrictions, losing areas of the farm to riparian/crop buffers or retirement of land from grazing. For these farms, identification of the most important actions to tackle and the time to complete all actions is vital to remain financially viable.
- More extensive with many waterways and a higher cattle to sheep ratio because any intensification of stock exclusion rules disproportionately impacts these farms.
- Smaller and suitable for alternative land uses so they may exit the sector or be absorbed by neighbouring farms as they are sold.
- Extensive with limited alternative land-uses.
- Those relying on a relatively small area of irrigation to provide a reliable feed source. If they lose those areas due to either a loss of access to water supplies or not being able to afford to upgrade, then there could be serious implications for the farm business.

62 Or other sources of finance.

2.2 Introduction

Otago is home to roughly 20 per cent of New Zealand's sheep flock and nine per cent of its beef herd. Here sheep and beef farming is at least as diverse as in any region in the country (if not more so), being influenced by topography and climate. Otago sheep and beef farms have an added and important sheep production system in the production of fine wool. Otago's production systems range from High Country stations running 0.5 Stock Units[63] per hectare to coastal properties with high rainfall and good pasture growth that can carry 12 or more SU per ha. The recently completed overview of the industry based on B+LNZ Farm Classes (Fisher & Burtt, 2022), which is informative, is elaborated in this report with an understanding of individual farm businesses (while maintaining farmer confidentiality).

In this chapter, data is presented from the 2020-21 production season for 41 Otago commercial sheep and beef farms that are a part of the B+LNZ Sheep and Beef Farm Survey[64]. In addition, 16 commercial sheep and beef farms were selected from the MPI Farm Monitoring and Benchmarking Programme (described in Section 1.5.1) to develop as case studies to test the impacts of different environmental actions on the farming business. The 16 farms were selected to cover as much of the range and diversity as possible amongst sheep and beef farms in Otago while still being able to undertake in depth analysis.

Image 7: Area of stream fenced off and planted. Waikoikoi Creek, Pomahaka Catchment.
Source: Craig Simpson, Watershed Solutions

63 B+LNZ standardisation is that one stock unit is the equivalent of one ewe with a lamb at foot. Hoggets, wethers, and rams are less than one stock unit. Mixed age beef cows are the equivalent of 5.5 stock units and grazing dairy cattle are 4.5 stock units. By comparison, Jersey cows are 6.5 stock units and Friesian cows are 8.5 stock units.
64 The B+LNZ Sheep and Beef Farm Survey collects financial and production data on farms across New Zealand.

2.3 Methodology

To capture some of the diversity in sheep and beef farming in Otago, B+LNZ took a two-step approach to this research. First, information was analysed for the 41 Otago sheep and beef farms in the B+LNZ Sheep and Beef Farm Survey to improve understanding at the scale of the individual businesses (Section 2.4). Second, 16 individual sheep and beef farms that are typical of the commercial sheep and beef farms in the region were developed as case studies to test the impacts of environmental actions for the farm business (Section 2.5).

The 41 Otago sheep and beef farms are the complete set of farms from this region that were included in the B+LNZ Sheep and Beef Farm Survey for 2020-21. The sample of 16 case study farms was taken from the MPI Monitoring and Benchmarking Programme, the basis of which is the B+LNZ Sheep and Beef Farm Survey but also includes additional farms. The 16 farms used in this research were specifically selected to inform the case study approach and so cover both the four B+LNZ Farm Classes[65] present in Otago (out of eight across New Zealand) and geographical spread (Table 2). In addition, farms that were running production systems that were deemed to be relatively uncommon were not selected.

Table 2: Distribution of farm sample used in case study approach

B+LNZ Farm Class number and name	Commercial Sheep and Beef farms in Otago (#)	Case study Sheep and Beef farms in Otago (#)	Average total farm area of case study farms (ha)
Farm Class 1: South Island High Country	110	4	11,000
Farm Class 2: South Island Hill Country	185	3	1,700
Farm Class 6: South Island Finishing and Breeding	595	6	700
Farm Class 7: South Island Finishing	120	3	300
Totals	**1,010**	**16**	**-**

2.3.1 Case study methods

OverseerFM data, and information in the farm environment plans, was used in FARMAX Red Meat (version 8.2.0.36; FARMAX) by KapAg[66] consultancy. In FARMAX, each farm was adjusted slightly so that its opening and closing livestock numbers were the same, which allowed them to be modelled in the 'long-term' mode as steady state. Actual livestock expenses for each farm were used by applying "per SU" figures to the 'steady state' livestock numbers. The land expenses were converted to a "per grazed hectare" figure so that the whole farm expenses changed depending on stock units and grazable area when the environmental actions were applied in FARMAX.

The product prices received were adjusted so that all farms were modelled using the same prices. This was done to remove variability that would be introduced by the diverse management approaches that lead to different product prices. Prices for livestock were compared to B+LNZ data on actual

65 The B+LNZ Farm Classes are explained in Appendix 1 for this chapter and in more detail in Chapter 2 of the *Farmers and Growers in Otago* Report (Fisher & Burtt, 2022).

66 https://www.kapag.nz/

prices paid for livestock. It was found that the schedule prices in FARMAX needs a slight adjustment to account for the more recent prices. For example, FARMAX was using $5.50/kgCW[67] as the long-term seasonal average lamb price, which was calculated by weighting the average prices from the prior five production seasons in the following manner:

- 2020-21 33%
- 2019-20 25%
- 2018-19 20%
- 2017-18 17%
- 2016-17 5%

However, a methodology relying on B+LNZ information on seasonal average prices paid for prime sheep and beef cattle for those years resulted in a long-term average lamb price of $7.13/kgCW, bull beef $5.27/kgCW, and prime cattle $5.36/kgCW. The B+LNZ figures were used in this research. Figure 7 shows the lamb schedule based on B+LNZ data that was used in the FARMAX modelling for this work. The prices received for any individual farm depended on the actual carcass weights and the months they were processed rather than the long-term average. The B+LNZ long-term average was used to calculate the monthly price.

While it is feasible that a maximum of ten per cent of a farm's current profitability (i.e., EBITR), may be allocated towards environmental actions without needing additional borrowing, for this work it was assumed borrowing occurred in all cases except the nitrogen fertiliser environmental actions. It was also assumed that the financial cost of environmental actions covered by borrowing funds was at an interest rate of seven per cent per year, and that borrowing sought by the farmer was approved by a lender (refer to Section 2.4.3.4). Other specific cost assumptions relevant to the environmental actions are outlined in the specific sections of this chapter.

B+LNZ provided KapAg with the following for either the 2019-20 or 2020-21 season:

- Data from completed B+LNZ Farm Plan: Environment Modules ("Farm Environment Plans")[68];
- Overseer analyses
    - Sheep, Beef, Deer, and Dairy animal reports;
    - Farm Details report;
    - Summary report; and
    - Block summary report;
- Overseer Data Input and Assumptions files[69];
- Financial and production performance information, including:
    - Open and Close Balance Sheets;
    - Income and Expenditure; and
    - Flow of funds; and
- Introductions to the farm consultants who prepared the Farm Environment Plans and Overseer files for the case study farms.

67 CW means carcass weight
68 https://beeflambnz.com/knowledge-hub/PDF/our-plan-templates-all-templates.pdf
69 https://beeflambnz.com/knowledge-hub/PDF/overseer-nutrient-budget-form.pdf

As part of the MPI Farm Monitoring and Benchmarking Programme, the farm consultant contracted by B+LNZ to develop and provide the Overseer files for each sheep and beef farm was required to use a Standard Operating Procedure for data collection and OverseerFM input that was created by B+LNZ.

KapAg's staff did not visit the farms themselves, instead they created the FARMAX files using the information provided and by speaking with the farm consultants. This was necessary as time and cost to personally visit all 16 farms was prohibitive. Although the information for each farm was "anonymised", to facilitate testing of some environmental actions for some farms it became necessary for B+LNZ to provide farm location information to KapAg so that characteristics such as length of waterways and soil pH information could be determined from other data sources.

B+LNZ went through each of the 16 farms and identified environmental actions that would be relevant for each farm. Many actions were identified in the Farm Environment Plans as risk areas of the farm or future environmental actions. These actions were then grouped into the following topics:

- Waterway protection (fencing of wetlands and waterways);
- Biodiversity (riparian planting, fencing areas of regenerating bush, excluding stock from tussock);
- Irrigation changes (change to more efficient systems, increase irrigation area, add water monitoring sensors);
- Land use change (remove cattle from farm and replace with sheep, exclude cattle from steep areas, retire LUC Class 6 land and plant in pines);
- Nitrogen (identify and remove any winter applied nitrogen fertiliser, reduce fertiliser application rates to 30 kg N/ha/yr);
- Phosphorus (identify farms where Reactive Rock Phosphate (RPR) might be suitable); and
- Winter cropping (limit farms to a maximum of 10% of the area of the farm or 50 hectares[70] in winter crop, add wider riparian buffers for crops adjacent to waterways, use direct drilling or minimum till if not already occurring, use a standoff pad for cattle).

KapAg assessed all farms for each of the environmental actions and applied the actions to the relevant farms in FARMAX modelling. ***Environmental actions were considered individually and not bundled together.*** KapAg provided a memo of the modelling results (financial and farm systems changes resulting from the actions) under each of the seven topics and a final summary memo. Those memos provided the basis of the results in this chapter. Additional Overseer modelling was done by B+LNZ's Principal Science Advisor to assess the impacts of different environmental actions on predicted nitrogen and phosphorus loss.

70 *Resource Management (National Environmental Standards for Freshwater) Regulations 2020 (LI 2020/174) (as at 05 January 2023) 26 Permitted activities – New Zealand Legislation*

Name: ORC baseline schedule adjtd (in use)

Sheep | Bull Beef | Deer | Prime Beef

Print | Long Term

☑ Use Long Term pricing only

Season	Adjust	Indicator Price -- 17 kg PM Lamb											
Season	Adjust	O	N	D	J	F	M	A	M	J	J	A	S
Average	Seasonal (%)	112	109	100	93	91	90	91	95	99	102	107	111
7.13	Indicator ($/kg)	7.99	7.77	7.13	6.63	6.49	6.42	6.49	6.77	7.06	7.27	7.63	7.91

Price/ kg | Charges | Relativities

Prices / kg												
Works ($/kg Cwt)	O	N	D	J	F	M	A	M	J	J	A	S
17 kg PM Lamb	7.99	7.77	7.13	6.63	6.49	6.42	6.49	6.77	7.06	7.27	7.63	7.91
24 kg Sheep	3.83	3.57	3.28	3.05	2.92	3.02	3.24	3.18	3.53	3.64	3.81	4.04
Store ($/kg Lwt)	O	N	D	J	F	M	A	M	J	J	A	S
Ewe Lamb	3.35	3.26	2.92	2.78	2.79	2.76	2.79	2.91	2.96	3.13	3.36	3.56
Ewe Hogget	3.67	3.65	3.42	3.18	2.85	2.57	2.47	2.37	2.54	2.91	3.51	3.64
MA Ewe	2.87	2.88	2.64	1.86	1.82	1.80	1.82	1.90	2.05	2.18	2.67	2.77
Ram Lamb	3.59	3.42	3.07	2.98	2.92	2.89	2.92	3.05	3.11	3.27	3.59	3.72
Ram Hogget	5.51	5.67	5.56	3.25	3.24	3.34	3.70	3.93	4.16	4.36	4.73	4.99
MA Ram	9.66	9.40	9.84	10.81	11.03	11.17	11.55	10.84	10.59	10.11	10.07	9.81
Wether Lamb	3.51	3.34	3.07	2.92	2.85	2.82	2.85	2.98	3.04	3.20	3.51	3.64
Wether Hogget	3.03	2.88	2.64	2.52	2.66	2.63	2.60	2.84	3.04	3.27	3.36	3.17
MA Wether	2.56	2.64	2.28	2.06	2.34	2.37	2.40	2.17	2.26	2.33	2.37	2.22

Net Sample Price	17 kg PM Lamb, Dec 22, 17 kg Cwt, Works	$ 119 / head

Figure 7: Screenshot of the sheep schedule, based on B+LNZ price and schedule data, used in FARMAX modelling
Source: FARMAX Red Meat v 8.2.0.36

2.3.2 Environmental actions

The initial thought for this work was to do two stages of modelling for each farm. One to bring it up to Good Management Practice (GMP) and the second to go further and take it to Good Management Practice Plus (GMP+). This methodology immediately became difficult due to the complex and diverse nature of sheep and beef farms, defining a list of GMP and GMP+ is only practical on a case-by-case basis. It is not practical to provide a comprehensive list that covers all potential GMP and GMP+ for the whole industry. When investigating the case study farms it became apparent that most of the farms were already applying what could be considered best practice as it related to their individual farms, specifically in terms of current regulation.

Most farms met regulations covering winter grazing, stock exclusion (or they were actively working towards completion of their fencing programme), and they were generally low-input and low-intensity farms. For this reason, an agreed list of Good Farm Practice Principles (Figure 8) that cover the areas of general principles, nutrients, waterways, land and soil, effluent, and water and irrigation, was considered the best way to address GMP and GMP+.

Thus, we created the list of environmental actions under each of the seven topics and all environmental actions that were relevant for each farm were considered and provided to KapAg for FARMAX modelling. From the list of 21 Good Farming Principles, the seven topics covered principles 1, 3, 4, 5, 9, 11, 13, 15, 20, 21 (Figure 8). Some were not applicable (e.g., effluent related principles 16 19) and others could not be modelled using FARMAX and Overseer because Overseer already assumes best practice is occurring. Some principles (e.g., 6 and 7) are assumed to occur in Overseer as a default that cannot be altered.

Promoting good farming practices

At the national level, the Governance Group will promote the Good Farming Practice Principles outlined below.

AGREED NATIONAL GOOD FARMING PRACTICE PRINCIPLES

GENERAL PRINCIPLES

1. Identify the physical and biophysical characteristics of the farm system, assess the risk factors to water quality associated with the farm system, and manage appropriately.
2. Maintain accurate and auditable records of annual farm inputs, outputs and management practices.
3. Manage farming operations to minimise direct and indirect losses of sediment and nutrients to water, and maintain or enhance soil structure, where agronomically appropriate.

NUTRIENTS

4. Monitor soil phosphorus levels and maintain them at or below the agronomic optimum for the farm system
5. Manage the amount and timing of fertiliser inputs, taking account of all sources of nutrients, to match plant requirements and minimise risk of losses.
6. Store and load fertiliser to minimise risk of spillage, leaching and loss into water bodies
7. Ensure equipment for spreading fertilisers is well maintained and calibrated.
8. Store, transport and distribute feed to minimise wastage, leachate and soil damage.

WATERWAYS

9. Identify risk of overland flow of sediment and faecal bacteria on the property and implement measures to minimise transport of these to water bodies.
10. Locate and manage farm tracks, gateways, water troughs, self-feeding areas, stock camps, wallows and other sources of run-off to minimise risks to water quality.
11. Exclude stock from water bodies to the extent that is compatible with land form, stock class and stock intensity. Where exclusion is not possible, mitigate impacts on waterways.

LAND AND SOIL

12. Manage periods of exposed soil between crops/ pasture to reduce risk of erosion, overland flow and leaching.
13. Manage or retire erosion prone land to minimise soil losses through appropriate measures and practices*
14. Select appropriate paddocks for intensive grazing, recognising and mitigating possible nutrient and sediment loss from critical source areas
15. Manage grazing to minimise losses from critical source areas.

EFFLUENT

16. Ensure the effluent system meets industry specific Code of Practice or equivalent standard.
17. Have sufficient, suitable storage available for farm effluent and wastewater.
18. Ensure equipment for spreading effluent and other organic manures is well maintained and calibrated.
19. Apply effluent to pasture and crops at depths, rates and times to match plant requirements and minimise risk to water bodies.

WATER AND IRRIGATION

20. Manage the amount and timing of irrigation inputs to meet plant demands and minimise risk of leaching and runoff.
21. Design, check and operate irrigation systems to minimise the amount of water needed to meet production objectives.

Implementing this principle may mean that Class 8 land is not actively farmed for arable, pastoral or commercial forestry uses as this land is generally unsuitable for these activities as described in the Land Use Capability Handbook.

Figure 8: Agreed National Good Farming Practice Principles
Source: Good Farming Practice: Action Plan for Water Quality (2018)[71]

Farming practices that involve contaminant losses to water or the abstraction of water can adversely affect aquatic ecosystems. For sheep and beef farms, the main contaminants of concern are phosphorus (P), suspended sediment (SS), faecal microbes (which are indicated by *E. coli*) and, to a lesser extent, nitrogen (N). Water abstraction is mainly used for livestock drinking and irrigation (where needed).

71 The document Good Farming Practice: Action Plan for Water Quality (2018) can be found at https://fedfarm.org.nz/FFPublic/FFPublic/Policy2/National/Good_Farming_Practice-Action_Plan_for_Water_Quality_2018.aspx and the principles are outlined by MfE here https://www.mfe.govt.nz/fresh-water/we-all-have-role-play/land

The level of risk varies between farms and the sensitivity of receiving waterbodies. Managing this risk is important and a range of environmental actions were selected for testing their impacts on the case study farms. Not all environmental actions were potentially relevant to all the case study farms but for most farms several environmental actions were relevant and therefore tested.

Most elevated losses of nutrients (phosphorus and nitrogen) to water begin with an enriched source area being mobilised. Sources include cultivation, fertiliser spreading, effluent spreading, and dung and urine deposition. This can result from nutrient input (e.g., fertiliser and imported supplementary feed) or mobilisation of nutrients already in the system. The enriched sources of phosphorus and nitrogen as well as loss pathways are shown in Figure 9.

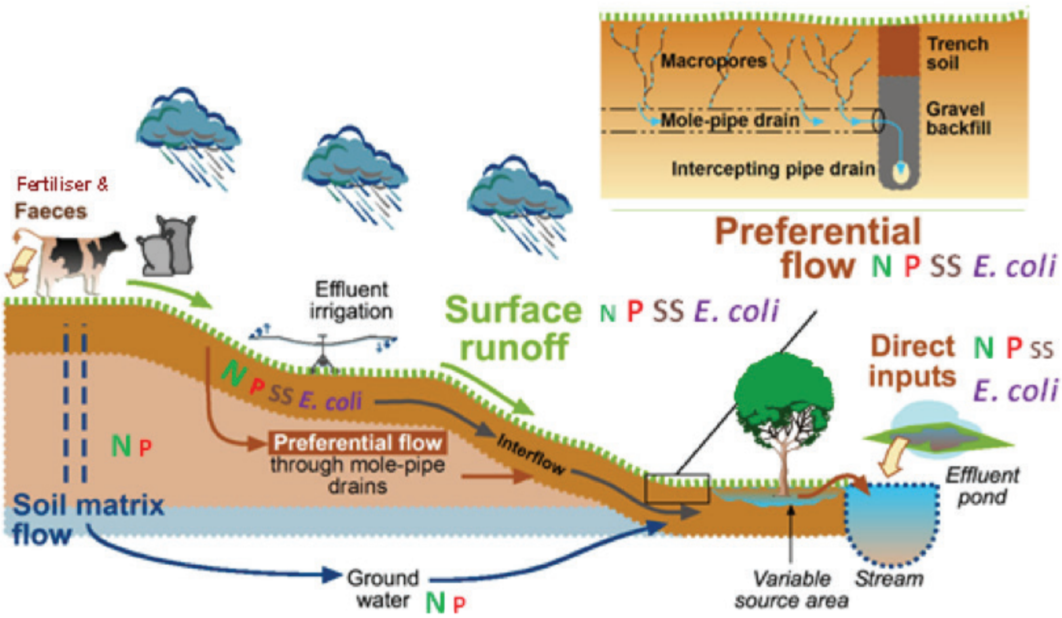

Figure 9: Conceptual diagram of the transport pathways involved in the transfer of contaminants (N, P, SS, and E. coli) from land to water. The presence and relative size of each of the contaminants indicates the importance of the pathway to contaminant-specific loss (McDowell et al., 2016)

In general terms, losses of contaminants to water are in either surface runoff or drainage or both. The predominant pathway for loss of phosphorus, suspended sediment, and faecal microbes (*E. coli*) is via surface runoff, while the pathway for nitrogen is drainage. Both pathways lead to contaminants in rivers and streams (Figure 9).

Phosphorus loss occurs because phosphorus is attached to soil particles and lost during erosion events. Examples of things that can increase the risk of loss are stream bank erosion caused by livestock accessing streams or pacing fencelines; wallowing by deer; bare soil; heavy animals on steep slopes; and extreme weather events. There does, however, need to be a transport pathway to a waterway for these risks to be realised. In addition, the concentration of phosphorus in the soil is reported as Olsen P[72] from a soil test and is an important consideration. When the Olsen P level exceeds optimum levels there is an increased risk of phosphorus loss during surface runoff events.

72 Olsen P is a soil test conducted to monitor soil P status. For NZ soils Olsen P is the best predictor of plant growth. https://www.fertiliser.org.nz/Site/about/soil-health-fertility/02-what-is-olsen-p-test.aspx

Losses of phosphorus are very site-specific and occur from a small percentage of the landscape from areas commonly referred to as critical source areas (CSAs). Phosphorus loss is strongly related to losses from CSAs, so identifying and managing these areas can result in considerable reductions in the losses of phosphorus, as well as sediment and faecal microbes (*E. coli*). CSAs are challenging to model using available computer software such as FARMAX and Overseer and were not specifically tested in this research. However, sections on management of CSAs, and sediment traps on sheep and beef farms are included here as general farm management actions that can have considerable benefits for water quality outcomes, often for low financial cost (Section 2.3.3.1).

In summary, the main drivers of phosphorus loss are losses of sediment and soil[73]; Olsen P levels[74]; the form, timing of application and loading of fertiliser[75]; and effluent applications causing ponding[76]. Management practices that involve the interception of nutrients and contaminants lost in overland flow include buffer strips[77], sediment traps[78], and natural[79] and constructed wetlands[80].

Nitrogen loss to water is predominantly via nitrate leaching rather than surface runoff, however groundwater and surface water can be highly connected. The main drivers of nitrogen leaching are urine patches, nitrogen fertiliser, and effluent. Lower stocking rates and low or nil nitrogen fertiliser applications mean that nitrogen loss is not often the main contaminant of concern on sheep and beef farms, rather it is those lost via overland flow pathways or via preferential flow pathways.

There are some management practices that present a greater risk of contaminant loss than others. Higher-risk farm management practices that have the potential to result in increased losses of nutrients and contaminants are:

- Some cropping[81];
- Cultivation[82];
- Intensive grazing on wet soils[83];

73 Occurs in CSAs. Small areas of a farm can be contributing most of its phosphorus losses.
74 Levels of phosphorus above the optimum for pasture or crop result in increased phosphorus losses.
75 Applications of fertiliser and/or effluent and rainfall events causing overland flow can result in phosphorus losses. Readily available forms of phosphorus fertiliser are more likely to exceed a plant's needs and increase the risk of losses than slower release forms, such as reactive phosphate rock (RPR).
76 Ponding (i.e., when the soil infiltration rate is slower than the effluent application rate) increases the risk of effluent phosphorus losses.
77 A grass strip left to reduce phosphorus, sediment, and *E. coli* in runoff through a combination of filtration and improved infiltration.
78 Sediment traps are used for the retention of coarse sized sediment. The water flows into the 'trap', which is designed to be longer, wider, and deeper than the existing channel bed. The sediment drops to the bottom of the 'trap' and the filtered water flows out. Labour is needed to empty the sediment on a regular basis.
79 Natural wetlands can be a sink and a source of phosphorus, particularly if the inflow is sediment-rich (e.g., from cropland or largely from surface runoff). As a wetland becomes choked with sediment its ability to retain phosphorus decreases. The form of phosphorus retained by wetlands is particulate phosphorus rather than dissolved phosphorus.
80 Constructed wetlands can be designed to remove phosphorus and sediment from waterways by decreasing flow rates and increasing contact with vegetation, thus encouraging sedimentation.
81 A higher-risk farm management practice as it may incorporate some or all of the other four factors in the list. To reduce the effects of grazing any or all of the other four factors can be addressed to minimise risk.
82 This activity can leave soil exposed and vulnerable to erosion. Erosion results in losses of phosphorus (primarily) and sediment. Cultivation also results in mineralisation of the nitrogen in the soil, which is then available for either plant uptake – or in some cases leaching to groundwater.
83 Effects from intensive grazing can occur in two ways. First, higher stocking densities of livestock cause soil damage, which increases the risk of overland flow and so losses of phosphorus, sediment, and *E. coli*, as well as reducing subsequent pasture growth. Second, it results in an area of condensed urination events that increases nitrogen leaching losses when urine is deposited on soils that are wet (defined as at or nearing field capacity). The figures most often quoted for urinary nitrogen load are 500 kg N/ha for a ewe and 1000 kg N/ha for a dairy cow (Haynes & Williams, 1993). The stocking density for dairy cows on pasture during the milking season can be around 70 90 cows/ha for a 24-hour period (a dairy cow is roughly 7.5 stock units, depending on the breed). During winter grazing this figure can be a stocking density of 300-600 cows/ha in the North Island of New Zealand (Drewry 2008).

- Intensive grazing on soils with a low soil water holding capacity (e.g., stony soils and excessively free-draining soils)[84]; and
- Fertiliser applications[85].

In addition to farm practices, other factors impact on the levels of nutrient and sediment loss. These factors include soil type, climate, and topography. Identical farming systems and practices can occur on different soil types and under different climates and result in different nutrient and sediment loss values. Given all the different sources of risk, levels of risk, and ranges of risk, the following environmental actions were selected to be tested on the case study farms across seven topics (Table 3).

Table 3: Summary of environmental actions tested across 16 case study farms

Topic	Environmental action	Sheep and Beef Case Study Farm(s)
Phosphorus loss	Check Olsen P levels and adjust fertiliser applications if required	
	Swapping current phosphorus fertiliser for Reactive Phosphate Rock (RPR)	SB08
Waterway protection	Fencing wetlands	SB06, SB09, SB15
	Fencing all wetlands and second order waterways	SB02, SB05, SB06, SB09, SB12, SB15, SB16
	Fencing wetlands and all waterways	SB01, SB02, SB04, SB05, SB06, SB09, SB12, SB15, SB16
	Fencing all wetlands and waterways and adding a stock water reticulation system	SB01, SB02, SB04, SB05, SB06, SB09, SB12, SB15, SB16
	Planting riparian areas	SB01, SB02, SB04, SB05, SB06, SB09, SB12, SB15, SB16
Winter forage crops	Reduce crop areas to below 50 ha or 10% of the property	SB02, SB09
	Creating a riparian buffer area between existing forage crops and waterways	SB02, SB09, SB15, SB16

84 In these situations, the main risk is nitrogen leaching from higher densities of livestock held for periods of time resulting in an increased number of urination events per hectare. As stony and very free-draining soils have a low capacity to hold water, nitrogen in the urine patches is more prone to leaching during rainfall events. Risk is elevated by a) higher stocking density and b) larger stock types with higher urinary nitrogen (volume and concentration). Thus, mature female cattle have a higher risk than sheep, deer, or younger cattle.

85 These need to be calculated using current soil test results so nutrient applications do not exceed soil and plant requirements for optimal soil nutrient pools and for plant growth. Fertiliser applications can result in losses when a) direct applications into waterways, and b) nutrients exceed plant requirements and are available in the soil to be lost in drainage events.

Table 3: Summary of Environmental actions tested across 16 case study farms

Topic	Environmental action	Sheep and Beef Case Study Farm(s)
Winter forage crops	Use winter stand-off pad for cattle to graze crop 6 hours a day then be held on a woodchip pad.	SB05, SB09, SB12, SB15
	Changing border dyke or k-line to more efficient irrigation systems	SB09, SB11, SB13
Irrigation	Changing border dyke and increasing irrigation area	SB09
	Using irrigation sensors for irrigation scheduling	SB09, SB13, SB14
	Eliminate any winter applied nitrogen fertiliser	No farms had any
Nitrogen fertiliser	Reduce nitrogen fertiliser applications and replace with lucerne baleage	SB01, SB02, SB05
	Reduce nitrogen fertiliser application rates to 30kg N/ha/yr by applying split applications	SB02, SB03, SB09
Tussock lands	Retire tussock areas	SB01, SB10, SB11, SB14, SB16
Farm system and land use change	Remove cattle and replace with sheep	SB01, SB05, SB07, SB08, SB10, SB12, SB15
	Remove cattle from steep areas	SB01, SB05, SB07, SB10, SB12, SB15
	Retire Class VI land from grazing and plant in exotics	SB08, SB10, SB11, SB15

2.3.3 Other environmental actions

In addition to the range of environmental actions tested in this research, there are other actions that are important tools for sheep and beef farms. These include management of CSAs and sediment traps.

2.3.3.1 Critical Source Area Management

The B+LNZ Farm Plan: Environment Module says the following about CSAs: "*areas in a paddock or on a farm that can contribute to relatively large amounts of nutrient and sediment losses to waterways*". They are often wet areas, such as gullies and swales, and where overland runoff converges sediment and nutrients can be transported (Figure 10). They may be wet or flow all the time or only occasionally during and after larger rainfall events or wet periods. Overland flow is the movement of water over the land, downslope toward a waterway, which can also carry contaminants to waterways such as sediment or faecal matter. "*A critical source area is the convergence of both a pollutant source and a transport pathway. The surface flow usually only occurs after a rainfall event to such a magnitude that water moves over the surface rather than draining through the soil*" (B+LNZ Farm Plan, Environment Module).

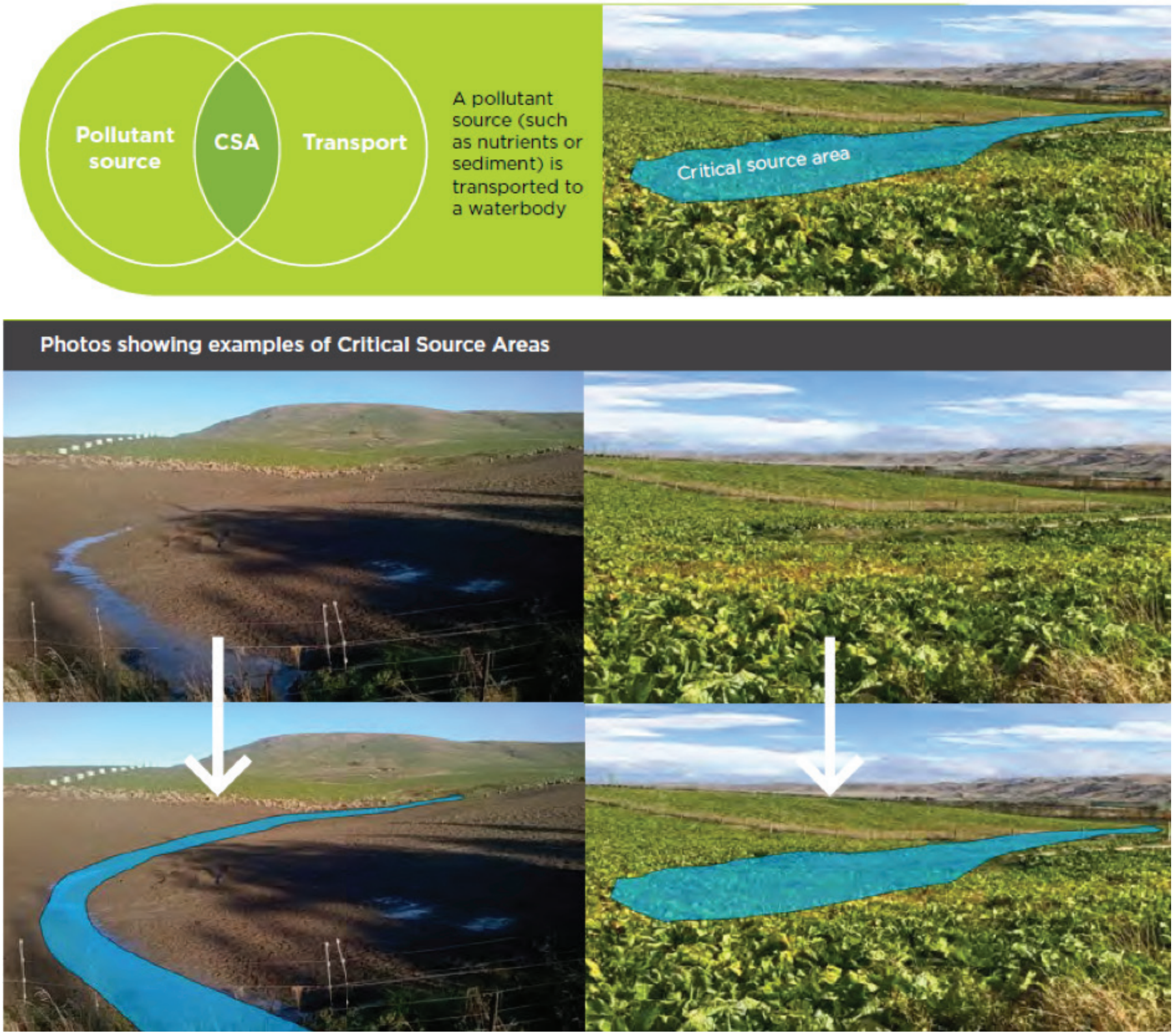

Figure 10: Critical source areas (CSAs)
Source: B+LNZ Farm Plan, Environment Module

Some environmental actions to help reduce the losses of contaminants from CSAs are:

- Identifying and isolating CSAs in winter crop paddocks and leaving these uncultivated and ungrazed;
- Fencing off CSAs and wet areas in a paddock to avoid soil damage, including temporary fencing during grazing events;
- Considering the slope of a paddock with a CSA before strip grazing (e.g., winter crop paddocks), and where possible, grazing should start at the top of the paddock working towards the CSA allowing uneaten crop to act as a buffer reducing contaminant transport into the CSA;
- Carefully managing livestock so that lighter livestock are grazed on higher-risk country at times when surface flows are occurring, e.g., not wintering cattle on steeper slopes; and
- Ensuring CSAs have vegetation established as ground cover.

2.3.3.2 *Sediment traps and constructed wetlands*

Common types of sediment trap on New Zealand livestock farms are:

a) Sediment settling ponds, which are areas either within a paddock or farm (or are situated 'edge of field') that store water that contains sediment and other contaminants; and
b) Sediment traps excavated into the bed of existing watercourses such as drainage ditches (Smith & Muirhead, 2023).

These traps collect and store the water for long enough to allow the sediment to settle before the water drains away through an overflow. A recent literature review relating to sediment traps found a wide range in effectiveness from 10 to 98 per cent (Smith & Muirhead, 2023).

Factors influencing the effectiveness of a sediment trap are:

a) The storage volume relative to the size of the catchment; and
b) The length of time the water is held in the trap giving the sediment time to settle.

Sediment traps need to be cleared of sediment on a regular basis.

Sediment traps are 'edge of field' technologies that are generally cost-effective alternatives on sheep and beef farms to constructed wetlands, which involve earthworks and capital investment, are designed for different purposes, and have a range of costs. The most expensive (on a per hectare basis) is usually those for treating nitrogen, which need sophisticated hydrological engineering to be effective. This type of wetland is not particularly relevant for sheep and beef farms because of their low nitrogen losses (all 16 sheep and beef case study farms in this research had a nitrogen loss of ≤15 kg N/ha/yr).

Constructed wetlands require expert guidance and support for development but can be effective for reducing phosphorus and sediment. However, the size of the wetland/s relative to the size of the catchment has a direct effect on the reduction of losses of phosphorus and sediment[86].

Constructed wetlands are estimated to reduce sediment loss by 50 to 90 per cent (Figure 11) and phosphorus loss by 25-50 per cent (Figure 12) depending on the size of the wetland in relation to the catchment area. The cost of a constructed wetland designed to remove nitrogen is estimated by NIWA/DairyNZ to be between $175,000 and $260,000 per hectare (excluding resource consent cost). This price will likely be prohibitive for some sheep and beef farmers. It may be completely unviable for some and impact farm profitability for others. However, if the wetland is not targeted at nitrogen losses. The range in impacts between farms of similarly costed environmental actions can be seen in the financial analysis contained in Section 2.5.

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86 NIWA has a useful online resource with guidelines for constructed wetlands *https://niwa.co.nz/freshwater/management-tools/restoration-tools/constructed-wetland-guidelines* that is also available in a NIWA/DairyNZ constructed wetlands guide (Tanner et al., 2022).

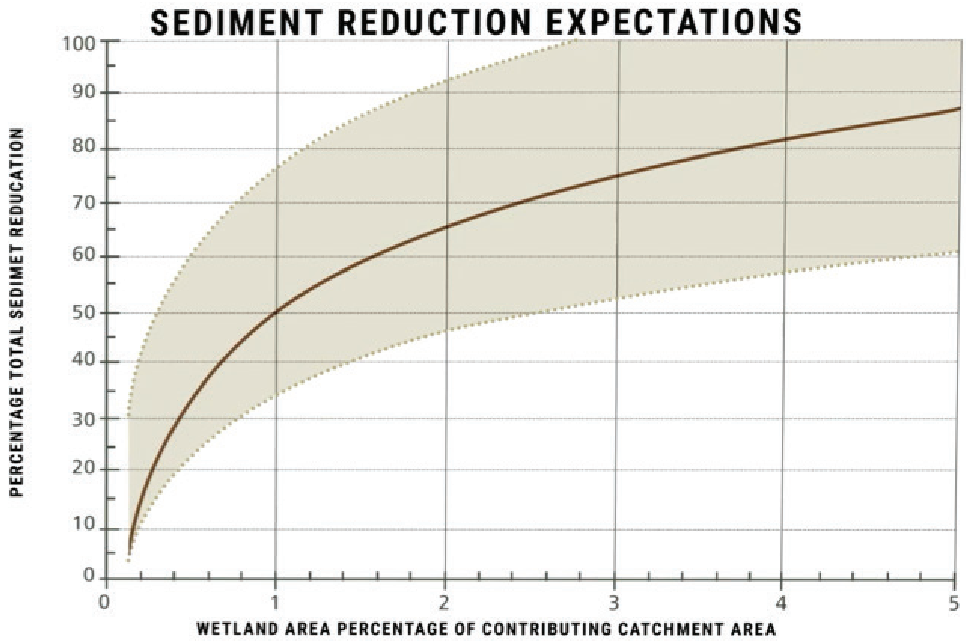

Figure 11: Sediment reduction expectations from a constructed wetland.
Source: NIWA website video https://niwa.co.nz/freshwater/management-tools/restoration-tools/constructed-wetland-guidelines

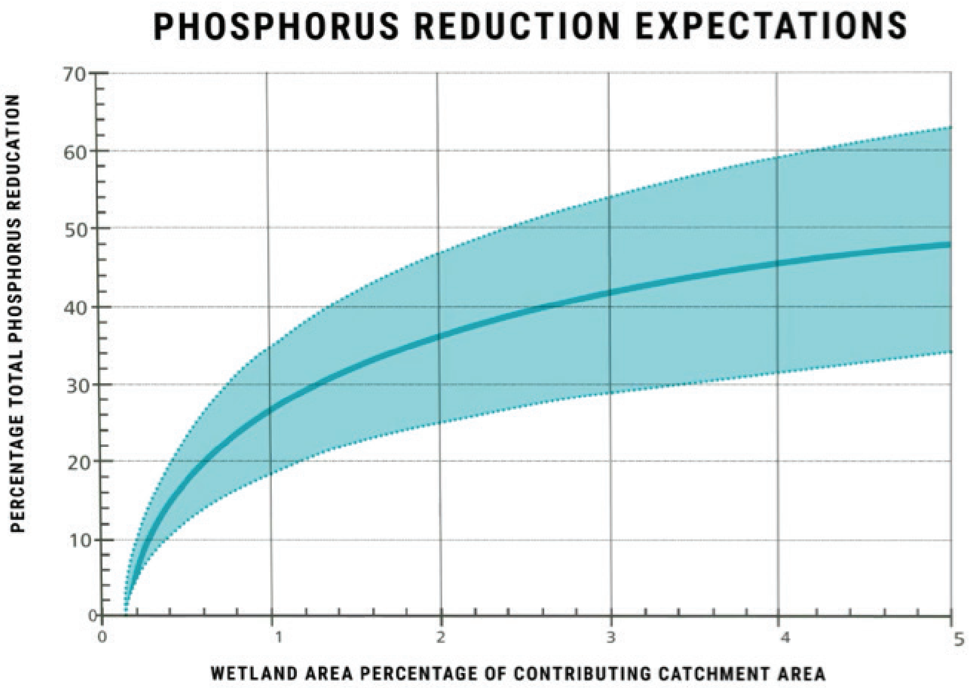

Figure 12: Phosphorus reduction expectations from a constructed wetland.
Source: NIWA website video https://niwa.co.nz/freshwater/management-tools/restoration-tools/constructed-wetland-guidelines

2.4 Sheep and Beef Farm Sample

As mentioned in the previous section, the sample of 41 sheep and beef farms described in this section consists of all the Otago farms included in the B+LNZ Sheep and Beef Farm Survey in 2020-21 (i.e., the Otago Survey). The B+LNZ Sheep and Beef Farm Survey has been conducted annually since 1950, having been established following the New Zealand Government's 1949 Royal Commission that was instructed to *"Inquire Into and Report Upon the Sheep-Farming Industry"* (following a post-WWII investigation)[87]. It is now over 70 years old, making it one of the longest running such primary sector surveys in the world. Time series information for Otago was presented in "Chapter 3: Sheep and Beef Cattle Farming" (Fisher & Burtt, 2022) of the Farmers and Growers in Otago Report (Moran, 2022).

In agriculture, most distributions of physical metrics are 'skewed' rather than being a 'normal' or 'bell-shaped' curve. A key example is the distribution of farm size (by stock units) in the New Zealand sheep and beef farming industry (Figure 13). Importantly, each farm characteristic has its own distribution and the seemingly endless combinations of these multiple distributions across farms are explanatory for the complex range of impacts of policy. There is a distribution around each of the average figures in the time-series information presented for sheep and beef farming (Fisher & Burtt, 2022) in the Farmers and Growers in Otago report.

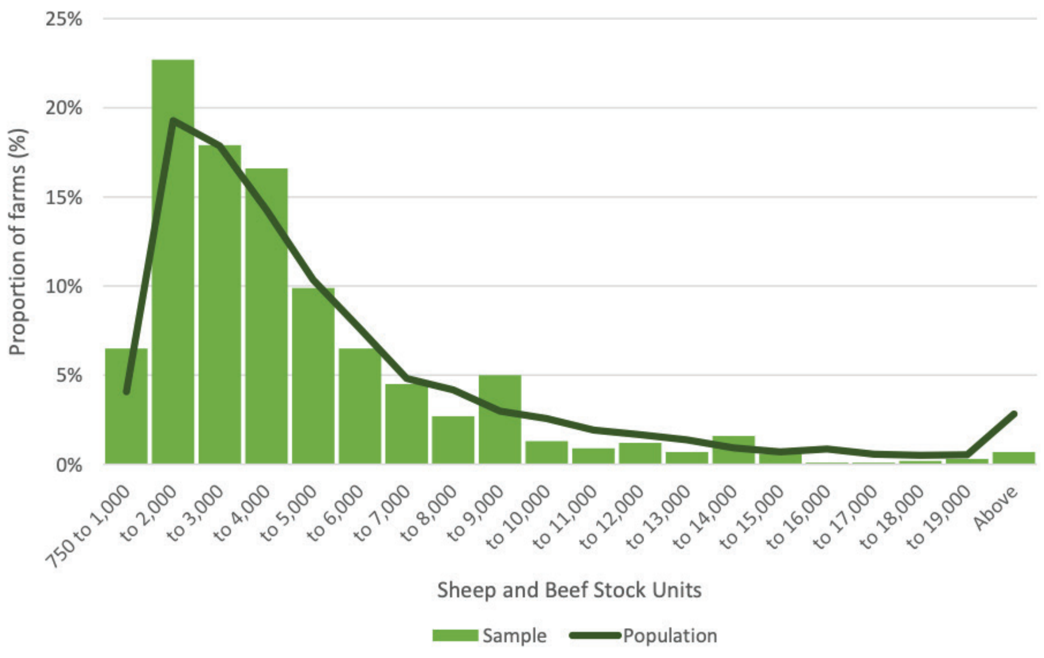

Figure 13: Distribution of the Population of Commercial Sheep and Beef Farms and the Sample in the B+LNZ Sheep and Beef Farm Survey
Source: B+LNZ

In Otago, few (if any) sheep and beef farms are on a single soil type or slope or are limited to one stock class. The most populous farm class in Otago is Farm Class 6: South Island Finishing and Breeding. In those parts of the region where natural rainfall limits pasture growth, the difference between a Farm Class 6 farm and a Farm Class 2 farm is sometimes the presence of irrigation, at least on part of the farm.

87 In its inquiry, the Royal Commission found that "*there is considerable division of opinion with no unchallenged premises of facts from which deductions could be safely made to formulate conclusions and proposals*". The recommendations included the amalgamation of the then Meat and Wool Boards and to collect and document "*factual information*" concerning farm production and economics.

2.4.1 Farm size and topography

The farms within the Otago Survey for 2020-21 were extremely diverse, particularly in size, mix of topography, and availability of water (either as rainfall or irrigation), reflecting the varying nature of the landscape across the region. The largest farms in the region are Farm Class 1 High Country farms, which range within the sample from around 1,500 grazeable hectares to well over 5,000 grazeable hectares (specific size is protected for confidentiality), followed by Farm Class 2 Hill Country farms, which range from almost 500 hectares to in excess of 2,000 hectares Farm Class 6 farms range from under 200 hectares to around 1,000 ha. The smallest farms, in terms of grazeable area and total farm area, are Farm Class 7 farms which range within the sample from around 250 hectares to 500 hectares.

There are overlaps in size between farm classes as categorisation into farm class depends on more factors than just physical size (e.g., climate, topography, and the way in which the farms are managed and farmed as businesses). For this report, farms have been grouped by size and are referred to as smaller, medium-sized, and larger farms (Figure 14). Around 30 per cent of the farms had a 'grazeable' area of 1,000 hectares or more[88] (larger farms). At the other end of the size scale, 20 per cent of the farms had a 'grazeable' area of 299 hectares or less (smaller farms). The medium-sized farms, with a grazeable area of 300 to 1,000 ha, form the remaining half of the farms in the Otago Survey.

Grazeable area (historically referred to as 'effective area') includes all pasture areas, scrub and matagouri, tussock, house, and curtilage[89] (plus other farm cottages), yards, roads, tracks, races, shelter belts and dams. To preserve privacy agro-forestry is not explicitly shown for individual farms in this analysis[90]. In practice, some parts of a farm that are categorised as 'grazeable' may not be grazed by livestock, while other areas may be grazed infrequently or at low stocking rates (e.g., grazing hoggets[91] in a tussock block for one month in spring). Total farm size is not reported to help maintain the confidentiality of those involved. Other details about the farms in the Otago Survey are presented as either percentages or on a 'per hectare' basis for the same reason.

Pasture production varies between farm classes, which are classifications of like farms (as explained in Appendix 1 of this chapter), and between farms, with improved pasture species such as ryegrass and clover comprising greater areas of the farm for finishing farms and finishing and breeding farms. Unimproved pasture species such as brown top and tussock may cover considerable proportions of high and hill country farms and these pasture species, in combination with rainfall or irrigation, directly affect potential pasture production and the carrying capacity of the farm for livestock.

88 This delineation was based on similar research in Southland, which found that farms above this size tend to operate differently from farms below this size (Moran et al., 2017) and can have more options available to them because of their scale (Moran et al., 2022). However, differences in climatic conditions between the two regions, particularly in precipitation, may mean that this is not necessarily the case in Otago.

89 The land immediately surrounding and associated with a farm's house/main dwelling.

90 Agroforestry is an area of forestry on farm where livestock may graze beneath. Over time as the canopy closes and grazing diminishes, the agro forestry area is transferred to forestry.

91 When a lamb is weaned off its mother it is called a hogget. By sixteen months it should have two teeth then called two-tooths. They grow two teeth each year. When a sheep is fully grown has eight teeth. A sheep lives about seven years. You can have a paddock of ram hoggets or ewe hoggets or mixed hoggets.

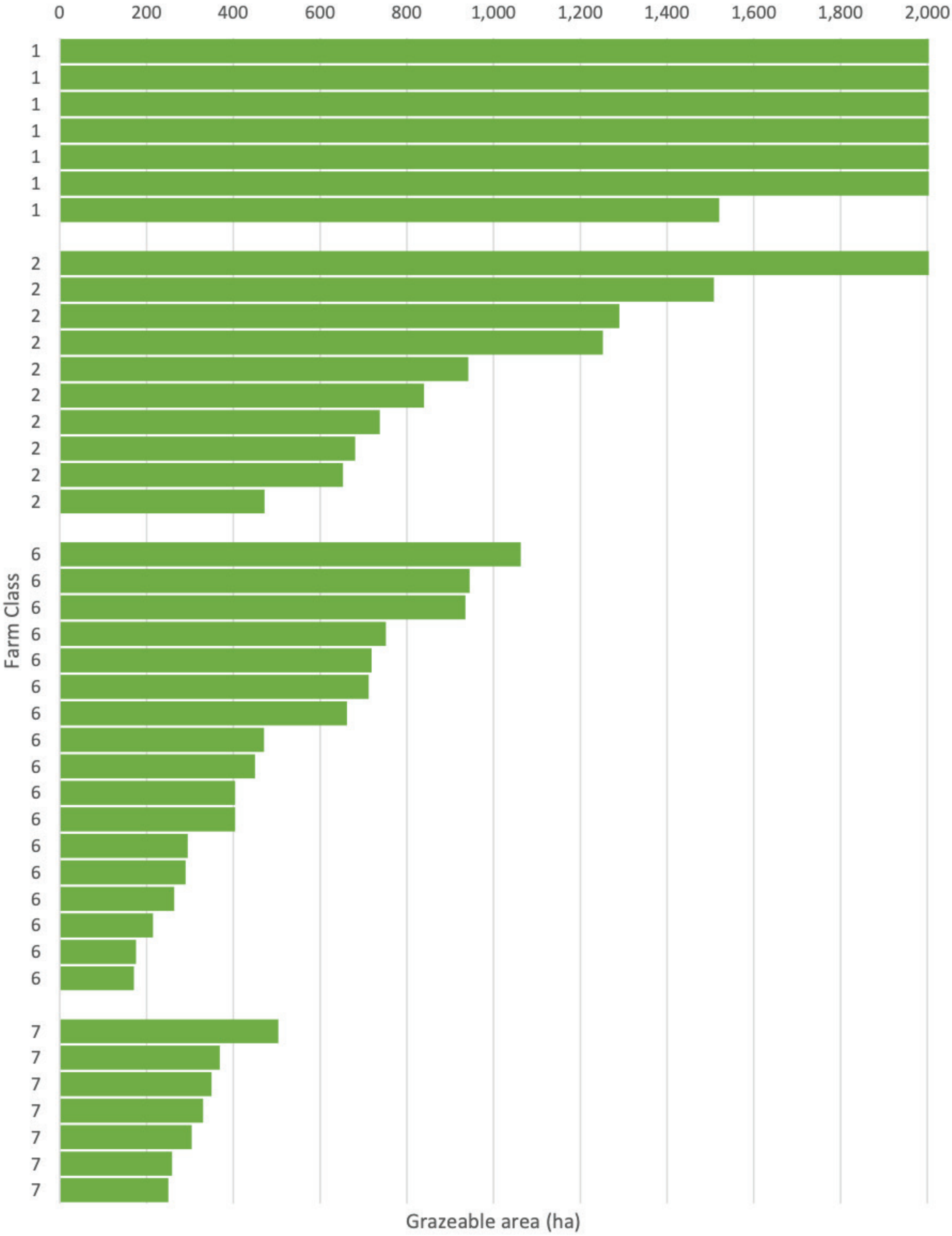

Figure 14: Distribution of farm size (grazeable ha) across 41 Otago sheep and beef farms 2020-21
Source: B+LNZ Sheep and Beef Farm Survey
Note: Farms are grouped by B+LNZ Farm Class in the graph.

Image 8: Mixed age crossbred ewes making for a challenging muster coming down off Rough Ridge before winter snowfall. Source: Emma Crutchley

Importantly, almost all 41 sheep and beef farms in the Otago Survey had a mixed topography of flat, rolling, and steep land, although the proportion of steep land varies between farm classes (Figure 15) . These farms had proportions of flat land ranging from nil to 100 per cent, and steep land ranging from nil to 95 per cent. Two farms had 100 per cent flat land, one of which is a Farm Class 7 farm, which is within the classification for a finishing farm as these farms tend to be mostly flat to rolling country.

Farm Class 1 High Country farms tend to have a greater proportion of steep land, and a smaller proportion of flat land, compared with farms in other farm classes. The carrying capacity of these farms is lower, they grow less pasture and consequently have lower pasture production and carrying capacity, carry less livestock, and are usually not able to finish stock because they do not have sufficient flat land (which tends to equate to high quality and quantity of pasture production). The area of steep land on High Country farms in the Otago Survey was typically thousands of hectares.

Farm Class 2 Hill Country farms have characteristics that result in limitations to pasture production. For example, one is completely flat but low annual rainfall constrains its livestock production and therefore the farm system is designed to suit its environment. If this farm had access to water for irrigation, then it would likely be classed as Farm Class 6. On average, 46 per cent of the land on Farm Class 2 Hill Country farms in the Otago Survey was classified as steep, though 86 per cent of one was steep.

Farm Class 6 Breeding and Finishing farms are mostly rolling with flat areas ranging from 0 to 40-45 per cent of the farm. Steep land is also part of the character of these farms with most in the Otago Survey having more than 25 per cent of total area classified as steep. This has implications for pasture production and carrying capacity. Steep land ranged from around 50 hectares at the lower end through to five farms having in excess of 400 hectares.

Farm Class 7 Finishing farms are high-producing grassland farms and typically have flat to rolling land enabling higher stocking rates, improved pastures, and cropping. These farms are usually located in south and coastal east Otago. Most of the Otago Survey farms had some steep land within their farming operation, ranging from 20 hectares to around 60 hectares.

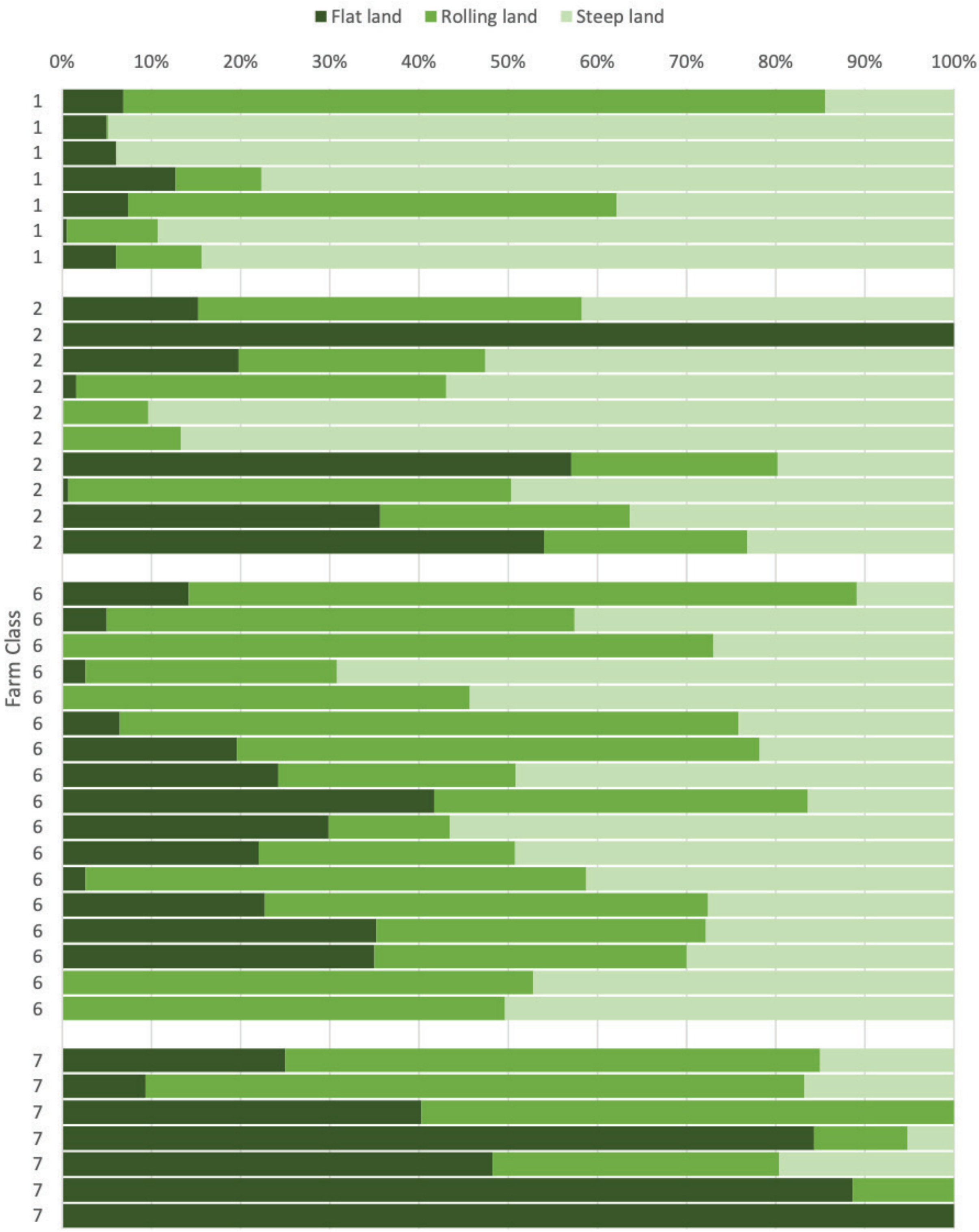

Figure 15: Topography on 41 sheep and beef farms in Otago
Source: B+LNZ Sheep and Beef Farm Survey

2.4.2 Farm management

2.4.2.1 Overview

The biophysical constraints of the land influence grazing and all key farming decisions. Steeper country is grazed lightly in comparison with 'the flats', and for Farm Classes 1, 2 and 6 there may be substantial proportions of the farm that are steep and have low stocking rates. Unimproved pastures including tussock and brown top, which are lower-yielding species, are prevalent on high country and hill country farms with the result being low stocking rates on those areas (which is most of the farm for some).

For larger-scale farms, tussock, matagouri and scrub are valuable for biodiversity, soil retention, and some sequestration. Scrub and tussock are included in grazeable area and may be lightly grazed at certain times of the year (often referred to as 'seasonal grazing'). Scrub is often used on many farms for livestock as shelter from inclement weather, which is especially important during lambing, and shade from the summer heat. Although grazing of these lower-yielding areas may be infrequent during the year, they are nonetheless an important part of the farming operation providing additional feed, shelter, and greater flexibility and resilience in farm management.

Farmers use areas of scrub and matagouri on a farm to provide shelter for sheep during snow events and shade from summer heat. Pasture continues to grow underneath matagouri as it only lightly shades plant species beneath it. Matagouri, like legumes, is a nitrogen-fixing plant that benefits surrounding vegetation. It also offers protection for native fauna, such as lizards and nesting birds. Matagouri and scrub benefit from infrequent livestock grazing.

The areas identified as 'ungrazed/other' consist of indigenous/native forest, mānuka, areas covered by a QEII covenant[92], Ngā Whenua Rāhui[93] areas, lakes, ponds, wetlands, riparian areas, rock, scree, sand, any other permanently non-vegetated areas, and land permanently set aside from grazing. More than one third of Otago Survey farms had ten per cent or more of their total farmland categorised as 'ungrazed/other'.

Stocking rates[94] are lower on larger farms, and relatively higher on smaller operations that have improved pasture species and a greater proportion of flat land. For 2020-21, stocking rates, which by convention are measured at mid-winter when pasture production is at its lowest, averaged 1.6 SU/ha[95] for Farm Class 1 High Country farms, 5.7 SU/ha for Farm Class 2 Hill Country farms, 8.4 SU/ha for Farm Class 6 Finishing and Breeding farms, and 11.1 SU/ha for Farm Class 7 Finishing farms. The Otago Survey farms in Figure 16 are ordered from lowest to highest stocking rates. Stocking rates on the most populous farm class – Farm Class 6 Finishing and Breeding farms – varied because those with access to water or in wetter areas tend to have a higher stocking rate than 'dryland' farms where water is more limited (but not to the extent of the limitations for Farm Class 2).

92 Land covered by such covenants is "forever protected" under the QEII National Trust. *https://qeiinationaltrust.org.nz/*
93 Ngā Whenua Rāhui is a Department of Conservation (DOC) fund that provides protection for Māori landowners through 25-year renewable kawenata. *https://www.doc.govt.nz/get-involved/funding/nga-whenua-rahui/*
94 By convention, per-hectare stocking rates are calculated, and refer to, using grazeable area.
95 SU/ha = stock units per hectare (grazeable)

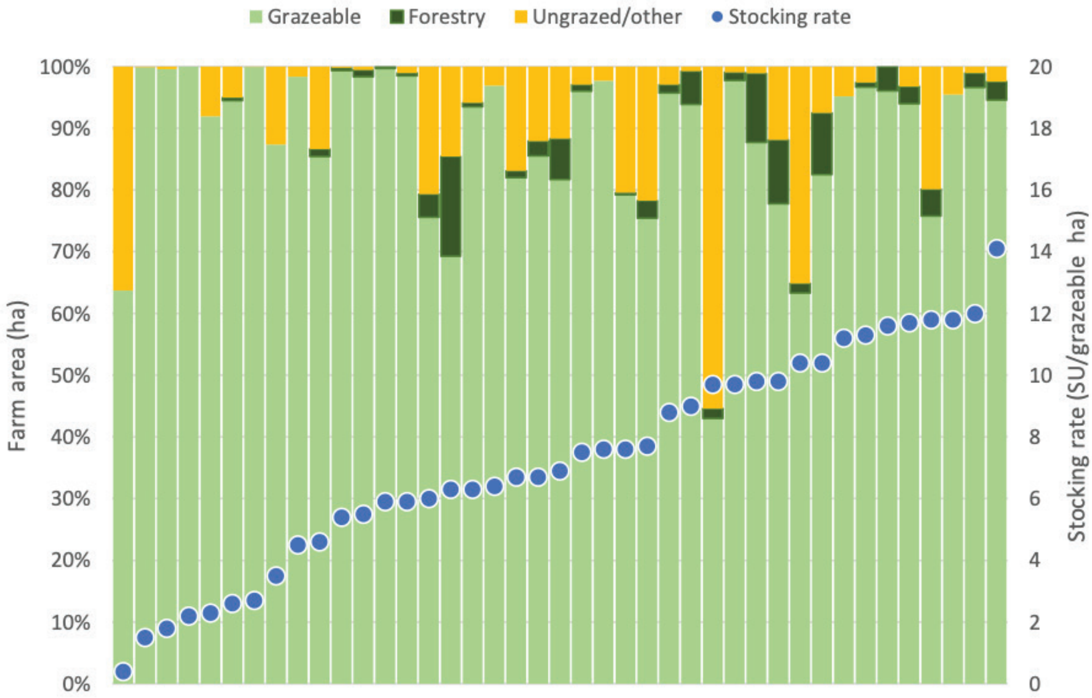

Figure 16: Grazeable land and stocking rates on 41 Otago sheep and beef farms 2020-21
Source: B+LNZ Sheep and Beef Farm Survey

2.4.2.2 *Forestry*

Seventy per cent of the 41 farms in the Otago Survey in 2020-21 included forestry[96] (Figure 16). The total area of forestry on each farm ranged from two hectares to over 500 hectares. Forestry was found on almost all the Otago Survey's Farm Class 6 farms, and most of the Farm Class 2 and 7 farms.

Establishing both native and exotic plantings is challenging for farms in drier areas. Higher altitude farms face further difficulties due to the cooler climate and, in some districts, planting of exotic trees may be banned or limited by regulations that endeavour to preserve natural features and/or landscape in a district.

Three farms in the Otago Survey had agro-forestry areas where livestock graze beneath the trees. As the trees grow, and the tree canopy closes, grazing diminishes, and these areas may be transferred to forestry or ungrazed area over time depending on the type of plantings and farmer intentions. For confidentiality, the agro-forestry area is included with forestry in Figure 16.

96 Exotic forestry tended for woodlot production and not grazed.

Image 9: Ettrick hill country sheep farm.
Source: Simon Moran.

2.4.2.3 *Livestock and Stocking Rates*

Sheep and beef farms in Otago predominantly carry sheep, although over time there has been a change in the ratio of sheep to cattle (numbers) towards an increased proportion of cattle. This change has been more pronounced on some farm classes than others with the ratio on high country farms relatively steady over time. Hill country and finishing and breeding farms have shifted towards cattle with relative gains to be made in selling beef cattle and to mitigate the continued decline in wool prices. Sheep also require a greater level of management and labour than cattle. Finishing farms tend to have a high proportion of sheep with few beef cattle and occasionally deer. Finishing farms are adaptable to market and climatic conditions, which influence their stocking decisions.

In Figure 17 livestock classes across the Otago Survey farms are shown in stock units on 1 July 2020 (i.e., 'at open' or the start of the production season, which runs from 1 July until 30 June). The farms had a mix of livestock classes dominated by sheep. One farm had only sheep, while two had only sheep and deer with no cattle. While two farms had only dairy cattle "at open", during the season a total of four farms received revenue from dairy grazing, which indicates movement of animals during the year. Dairy grazing in Otago is an important source of revenue for some sheep and beef farmers. Ten per cent of the Otago Survey farms had dairy grazing in 2020-21. The proportion of farms with dairy grazing revenue has fluctuated between zero and 11 per cent during the period from 2010-11 to 2020-21 (typically closer to 10%) and is influenced by farm policy decisions and, on occasion, changes in the sample for Otago used in the B+LNZ Sheep and Beef Farm Survey[97].

97 The Sheep and Beef Farm Survey sample of farms is continually being refreshed with individual farms surveyed for an average of about seven years, which means trends are well measured.

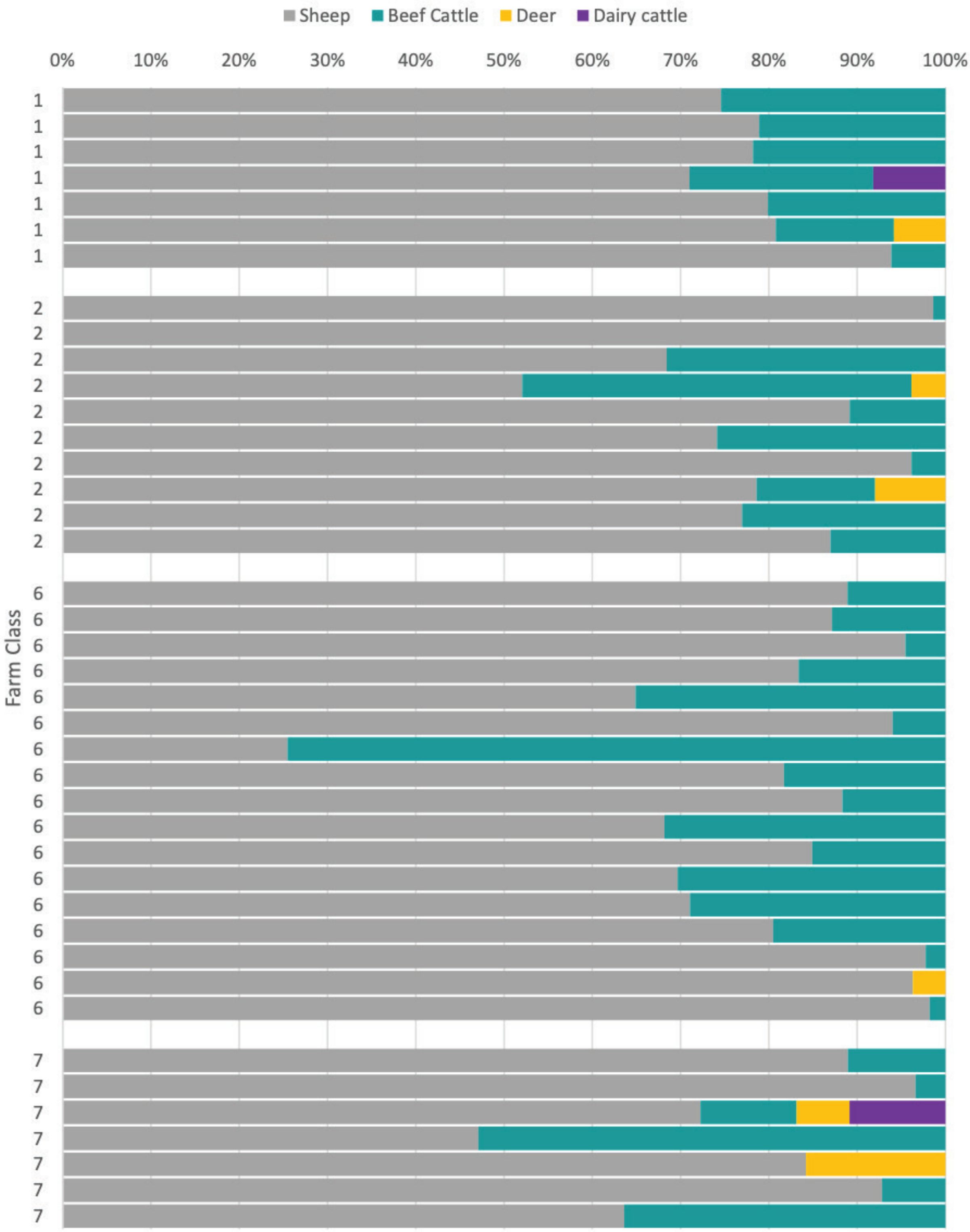

Figure 17: Livestock mix (using stock units) on 41 Otago sheep and beef farms 2020-21
Source: B+LNZ Sheep and Beef Farm Survey

2.4.2.4 Crops for Feeding Livestock

All but one of the 41 Otago Survey farms had an area on farm for winter feed in 2020-21, ranging in size from three hectares to over 200 ha (Figure 18). One farm, a steep hill country farm, had no specific area utilised for winter cropping, which is likely due to the topography of the farm, however some feed was purchased, which may have covered winter feed requirements. Two large farms had in excess of 200 hectares of winter feed cropping, but these areas were less than ten per cent of the farms' grazeable area. Four of the 41 farms grazed dairy cattle (cows and heifers) in 2020-21 and increased feed requirements in winter would necessitate crops (or some other supplementary feed).

For the 41 farms in the Otago Survey in 2020-21, there was no clear relationship between stocking rates and winter grazing area (as a percentage of total grazeable area). Consequently, there is a need for alternative feed sources in winter, including supplementary feed produced and conserved on-farm, as pasture growth halts and levels of pasture fall during long winters.

Drystock farms predominantly farm to the grass growth curve. This type of production system means that the amount of pasture that can be grown, and the times of year that it grows, dictate the livestock numbers carried and the type of system operated.

Forty of the 41 farms grew winter feed – i.e., for livestock in winter. Winter feed area as a percentage of grazeable area ranged from less than one per cent to just under 15 per cent (though winter feed area exceeded ten per cent of grazeable area on two farms). Nine farms had 50 or more hectares in winter feed area in 2020-21. Typically (but not always) new grass follows a winter feed crop. The exception is 'grass to grass' where pasture may be direct drilled to reduce cultivation of soil.

There is a range of cropping behaviours in the Otago Survey farms. While almost all farms had winter crops, around one-quarter also had summer crops in 2020-21. These summer crops are used to mitigate against dry conditions and were used by farms from all farm classes with a decent proportion of suitable (flat or rolling) land.

Image 10: Shorn mixed age ewes welcoming a fresh break on a sunny July morning.
Source: Emma Crutchley

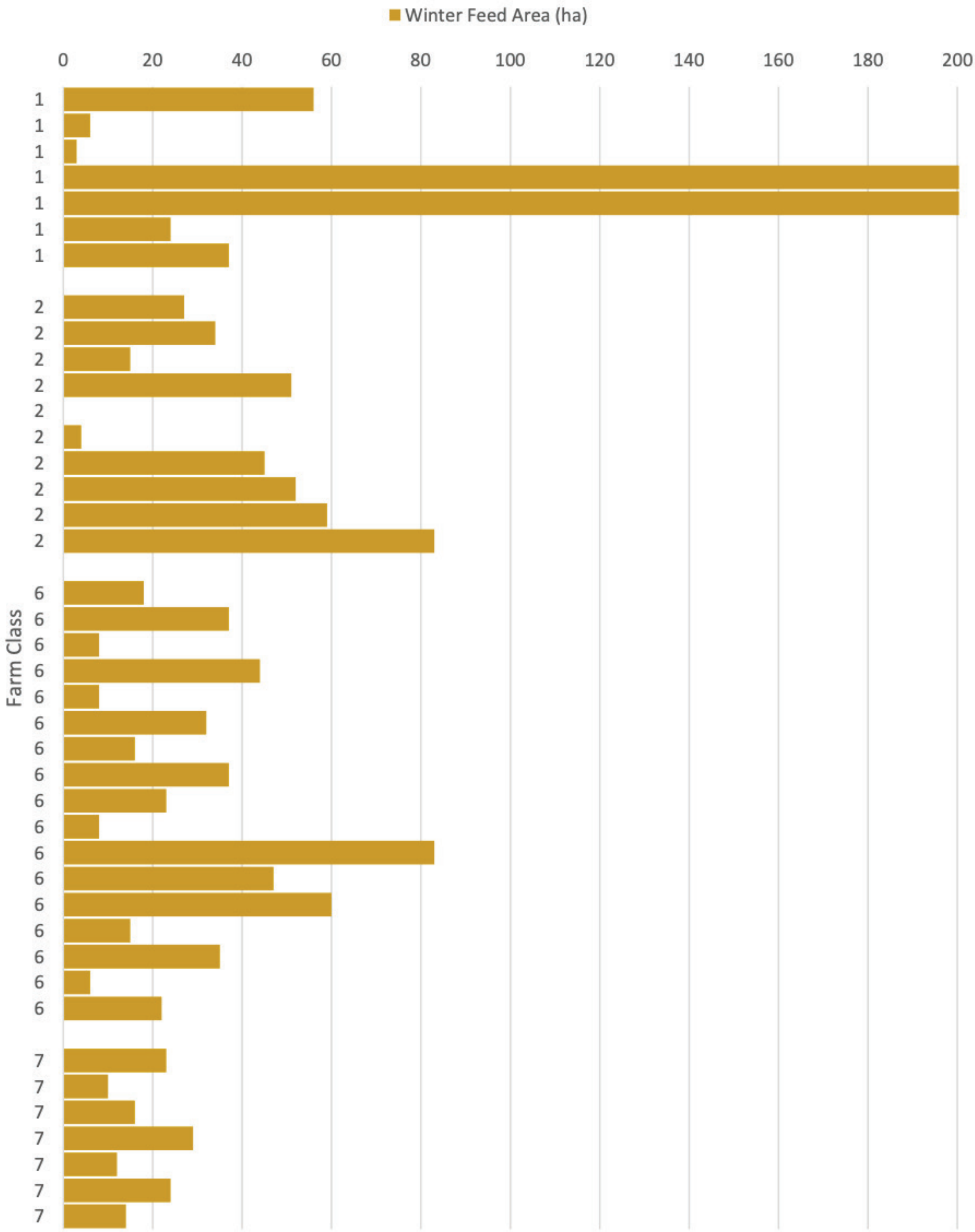

Figure 18: Land area used for winter feed on 41 Otago sheep and beef farms 2020-21
Source: B+LNZ Sheep and Beef Farm Survey

2.4.2.5 Fertiliser Applications

Plants need nutrients to grow. Nutrients are needed to grow crops for grazing of livestock in winter and planting of winter crops occurs generally in late spring and in February in Otago. Fertiliser use on Otago sheep and beef farms is low and targeted to supply nutrients to crops, pasture renovation (re grassing), or to boost pasture on silage paddocks (to a lesser degree). Maintenance fertiliser is also commonly applied to pasture, especially areas of improved pasture species, to support pasture production.

Fertiliser applications vary between seasons due to climatic conditions, soil fertility, fertiliser prices, production objectives, regulations, and revenue considerations. Sheep and beef farmers tend to apply maintenance levels of phosphorus fertiliser on pastures and very little nitrogen fertiliser (using it tactically). Usage of fertiliser on crops is more variable but is typically higher. Crops require nutrients to grow, and for high yields – young crops and new pasture are very efficient at using fertiliser as they mature.

In this analysis, fertiliser applications are average applications per hectare for 2020-21 to **applied areas,** not to the grazeable area. Fertilised pasture area ranged from zero to 97 per cent of grazeable area, with Farm Classes 6 and 7 more likely to apply fertiliser to larger proportions of pasture areas – around 70 per cent of grazeable area on average – than Farm Classes 1 and 2. **Fertiliser applications are not equal to nutrient losses.**

Over half of the 41 farms in the Otago Survey applied 20 kg of phosphorus per hectare per year (kg P/ha/year) or less to the area of pasture that was fertilised in 2020-21. The amount of phosphorus applied ranged from 10 kg P/ha/yr to 75 kg P/ha/yr. Nitrogen applied to crops averaged around 60 kg N/ha in 2020-21, with three-quarters of farms applying under 80 kg N/ha. The amount of fertiliser applied to pastures is below 30 kg/ha for both phosphorus and nitrogen for most of the Otago Survey farms in 2020-21 (Figures 19 and 20). Around 30 per cent of farmers used less than 10 kg N/ha/yr on pasture (Figure 20).

It makes no economic sense for a farmer to apply fertiliser in a manner that effectively results in losses of the nutrients that the farmer has paid for. Direct losses of phosphorus from fertiliser applications can occur if application occurs shortly before a rainfall event large enough to cause surface runoff, if application rates exceed plant requirements, and if a more readily available form of phosphorus fertiliser is used. Generally, losses of phosphorus are related to phosphorus levels in the soil above agronomic optimum (measured using Olsen P), which is not generally something that occurs on extensive sheep and beef farms. In addition, the use of Farm Environmental Plans and relationships with fertiliser company advisors when they identify the areas of risk and opportunity related to an individual farm have helped ensure that fertiliser applications are managed effectively.

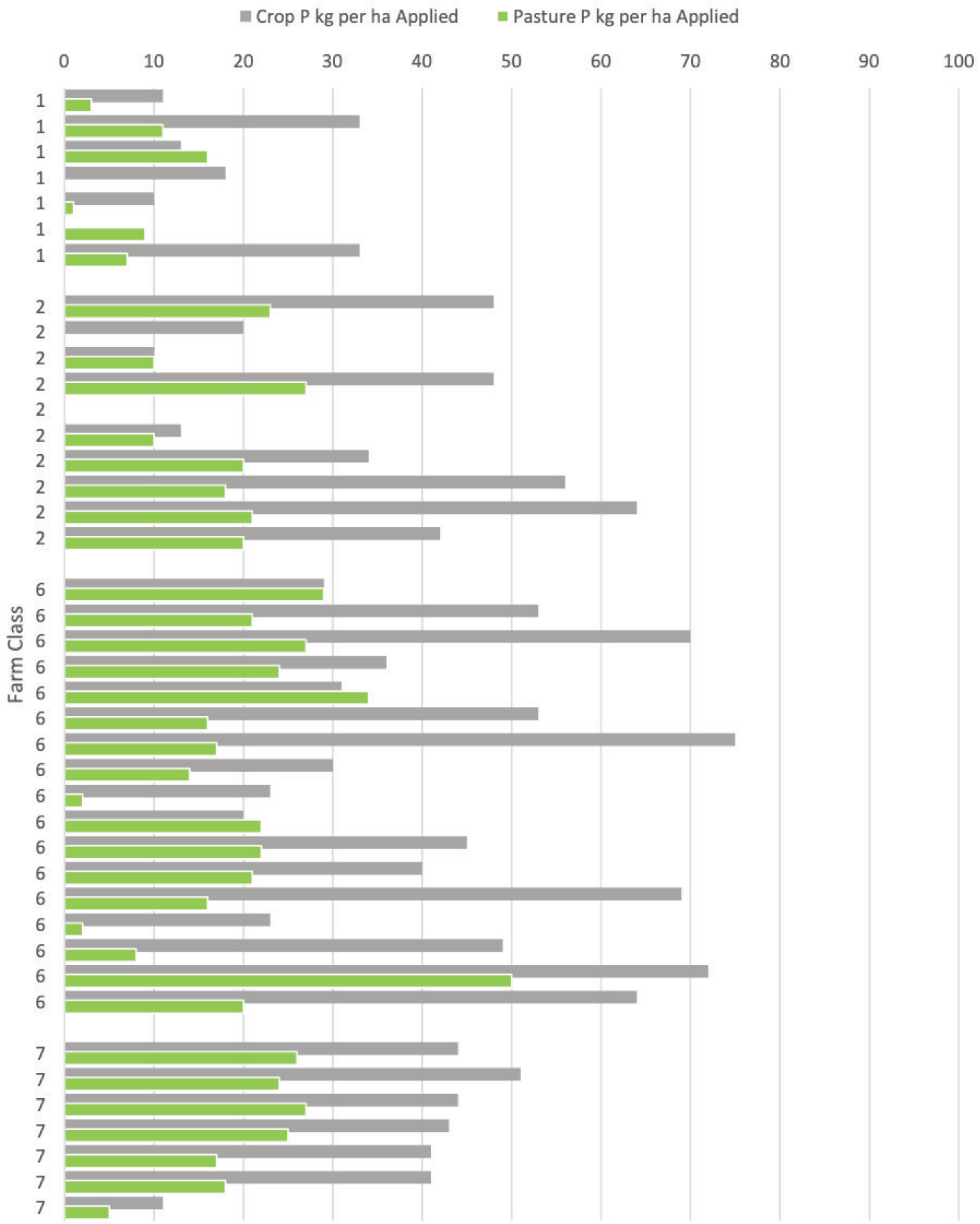

Figure 19: Use of phosphorus fertiliser on 41 Otago sheep and beef farms 2020-21
Source: B+LNZ Sheep and Beef Farm Survey

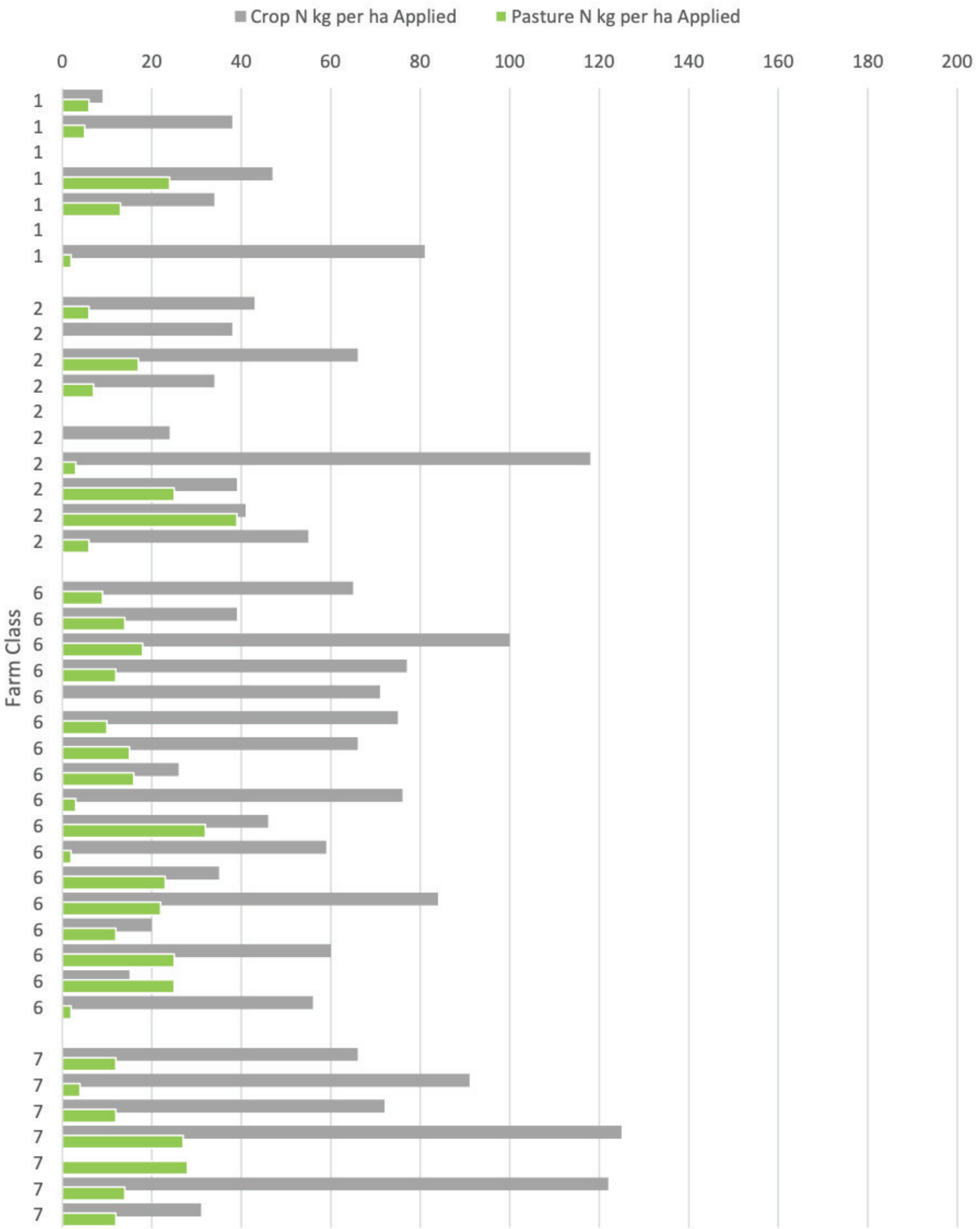

Figure 20: Use of nitrogen fertiliser on 41 Otago sheep and beef farms 2020-21
Source: B+LNZ Sheep and Beef Farm Survey

Applications of fertiliser to crop tend to be more variable between farms than those of applications to pasture (Figure 21). This circumstance could be related to different crop types, different potential yields, and variable soil fertility and consequently nutrient requirements.

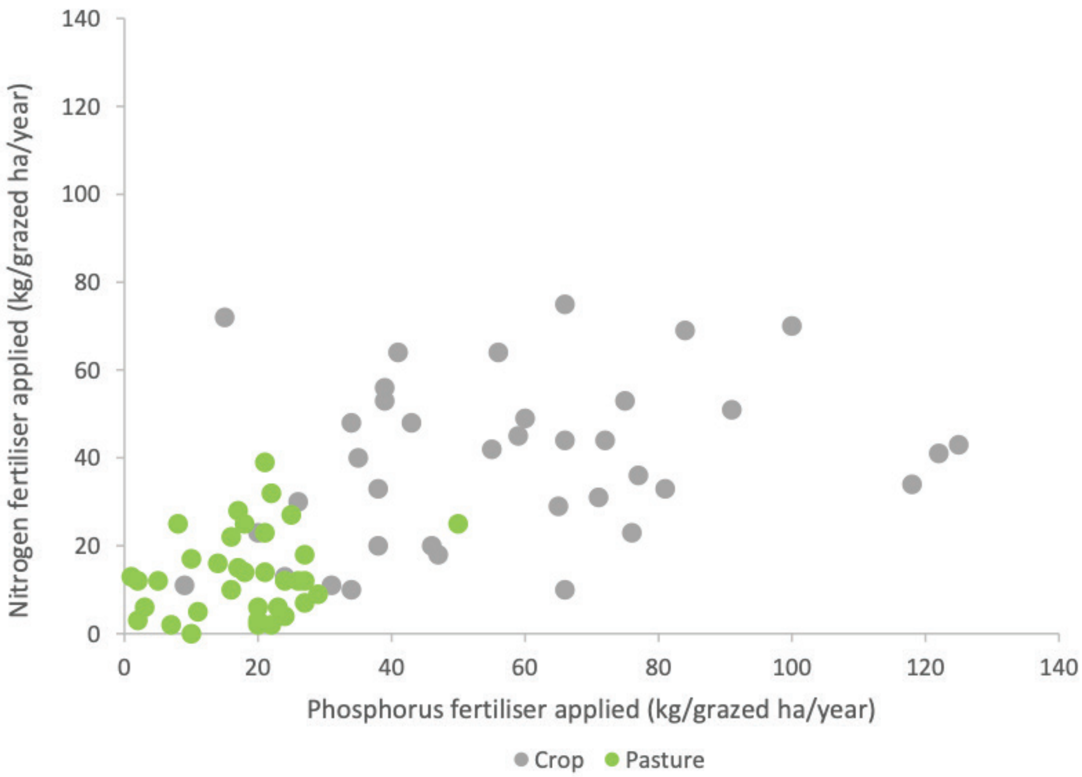

Figure 21: Use of nutrients on 41 Otago sheep and beef farms 2020-21
Source: B+LNZ Sheep and Beef Farm Survey

2.4.3 Farm finances

2.4.3.1 Revenue

Typically, sheep and beef farms have multiple revenue streams to manage risk from market volatility and climatic conditions. These multiple revenue streams, and the way that different livestock classes complement each other and interact, mean the farm businesses are complex to operate, analyse and understand. It also means they are diverse: two neighbouring farms of similar size with similar topography and climate may run very different farming operations despite appearing similar from the outside. In Otago, the industry is more heavily influenced by sheepmeat and wool than in other parts of New Zealand, as farmers have developed their farming systems considering financial and physical factors and constraints – such as topography, climate, pasture production, and natural benefits from running predominantly sheep-based operations.

Integration between sheep and beef farms within the industry and with other sectors is important for successful farm operations. Finishing farms need other farms to breed sheep and cattle for them to purchase, and vice versa for a hill- or high-country breeding operation, creating a dependency between farm businesses. Dairy farms may graze young stock or winter cows (or both) on sheep and beef farms and may purchase supplementary feed grown on sheep and beef farms. Revenue from crops and dairy grazing can be considerable for some operations. Four farms in the Otago Survey earned dairy grazing revenue in 2020-21. Most farms harvested hay or silage during the season and one-third of Survey farms sold hay. Generally, the hill country and finishing farms had surplus feed to sell.

The sale of fine wool is a large revenue stream for high-country farms, in particular, and for some hill country farms. Revenue from wool ranged from less than $2,000 to more than $700,000 per farm in 2020-21. Revenue from wool is depicted in Figure 22, while expenditure on shearing is shown in Figure 23 (on page 74). Expenditure on shearing exceeded revenue from wool for around 60 per cent of sample farms in 2020-21. Expenditure on shearing exceeded revenue from wool on all Farm Class 7 farms and most Farm Class 6 farms. Prices for strong wool, which is found on most sheep breeds in the region, are low by historical standards while per-head shearing costs have increased markedly.

At a national level, shearing expenses were equivalent to around $4.20 a head in 2016-17. In 2018-19, they jumped by $1.10 a head (on average) and the upward trend has continued. In 2022-23, shearing expenditure is forecast to be around $5.75 a head – up nearly 40 per cent on six years earlier. Shearing is essential for animal welfare and has come to be seen as a necessary expense for most sheep and beef farms rather than part of a revenue-earning enterprise. The exception is fine wool enterprises, which is a sector where wool prices are stronger than for crossbred wool.

Revenue from sheepmeat is the main source of income for sheep and beef farms in the region though on average 20-25 per cent of gross farm revenue on high country farms is from wool. A concentration on fine wool sheep breeds and an ideal climate for sheep that thrive at higher altitudes and in dry underfoot conditions, and which produce fine wools, means these farms earn most of their wool revenue from the sale of fine wools.

Half the Otago Survey farms earned ten per cent or less of their revenue from beef cattle in 2020-21. Farmgate prices for cattle have strengthened since 2020-21, the season for which this analysis was done, and cattle revenue will have become more important to sheep and beef farmers since then. With volatility in market prices, having multiple revenue streams increases the financial resilience of the operation. An example of the volatility of farmgate prices is wool prices, as discussed above and which fell to historic lows in 2020-21 for medium to strong wool types (impacting most farmers with crossbred sheep). Beef cattle revenue allows farmers to offset or buffer against low sheepmeat prices. Beef cattle also play an important role in farm management practices, often ‘cleaning up’ pastures following sheep grazing and as a part of parasite management.

As noted previously, four farms had earned income from dairy grazing, with one farm wintering cows and all four had annual revenue from grazing young dairy heifers. Six sheep and beef farms sold deer and/or velvet in 2020-21, a lossmaking exercise for one farm (depicted with a negative yellow bar in the revenue streams graph). Finishing farms (Farm Class 7), which tend to be relatively flat and have the smallest average area within the region, grow fodder crops for their own livestock but some farms also grow cash crops or sell. Within the 41 farms, one finishing farm had crop revenue (i.e., cash crops) of around 35 per cent of gross farm revenue in 2020-21. Its main revenue source was sheep (around 50% of total revenue).

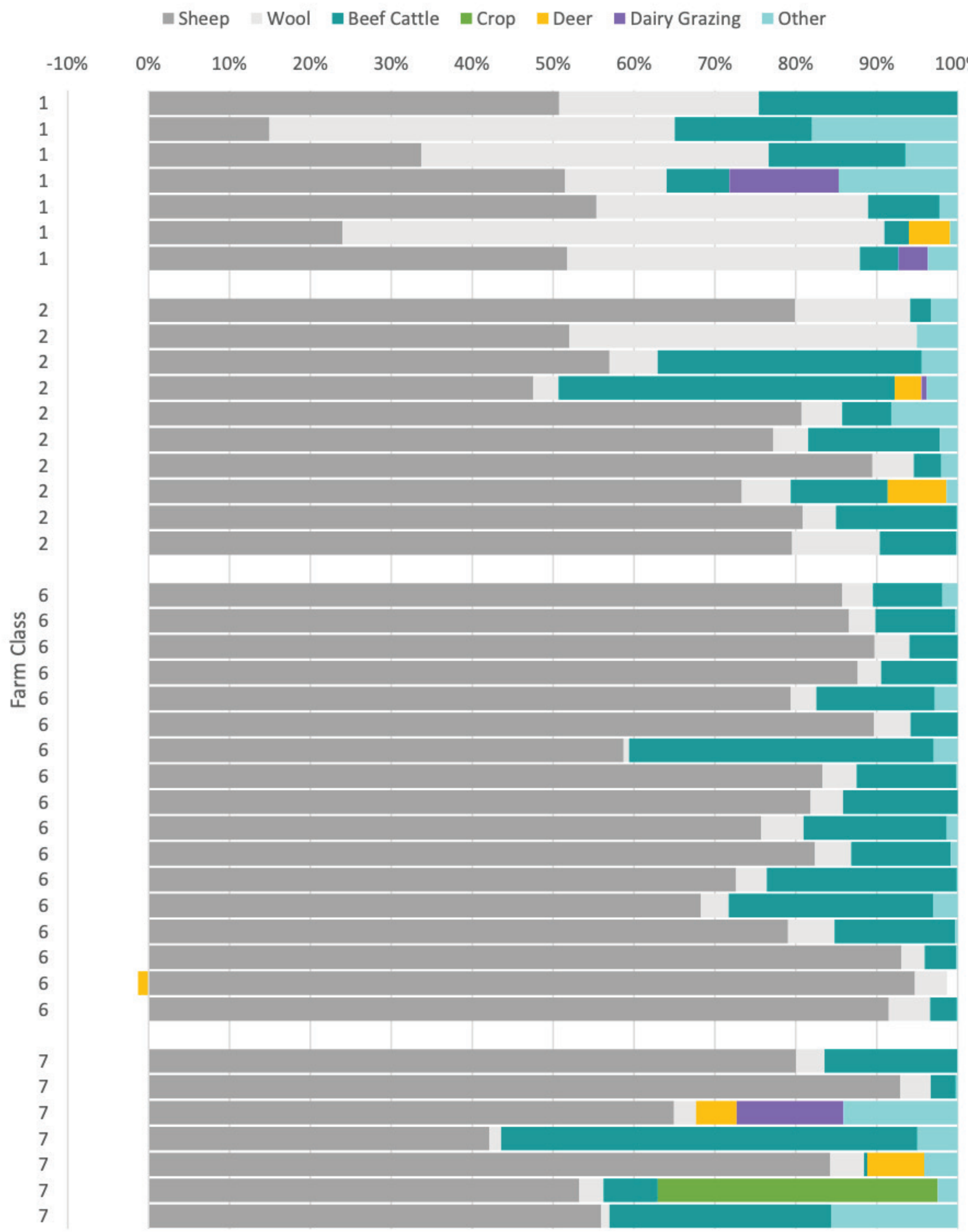

Figure 22: Mix of revenue streams for 41 Otago sheep and beef farms 2020-21
Source: B+LNZ Sheep and Beef Farm Survey

2.4.3.2 Expenditure

Expenditure per farm ranged from approximately $150,000 to over $800,000 for the 41 farms in the Otago Survey in 2020-21. Average farm expenditure for 2020-21 was $505,250 per farm. On a per hectare basis, farm expenditure ranged from below $100/ha (for two high country farms) to more than $1,000/ha for almost a quarter of the Otago Survey farms, which were typically finishing and breeding, or finishing farms (Farm Classes 6 and 7).

Since 2020-21, which is the latest season for which final Survey data are available for analysis, the cost of farm inputs has increased sharply. Average total farm expenditure increased in 2021-22 driven by inflation and upwards cost pressure on all categories of expenditure. Onfarm inflation persisted into 2022-23 and in the year to March 2023 on-farm inflation was 16.3 per cent[98] (the highest rate since 1981). Prices increased for all categories of farm inputs; however, interest expenditure was a key driver as interest rates increased. One average, sheep and beef farmers spend around 11 per cent of total farm expenditure servicing debt. Average farm expenditure is forecast to increase to over $535,000 for 2022-23 – compared with around $505,000 in 2020-21 Farm expenditure is a combination of volumes of farm inputs and their respective prices. As input prices increased, sheep and beef farmers sought to contain costs by reducing the volumes of farm inputs in 2021-22 and 2022-23. Nonetheless farm expenditure increased while farm-gate prices for sheep meat outputs declined (from 2021-22 levels).

The largest areas of expenditure on Otago sheep and beef farms are, on average, 'fertiliser, lime, and seeds', 'interest and rent', 'shearing' and 'repairs and maintenance'. Combined, these four categories (out of 13 categories in Figure 23) accounted for an average of approximately 46 per cent of total farm expenditure for the 41 farms in 2020-21. Of course, there was a range around the average, e.g., expenditure on those items for some high country farms with very low debt servicing and/or rent and relatively low fertiliser, lime and seeds expenditure was below the average for the Otago Survey.

Spending on fertiliser, lime and seeds tends to vary between years because of environmental factors, such as seasonal conditions, that impact feed availability, as well as financial considerations[99]. Fertiliser, lime, and seeds expenditure as a proportion of total farm expenditure ranged from:

- 5 to ~15 per cent for Farm Class 1;
- 0 to >30 per cent for Farm Class 2;
- 7 to ~30 per cent for Farm Class 6; and
- 8 to ~20 per cent for Farm Class 7 Survey farms.

Expenditure on 'repairs and maintenance' varies between years in line with revenue fluctuations. When budgets indicate a decrease in revenue, or profitability is low, farmers tend to defer spending on repairs and maintenance however deferred maintenance must eventually be undertaken to maintain both the asset and the efficient running of the farming operation. Repairs and maintenance spending ranged from 2 to 18 per cent of farm expenditure in 2020-21 with an average of around $40,000 per farm for Otago Survey farms.

98 https://beeflambnz.com/sites/default/files/data/files/Sheep-Beef-On-Farm-Inflation-23.pdf

99 Nutrient management is discussed in more detail in Chapter 2 of the *Farmers and Growers in Otago* Report (Fisher & Burtt, 2022).

Image 11: Angus heifers spending there winter on the lower hill country, a relatively low input part of the overall farming system.
Source: Emma Crutchley

Labour (i.e., wages and rations) and shearing are other key areas of expenditure for sheep and beef farms, and with a higher ratio of sheep to cattle in Otago when compared to other parts of New Zealand there tend to be greater demands on labour. Owner-operator farms with no, or few paid employees are in all farm classes, not purely smaller operations. Even large hill country farms ranging from roughly 500 to more than 1,000 hectares may have low levels of paid-labour and employ casual labour at different times of the year when needs arise. However, three-quarters of the Otago Survey farms paid wages and rations (total remuneration being cash plus housing, utilities, meat, protective gear etc) in 2020-21. Shearing expenditure averaged $22,700 per farm in 2020-21, however, since then, shearing expenses have risen by four to five per cent a year and shearing expenditure for 2022-23 is estimated to be around $24,700 per farm.

About 15 per cent of the farms in the Otago Survey paid irrigation charges, notably on some of the high country farms in Figure 23. Irrigation and access to water enables these extensive farms to increase yields from crops or pasture species. The cost of irrigation infrastructure and maintenance is often prohibitive for smaller farms, and within the Otago Survey no Farm Class 6 or 7 farms paid irrigation charges in 2020-21.

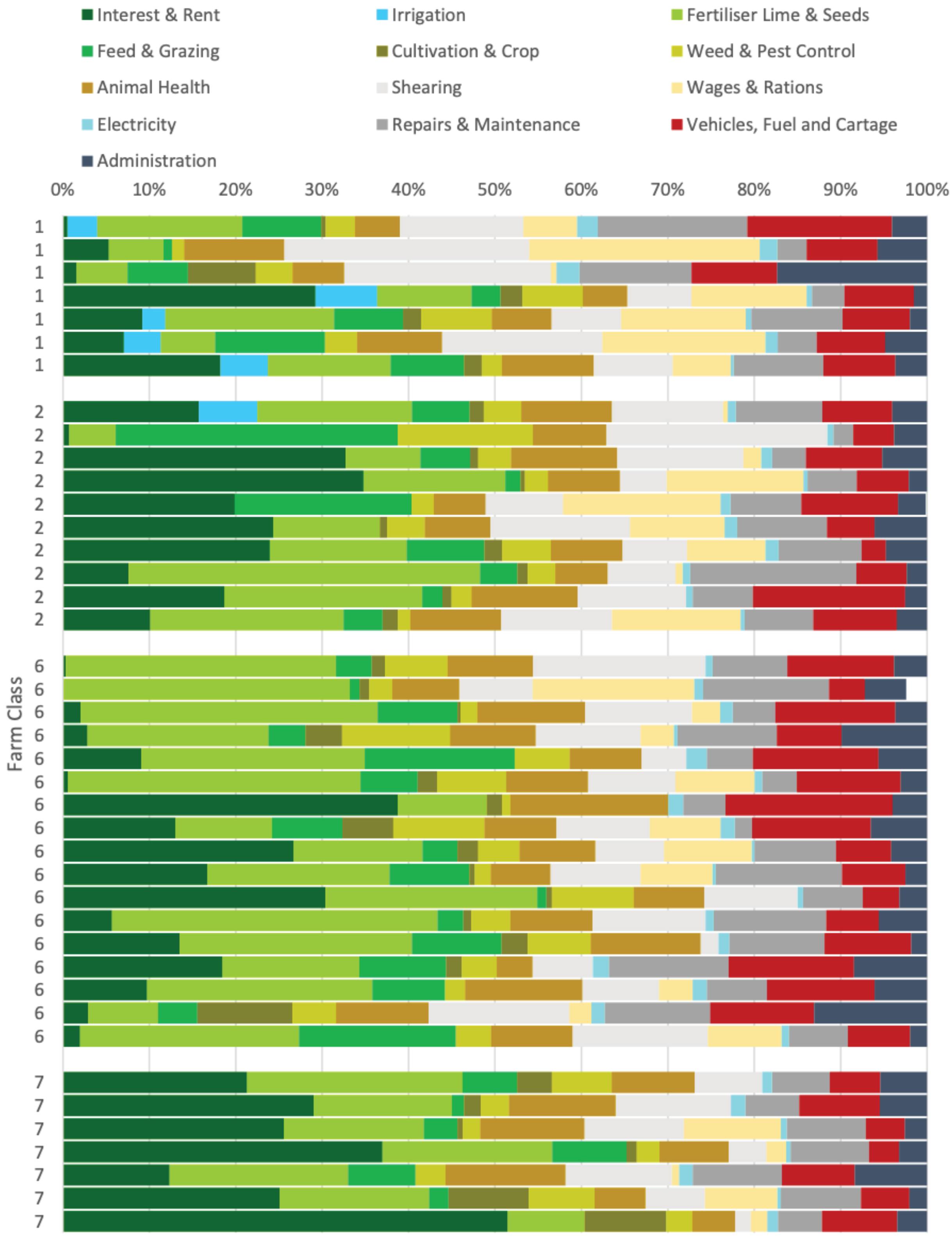

Figure 23: Variability in expenditure for 41 Otago sheep and beef farms 2020-21
Source: B+LNZ Sheep and Beef Farm Survey
Note: Administration includes items such as legal fees, consultant fees, bank fees, accounting fees, training, subscriptions for the business, phone, and internet.

Finishing and breeding farms (Farm Class 6) averaged around 20 per cent of expenditure on fertiliser, lime and seeds, a slightly higher proportion than other farm classes. Finishing and breeding farms were more likely than finishing farms to renovate pastures by planting new grass when following winter crops. Finishing farms, by comparison, typically have more cultivation and crop expenses. Fertiliser, lime, and seeds expenditure per farm ranged from around $10,000 to over $100,000 (for five farms) within the finishing and breeding Survey farms (Figure 24).

Feed and grazing, which are highly variable expenses, depend on farming policies, production needs and climatic conditions. Generally, most sheep and beef farmers are self-sufficient for livestock feed (i.e., almost all feed consumed is produced on farm). Many farmers conserve homegrown feed from peak pasture growth (e.g., hay, silage, or baleage) but there may be other types of feed or times when it is necessary to purchase feed.

In 2020-21, feed and grazing expenditure ranged from less than $5,000 to more than $60,000 per farm (average ~$29,000) with larger farms spending more in absolute terms. The climate varied across the region in 2020-21. For example, spring 2020 was dry, particularly for Central Otago and southern parts of the region, and some expenditure was needed for feed. Following this, heavy rainfall over summer resulted in flooding and damage to crops and infrastructure for parts of the region, with Central Otago and Strath Taieri badly affected. Climatic events such as these increase expenditure and add to the variability of revenue, expenditure, and profitability between farms.

Elsewhere, autumn 2021 was particularly dry for Clutha district and rain arrived late (in May). As a result, feed and grazing expenditure increased because feed reserves depleted going into winter.

Weed[100] and pest control is an important area of expenditure for sheep and beef farmers as they seek to manage invasive species or pests that can bring disease or compete with livestock, pastures, crops, and forests thereby impacting productivity. Weed and pest control is integral to protecting established or regenerating indigenous plantings which are susceptible to damage from rabbits, deer, pigs and exotic species. Many farmers spend a considerable amount of time, money and resources protecting natural assets.

Costs for crop protection products and pesticides have risen sharply in recent years. In some instances, this was due to shortages throughout the global supply chain because of Covid-19. There have been some closures of businesses supplying agrochemicals, which restricts availability and places upward pressure on prices. Farms with crops, seeds and feed may require more weed and pest control measures. Insects, particularly grass grub, Porina and weevils, impact pasture production. For other farmers, higher spending may be incurred to protect their farm from invasive species such as possums and deer, rabbits, and wild pigs, which spread disease, consume pasture, or kill lambs (respectively for species noted). Some variability between farms is related to their location and the responsibility of landowners to control pest plants and animals in accordance with the rules in the Regional Pest Management Plan.

100 Weeds includes woody weeds like gorse and broom, and expenditure on controlling these species is considerable for some farms.

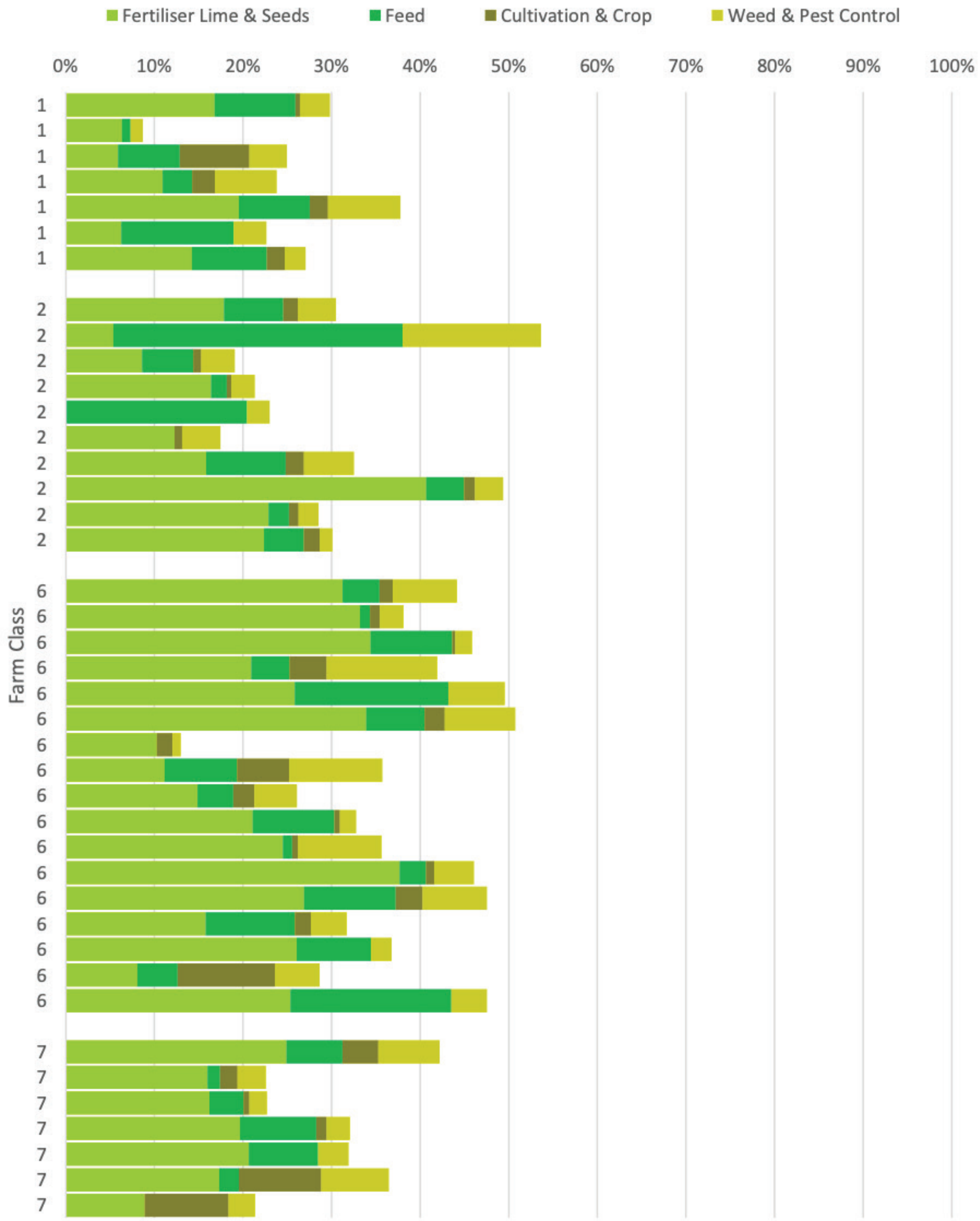

Figure 24: Expenditure on pasture and crop management for 41 Otago sheep and beef farms 2020-21
Source: B+LNZ Sheep and Beef Farm Survey

Image 12: Mixed age cows eagerly heading for a higher altitude where they will spend the winter harvesting low quality pasture in extensive tussock areas.
Source: Emma Crutchley

Interest and rent payments are a considerable portion of annual expenditure for sheep and beef farmers (Figure 25). On average, interest and rent payments were 14 per cent of total farm expenditure for the Otago Survey farms in 2020-21. Since then, interest rates for term debt and overdraft borrowing have increased bringing increased pressure to cashflow requirements and a reduction in profit margins. Interest payments averaged $50,595 per farm in 2020-21 and are forecast to average around $57,000 per farm in 2022-23. Rent payments have remained relatively steady since 2020-21, averaging approximately $20,000 per farm at that time and increasing slightly to an estimated $21,000 in 2022-23. Ten farms made interest payments over $100,000 in 2020-21 while some farms had nil or very low levels of debt. One farm received income from leased land but also paid interest – a small amount – in 2020-21. These examples add another dimension to the diversity that is drystock farming. Not all farmers own the land they farm. It may be subject to a Crown Pastoral Lease, or a lease of private land that is owned by a third party.

Among the farms in the most populous farm class – Farm Class 6 finishing and breeding farms – interest and rent combined averaged around nine per cent of total farm expenditure. Finishing farms (Farm Class 7) had a higher proportion of total farm expenditure dedicated to interest and rent when compared to other farm classes, which was due to relative term debt levels for what are smaller farms. Six of the seven finishing farms paid interest in 2020-21, comprising an average of 14 per cent of total farm expenditure. This higher proportion of expenditure on debt-servicing places this smaller class of farm at greater risk from interest rate increases and revenue fluctuations. It can also constrain other areas of expenditure as interest and rent payments take precedence. In worst cases, a farm's productivity declines through lack of nutrients and other inputs, and less repairs and maintenance.

As a general comment, because interest and rent obligations take precedence over more 'discretionary' expenditure, other spending is constrained when interest and rent expenditure rises. In worst cases, farm productivity falls through lack of nutrient (and other) inputs, and repairs and maintenance.

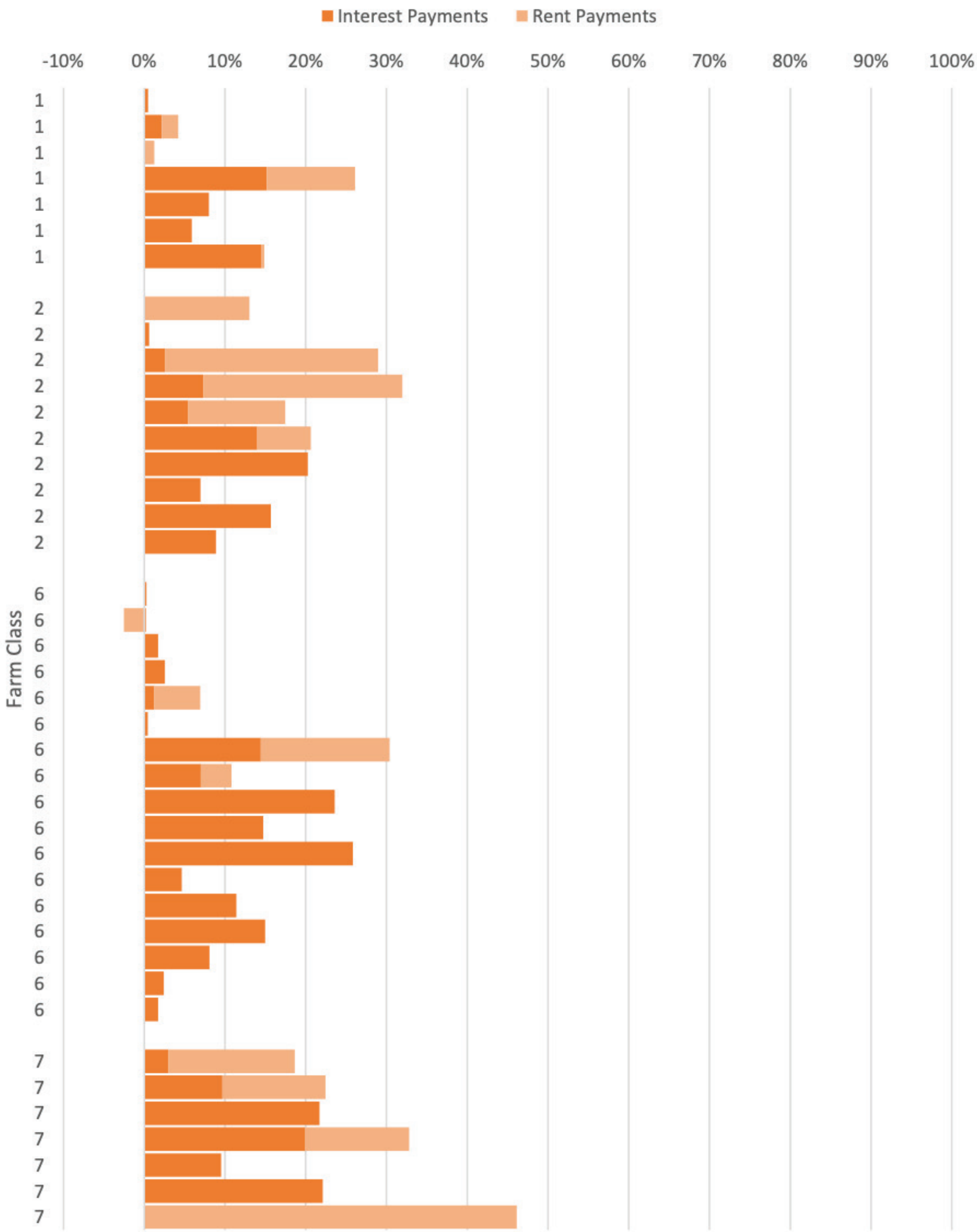

Figure 25: Costs of capital (land) for 41 Otago sheep and beef farms 2020-21
Source: B+LNZ Sheep and Beef Farm Survey

2.4.3.3 Profitability

In this analysis, profitability is measured using Earnings before Interest, Tax, Rent and bona fide managerial remuneration (EBITRm[101]), which makes it possible to compare farms on an equivalent basis of being debt-free, freehold and owner-operator. From EBITRm, farm businesses have additional expenditure including payments of interest, tax, and rent, as well as repayments of principal, farm capital purchases (such as farm machinery or infrastructure) and personal drawings for the farm family[102]. Therefore, EBITRm is not a measure of disposable income or free cash because there are other commitments to be met and those differ from one farm to the next depending on several factors.

Per-farm measures do not consider farm size, which for the sheep and beef industry varies considerably. The use of per-hectare measures allows comparison between farms of different sizes on a consistent basis (Figure 26). Smaller finishing farms are more profitable, on average, per hectare than farms in other farm classes. High country and hill country farms have relatively low levels of profitability per grazeable hectare due to the sheer scale of those properties. Sizeable areas of relatively low-yielding pasture species are included in grazeable area and allow for flexibility in farm management (see Section 2.4.2).

On a per farm basis, profitability averaged around $200,000 for high country farms; $265,000 for hill country farms; $228,000 for finishing and breeding farms; and $280,000 for finishing farms in 2020-21. Profitability between farms ranged from $35,000 to over $400,000.

Productivity and production are not necessarily an assurance of profitability. Profitability depends on a complex mix of factors, including livestock weights, growth rates, and losses, and expenditure. The most profitable farmers tend to be those who are skilled at adapting their production system to the local environment and achieving their goals, rather than focusing on a single aspect of their business (Fisher & Burtt, 2022: p. 49).

On-farm inflation soared to over ten per cent per year in 2021-22 (the season following the results presented here) and farmgate prices also increased substantially with high demand from global consumers for red meat products. Profitability in 2021-22 is provisionally estimated to have been higher than 2020-21 due to increased revenue. However, a large decrease in farm profitability is forecast for 2022-23[103], with factors such as a poor start to the season, lower farmgate prices and continued upward pressure on farm expenditure combining to reduce profit margins.

When revenue decreases, or expenditure increases, or a combination of both, farmers will make tactical decisions to preserve sustainability of their businesses within the constraints of a biological system. In other words, it is difficult to change some aspects of planned production and farming activities due to the complex nature of farming, which involves biological processes and the associated elapsed time, reproduction rates and seasonal conditions (to name just a few considerations).

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101 EBITRm is a standardised measure that facilitates benchmarking and is frequently used in the sheep and beef sector. EBITRm and EBITR for all 41 survey farms were equal, EBITRm in this profitability section is equivalent to EBITR.

102 New Zealand sheep and beef farms are overwhelmingly family owned (over 90 per cent) with an average of five people living on each farm and many other operations are Māori Trusts. More information is available at Making Meat Better *website*.

103 B+LNZ *Mid Season Update 2022 23* pg. 3

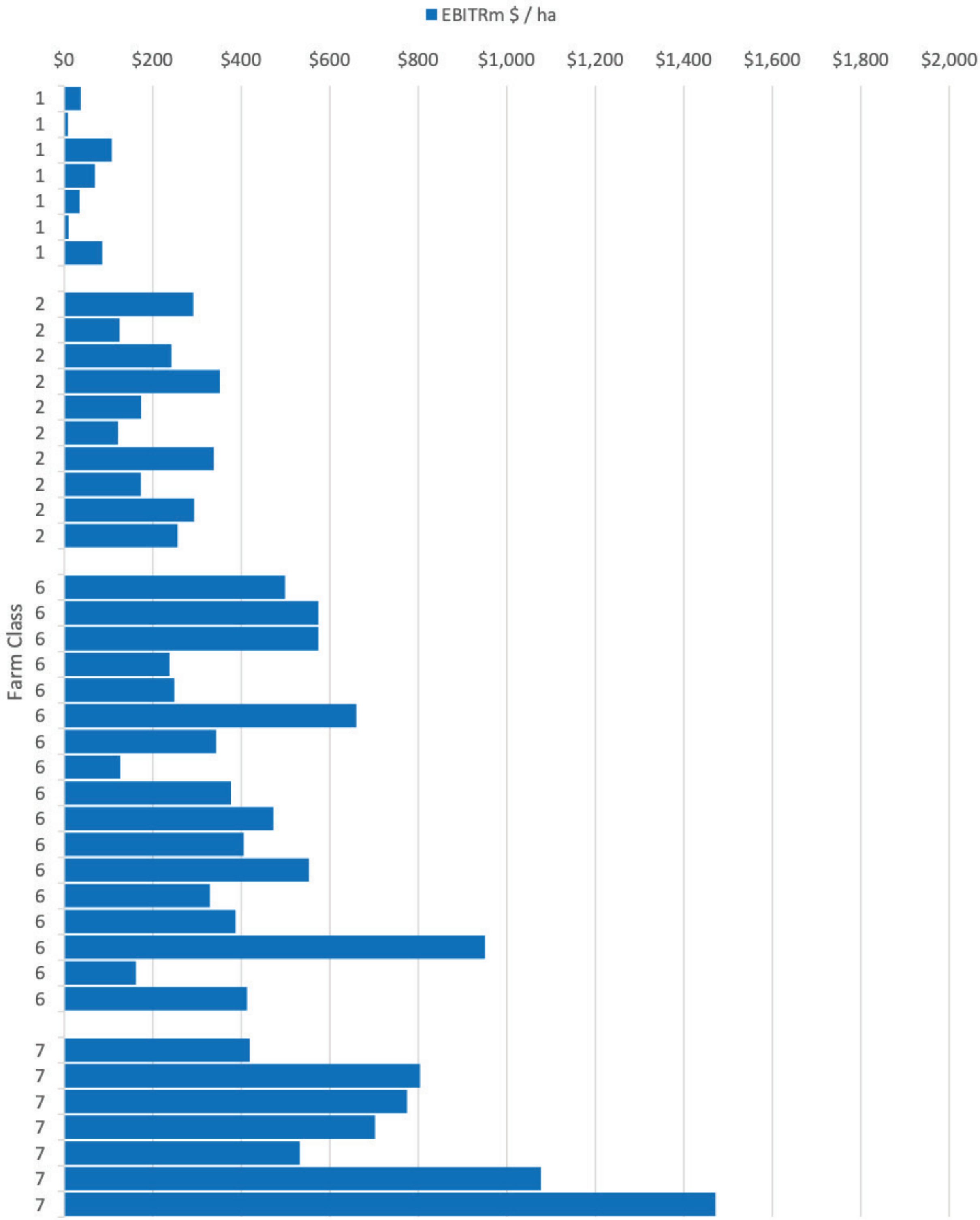

Figure 26: Profitability per hectare for 41 Otago sheep and beef farms 2020-21
Source: B+LNZ Sheep and Beef Farm Survey
Note: The profitability per hectare measures is strongly influenced by the classification of grazeable land, which for high country stations in Otago tends to be most of a farm (in varying degrees) because their scale, which makes this assessment challenging.

2.4.3.4 Farm debt

Sheep and beef farmers have relatively low levels of debt compared to other land uses. Debt is often kept low out of necessity, that is to mitigate risks such as those that result from fluctuations in farmgate prices. Low debt levels (or a low debt-to-asset ratio) often aids financial and whole farm business resilience. Sheep and beef operations often do not have the consistently high levels of profitability necessary to sustain increased debt, and so the cost of environmental compliance for sheep and beef farms generally is more impactful compared to most other industries.

For the Otago Survey farms, there is no relationship between profitability and interest and rent as a share of farm expenditure shown in Figure 27. This lack of relationship between profitability and debt servicing is not unique to Otago. It is common across sheep and beef farms in New Zealand. High debt levels do not imply that a farm is likely to be more profitable. Debt levels for each farm reflect a mixture of risk appetite, history of the farm and past decisions, succession plans, and age and stage of farmers, as often farmers earlier in their career may have higher debt levels due to borrowing to buy into the farming assets.

For future borrowings or an ability to borrow for environmental compliance or regulations there are two aspects to consider: the willingness of banks to lend to sheep and beef farmers and the willingness of farmers to increase their debt levels[104]. Farmers' access to credit depends on meeting banking credit policies and criteria and includes such metrics as profitability, cashflow and serviceability, debt-to-asset position, and security, for example. For sheep and beef farmers, increased borrowing impacts the balance sheet, debt-to-asset ratios, and cashflow with increased debt servicing needed. Increased debt levels may also impact succession decisions and overall farm financial health and risk.

Image 13: K-Line irrigation in a sheep paddock on a farm in the Waitaki District.
Source: Emma Moran

104 The tension between the stewardship of fresh water and a farm's financial position, particularly in relation to farm debt and land values, is of real concern for communities in regions around New Zealand. While farm debt is important in the context of freshwater management, the topic is complex, and our joint knowledge is limited. To shed some light, Environment Southland set up a research project in 2021 that centred on a panel of local experts, known as the Farm Debt Working Group, supported by a technical team from industry-good groups. The main output from this project is a report titled *Farm Debt, Farm Viability and Freshwater Management in Pastoral Southland* (Moran, McDonald, & McKay, 2022).

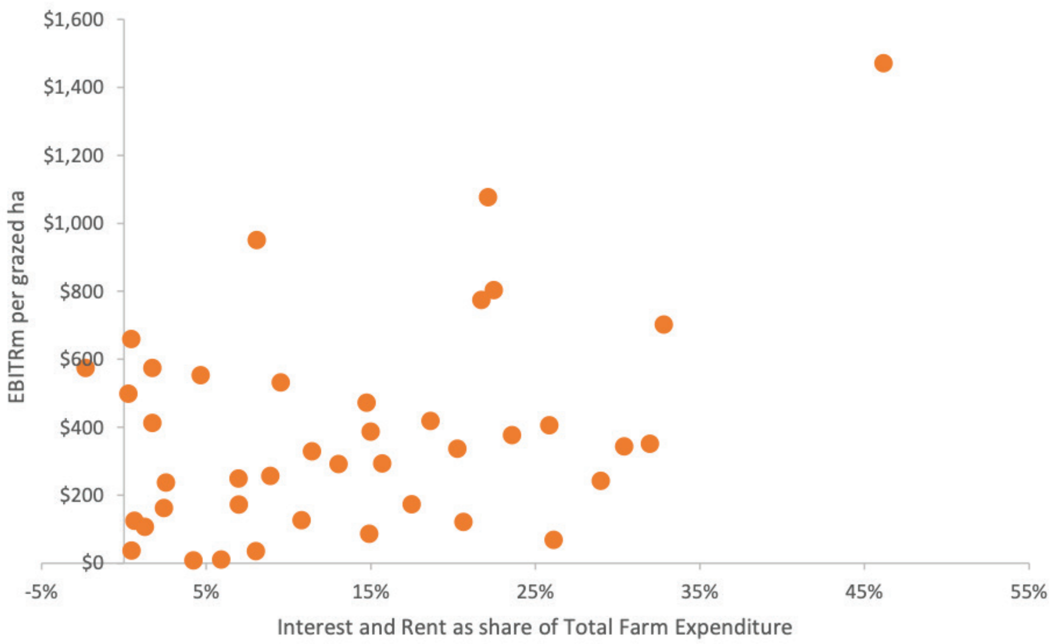

Figure 27: Costs of capital (i.e., interest and rent payments) and profitability for 41 Otago sheep and beef farms 2020-21
Source: B+LNZ Sheep and Beef Farm Survey

2.5 Farm Case Studies

The general methodology (including key assumptions) for the farm case studies is outlined in Section 2.3.1, including a summary table of the environmental actions tested by case study farm. The analysis in this section is presented by topic rather than case study farm to avoid repetition and make comparisons between farms easier.

Of the 16 sheep and beef farm case studies presented in this section, eight are located in the Clutha Mata-au Freshwater Management Unit (FMU) and eight across the region's other FMUs (Catlins, Taieri, Dunedin and Coast, and North Otago)[105]. From a more geographical viewpoint, 11 farms are in east Otago (Catlins FMU, Lower Clutha Rohe, Taieri FMU, Dunedin and Coast FMU, and North Otago FMU) and five farms are in central and west Otago (Roxburgh, Manuherekia, Dunstan and Upper Lakes Rohe of the Clutha Mata-au FMU).

- The 11 farms in east Otago covered a total of just under 10,000 hectares and, on average, were around 900 hectares in size; and
- The five farms in central and west Otago covered a total of just under 46,000 hectares and were, on average, roughly 9,000 hectares in size (i.e., ten times the size of the farms in east Otago).

105 An FMU is a waterway or multiple waterways that ORC believe is the appropriate scale for managing water, including the setting of freshwater objectives and limits. This can be a river catchment, part of a catchment, or a group of catchments. The largest FMU in Otago is the Clutha/Mata-au, which has been divided into five sub areas called 'Rohe'. For more information on Otago's FMU refer to: https://www.orc.govt.nz/plans-policies-reports/regional-plans-and-policies/water/freshwater-management-units and https://www.orc.govt.nz/plans-policies-reports/land-and-water-regional-plan/find-your-area

Table 4 is a summary of basic information for the 16 farms used in this research to test the impacts on businesses of environmental actions. The estimates of nitrogen and phosphorus losses, and average rainfall are from Overseer[106], Greenhouse Gas (GHG) values are from FARMAX and represent methane from ruminants, nitrous oxide from soils, and carbon dioxide from urea hydrolysis[107], expressed as kilograms of carbon dioxide equivalent per total hectare. Financial metrics, stock ratios and stocking rate are sourced from FARMAX.

The range in annual rainfall extends from just over 500 mm per year to just under 1,500 mm per year (an almost three-fold difference). The farm stocking rates range from less than one stock unit per hectare to slightly more than 17 stock units per hectare. While sheep are by far the predominant stock type, all the case study farms included beef cattle up to a maximum of half the total stock units on a farm. Three of the 16 farms also included a deer enterprise.

Estimates of nutrient losses to water (i.e., nitrogen and phosphorus) fall within relatively narrow bands while GHG emissions per hectare are extremely variable. This variability is because, as a general rule, GHG emissions per hectare tend to reflect a farm's stocking rates on its grazed areas, and so its production system. This relationship is in addition to the range of non-grazed areas across the farms, which also influences a farm's GHG emissions when expressed on a per hectare basis.

Figure 28 (on page 86) shows the annual stock units per hectare of individual blocks within each farm, which shows the carrying capacity of different blocks. These data are sourced from Overseer and show the range in block carrying capacity (or stocking rate) within a farm. The marked differences in how a farmer stocks their farm, both within a farm and between farms, is a response to levels and quality of pasture production and feed supply, which is influenced by factors including (but not limited to):

- Pasture species
- Slope and topography
- Climate including rainfall
- Irrigation
- Fertiliser regime
- Soil type
- Grazing management.

Sheep and beef farms are generally grazed rotationally where livestock moves around the farm in mobs. The length and frequency of grazing events varies across blocks based on pasture supply but also considerations such as: shade and shelter available (e.g., tussock blocks are valuable for shelter during lambing), increased risk of contaminant loss at certain times of the year (e.g., cattle are excluded from steep slopes during wet and winter months), farm subdivision and paddock size, and livestock class. For example, lambs tend to be offered the best grass and are not usually expected to 'graze out' a paddock entirely, while other livestock such as older cattle or ewes are then grazed in the paddock to tidy up.

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106 OverseerFM and Overseer Science versions were both used.

107 Urea hydrolysis is a chemical reaction that transforms the urea in urine into ammonia and carbon dioxide or bicarbonate.

Rotational grazing is critically important for maximising pasture growth and quality, maintaining feed supply, and improving livestock production per hectare. Most sheep and beef farms (particularly those with breeding stock) operate their systems with a combination of rotation grazing and then set stocking for a period over lambing/calving/fawning. Pasture productivity from either rotational grazing, or a combination or rotational grazing with spring set stocking, results in higher pasture productivity compared to set stocking all year round .

Rotational grazing allows for preferential feeding where stock classes can be offered the first grazing of a paddock to selectively graze the highly quality feed (e.g., lambs), which can then be followed by other stock classes that are used to ‘clean-up’ the paddock and eat the lower quality feed which has the benefits of maintaining pasture production and avoids rank grass and a need for topping of paddocks. The grazing intensity of an individual grazing event is termed a ‘stocking density’ (the number of stock units per hectare in the paddock or block during a grazing event) and is higher than the annual average ‘stocking rate’ in a partially, or fully, rotationally grazed system.

Most sheep and beef farms are relatively self-sufficient for feed, meaning the farm is stocked at a rate that roughly matches the feed grown - allowing for a 'smoothing' of the annual pasture growth curve, with peaks over spring and summer being conserved as hay, baleage and silage for winter. On a pastoral farm there needs to be sufficient stock to graze for optimal pasture management otherwise pasture must be 'topped' to prevent it going to seed and turning 'rank' (so is inedible) and more weed management is needed. In other words, a sub-optimal stocking rate needs more labour for pasture management.

Overseer-predicted nitrogen leaching loss for the 16 case study farms ranged from two to 15 kg N/ha/yr. Overseer Ltd was contacted for information on Otago sheep and beef farms within their dataset. They had 52 sheep, beef and deer farms with data for 2020/21. The mean nitrogen leaching loss for these was 8.6 kg N/ha/yr, the upper quartile was 10 kg N/ha/yr and lower was 5 kg N/ha/yr. Thus, the range in Overseer predicted losses from the 16 case study farms effectively represents the spread of loss of those sheep and beef farms in Otago that have an Overseer nutrient budget.

Image 14: Flax being used for riparian planting on a farm in the Clutha District.
Source: Emma Moran

Table 4: Basic farm information for the 16 Sheep and Beef Case Study Farms in Otago 2020-21

Farm	B+LNZ Farm Class[1]	Farm Size[2]	Rainfall (mm/yr)	Stocking Rate (SU/grazed ha)	Sheep: cattle: deer (%)	Farm profitability (EBITR3[3]/ farm)	Farm mapped in S-map (Y/N)	Risk of Phosphorus Loss (kg P/ha/yr)	Estimated Nitrogen Loss (kg N/ha/yr)	GHG emissions (kg CO2-e/total ha/ yr or grazed ha/yr)	
SB01	6	Medium	915	17.1	91:9:0	$236,000	Y	0.6	15	5,000	5,700
SB02	6	Medium	725	9.4	74:26:0	$370,000	N	0.1	7	2,450	3,250
SB03	7	Small	800	15.2	96:4:0	$169,000	Y	0.5	9	4,750	5,200
SB04	7	Medium	915	16.5	85:9:6	$281,000	Y	0.8	15	5,180	5,500
SB05	6	Medium	990	13.7	73:27:0	$142,000	N	0.2	15	3,400	4,900
SB06[4]	2	Medium	795	6.1	70:30:0	$60,000	Partial				
SB07	7	Medium	795	13.9	89:11:0	$80,000	Y	0.3	12	3,650	4,800
SB08	6	Small	>1,000	13.7	90:10:0	$143,000	N	2.2	11	2,750	4,600
SB09	6	Medium	630	10.0	73:27:0	$23,000	Y	0.2	9	2,950	3,600
SB10	1	Large	>1,000	0.5	76:24:0	$25,000	Partial	0.6	7	100	200
SB11	1	Large	790	1.5	78:16:6	$316,000	Partial	0.3	4	500	500
SB12	2	Large	590	4.4	70:30:0	$259,000	N	<0.1	2	1,250	1,500
SB13[5]	1	Large	530	2.4	86:14:0	$131,000	Y	0.2	7	1,050[4]	
SB14	1	Large	600	1.3	82:18:0	-$119,000	Y	0.1	5	800	850
SB15	2	Large	>1,000	3.1	45:50:4	$852,000	N	0.6	10	2,100	3,000
SB16	6	Medium	860	4.9	86:15:0	$297,000	N	0.4	13	3,250	3,600

Notes: 1 Farm Class: 1 = South Island High Country; 2 = South Island Hill Country; 6= South Island Finishing and Breeding; and 7 = South Island Finishing

2 Farm size: smaller ≤ 300 grazed hectares; medium > 300 and < 1,000 grazed hectares; and larger ≥ 1,000 grazed hectares.

3 Earnings before interest, tax and rent and debt repayments

4 SB06 and SB13 not modelled in FARMAX due to complexity of system

5 SB13 GHG emissions figure from Overseer rather than FARMAX as the farm was not modelled in FARMAX

Figure 28: Distribution of average block stocking rates (as reported in Overseer) within 16 sheep and beef farms in Otago 2020-21

Source: B+LNZ

Note: While the farms are ordered by Farm Class they are presented in a random order here (i.e., not as Case Studies 1 to 16). Also, a 'block' is usually a series of paddocks managed in a similar fashion.

2.5.1 Phosphorus fertiliser

Farm management of fertiliser applications to reduce phosphorus losses focused on two environmental actions:

1. Considering phosphorus fertiliser use by checking each farm's maintenance phosphate needs and comparing them to the actual amounts being applied in a specific year.
2. Checking each farm's pH level of the soil types present on farm and the farm's rainfall to identify suitable candidates for applying reactive phosphate rock (RPR) as a maintenance fertiliser.

For the first environmental action, each farm's phosphorus maintenance needs were determined by reviewing the 'Blocks Detail' report in the farm Overseer 'Year End' account and comparing it with the actual fertiliser applied to the same blocks. Risk to waterways was indicated by Overseer-predicted risk of phosphorus loss (Table 5). Three of these farms were then tested in Overseer to determine the Overseer-predicted phosphorus loss risk value if phosphorus fertiliser levels were reduced to maintenance only.

For the second environmental action, the conditions needed for successful use of RPR were determined from a limited literature review and a marginal economic analysis (Excel spreadsheet rather than FARMAX) was then applied to the most relevant farm of the 16 case study farms to show the impacts of change in fertiliser type.

The retirement of LUC[108] Class VI land was tested later in the modelling process and results are presented in another section. This environmental action was generally the most effective action of those tested for phosphorus loss risk, however there were negative impacts on farm financial viability and considerable farm system change.

2.5.1.1 Maintenance Phosphorus fertiliser

Of the 16 farms, the Overseer modelling suggested that six farms were applying 'above maintenance' levels of phosphorus fertiliser to their fertilised grazeable areas, eight were applying 'below maintenance' and two were 'at maintenance' (Table 5). Livestock grazing will spread phosphorus across the whole farm, which disperses the effective application rates therefore it is worthy of determining whether the fertiliser applications averaged over the whole farm were above maintenance or not. In addition, if Olsen P levels are not at either the agronomic or economic optimum then applying fertiliser above maintenance increases the Olsen P level closer to optimum.

The soil test data used was default data with actual fertiliser applications so it can be assumed that those farms who are applying above maintenance are aiming to increase their Olsen P levels. The Fertiliser Association of New Zealand recommends, in their booklet titled *Fertiliser Use on New Zealand Sheep and Beef Farms,* that farmers who are below optimum soil fertility levels apply enough nutrient to maintain their current soil fertility where possible. Often when finances are tight fertiliser applications can decrease or stop as it is a major farm expense. However, completely withholding phosphorus is only recommended if at farm is at or above the economic optimum soil fertility level (Morton & Roberts, 2018).

108 The Land Use Capability System has been used in New Zealand since 1952. It has two key components: firstly, a Land Resource Inventory was compiled as an assessment of physical factors considered to be critical for long-term land use and management; secondly, the inventory is used for Land Use Capability Classification, whereby land is categorised into eight major classes according to its long-term capability to sustain one or more productive land uses (i.e., its versatility). In recent years, the Physiographic Environments of New Zealand (PENZ) project (part of the *"Our Land and Water" National Science Challenge*) has developed a more in-depth understanding of the inherent susceptibility of the landscape for contaminant losses. More information on the LUC System is available at: *https://beeflambnz.com/knowledge-hub/PDF/map-your-land-resources-%E2%80%93-land-use-capability-approach.pdf* and the PENZ project at: *https://ourlandandwater.nz/project/physiographic-environments-of-new-zealand/*

Further analysis showed that three of the six farms applying phosphorus at 'above maintenance' levels (19% of the 16 case studies) were doing so on a whole farm basis: SB01; SB02; and SB07. For the analysis, the phosphorus fertiliser application rates were altered in Overseer for farms SB01, SB02 and SB07 which were applying 44, 42 and 71 per cent above maintenance, respectively. There was no resulting change in farm phosphorus loss risk estimates. The B+LNZ Sheep and Beef Farm Survey indicates that these rates of phosphorus fertiliser above maintenance are not necessarily a regular occurrence. In drystock farming, fertiliser use tends to occur when the fertiliser prices are favourable, and revenue allows. The analysis showed that all six farms could reduce their expenses by reducing fertiliser applications to maintenance levels. The predicted reduction for the six farms ranged between five and 49 per cent in phosphorus fertiliser cost. However, it is sensible that farmers replenish soil phosphorus levels in a season with higher-than-average profitability.

Table 5: Phosphorus fertiliser usage and risk of phosphorus loss for 16 sheep and beef farms in Otago 2020-21

Farm	Maintenance phosphorus (kg P/ha)	Actual phosphorus (kg P/ha)	Difference between maintenance and actual (%)	Average rate over whole farm (kg P/ha)	Calculated phosphorus loss risk (kg P/ha/yr)[1]
SB01	16	23	+44%	18	0.6
SB02	12	17	+42%	16	0.1
SB03	22	22	0%	22	0.5
SB04	19	20	+5%	17	0.8
SB05	13	5	-62%	7	0.2
SB06	10	3	-70%	3	<0.1
SB07	14	24	+71%	23	0.3
SB08	32	27	-15%	16	2.2
SB09	19	19	0%	19	0.2
SB10	12	<1	-99%	1	0.6
SB11	11	3	-73%	1	0.3
SB12	12	20	+67%	1	1.1
SB13	19	7	-63%	1	1.0
SB14	12	10	-17%	2	0.1
SB15	19	37	+95%	9	0.6
SB16	18	15	-17%	13	0.4

[1] Using Overseer version 6.5.0.

2.5.1.2 Reactive Phosphate Rock (RPR)

RPR is a more environmentally friendly form of phosphorus fertiliser for annual application on livestock farms (Quin & Zaman, 2012). The phosphate in RPR, when applied annually, takes longer to become available for plants to uptake than the phosphate used in super phosphate. When RPR is used the risk of phosphorus losses to water from fertiliser are lower compared to more soluble forms of phosphorus fertiliser.

The length of time for the phosphorus to become available to plants varies depending on the source of the rock. As an example, for rock sourced from Sechura in Peru (the main source at the time of the trials), the total cumulative percentages of phosphorus available to the plant each year were: 30% in year 1, 53% in year 2, 70% in year 3, 82% in year 4, 91% in year 5, and 96% by year 6 (Edmeades et al., 1991). To be roughly equivalent to annual applications of super phosphate, farmers need to apply 3.5 times the amount of RPR in year one, 2.0 times in year two, and 1.5 times in year three (Edmeades et al., 1991). Farmers are advised not to apply RPR in locations with rainfall of less than 800mm/yr and pH greater than 5.5 to avoid even greater lag times (Edmeades et al., 1991).

Suitable rainfall areas in Otago possibly include areas around Highway 8 (Milton to Beaumont), Highway 90 (Beaumont to Gore), and West of Wanaka and many of the soils in these areas are also likely to have a suitable pH (Appendix 2 in this chapter). In situations where there are suitable conditions and soil test results suggest that ‘less than maintenance’ levels of phosphorus fertiliser is needed (e.g., where soil Olsen P levels are above the agronomic optimum and thus applying fertiliser below maintenance will help reduce those soil Olsen P levels to within the optimum range), there may be an opportunity for farmers to switch towards using RPR in maintenance amounts (which as we have shown above does not have all the phosphorus available to the plant for the first few years – thus application rates could be at maintenance but the amounts of phosphorus released each year are below maintenance). However, it is unlikely that many sheep and beef farms will have soil test results that indicate high levels of Olsen P (above the agronomic optimum), especially hill and high country farm types.

Only one of the 16 case study farms (SB08) had both the rainfall and soil pH levels that made it suitable for considering using RPR. The farmer applied below maintenance phosphorus fertiliser in 2020-21 and the farm’s soil Olsen P level was 25.

2.5.1.3 Case Study Farm – SB08

This is a medium-sized breeding/finishing property located in South Otago in an area that has an annual rainfall over 1,000 mm/yr and a soil pH of less than 5.5, making it suitable for considering the use of RPR. In addition, it has a high Overseer-predicted phosphorus loss risk (2.2 kg P/ha/yr).

This high phosphorus loss is due to a few factors that are associated with a lack of data rather than the farms characteristics. The farm is not mapped by S-Map[109] which is a digital soil map for New Zealand that is maintained by Manaaki Whenua Landcare Research. Therefore, the soils entered into Overseer have come from the fundamental soil layer which is a coarser level than a soil type. This farm has sizeable areas mapped as podzol soil that have a naturally high phosphorus loss risk. Drystock farms are disproportionately more likely to not be mapped in S-Map, which increases the level of inaccuracy and unreliability of the Overseer-predicted nitrogen and phosphorus losses. In addition, the soil test results of an Olsen P of 25 suggest that this farm has naturally high soil phosphorus levels.

109 https://smap.landcareresearch.co.nz/

Currently 57 tonnes of Sulphur Gain 15S[110] is applied as a maintenance fertiliser over two-thirds of the farm for a total cost of around $30,000 or $158/ha to the application area. This current fertiliser was substituted with a mix of RPR and sulphur fertiliser (Table 6). Applying chemically equivalent amounts and accepting the three- to five-year lag periods has a total annual cost of $187/ha. If the amount of RPR applied is increased to compensate for the reduced level of available phosphate across years three to five, then the total annual cost increases to $375/ha.

The case study farm had an annual profit (EBITR) of $143,500.

If the current phosphorus fertiliser was replaced with the agronomically equivalent amount of RPR, then the modelling estimated a reduction in profitability of roughly 30 per cent to $102,250, and the Overseer-predicted risk of phosphorus loss decreased by 0.1 kg P/ha/yr from 2.2 to 2.1 kg P/ha/yr.

Table 6: Results of replacing current phosphorus fertiliser practice with reactive phosphate rock for SB08

Farm fertiliser regime	Form of phosphorus fertiliser	Ratio N-P-K-S (%)	Application rate (kg/ha	Applied Cost* ($/ha)
Current	Sulphur fortified phosphate	0-9-0-15	300	$160
Chemically equivalent phosphate rock and sulphur	Phosphate rock	0-12-0-0	211	$135
	Sulphur	0-0-0-90	48	$50
Agronomically equivalent phosphate rock and sulphur	Phosphate rock	0-12-0-0	500	$325
	Sulphur	0-0-0-90	48	$50

Note: Applied cost consists of the fertiliser and its spreading

2.5.2 Waterway protection

Waterway protection is important for reducing the transport of contaminants (e.g., sediment, faecal coliforms, phosphorus and, to a lesser degree, nitrogen) lost via overland flow pathways and direct deposition, into waterbodies. Prohibiting cattle and deer from having direct access to waterbodies and streambanks that are not already fenced under the current Resource Management (Stock Exclusion) Regulations 2020 was tested as an environmental action to further protect waterways and focused on three variations:

1. Fence off wetlands,
2. Fence off rivers and streams second-order[111] or wider on slopes greater than 10°,
3. Fence off all waterways on slopes greater than 10°.

110 Sulphur Gain 15S is a fertiliser with sulphur, phosphorus and calcium content.

111 The branching nature of a river and its tributaries are known as stream order or Strahler order. It is used to define the size of a stream based on the hierarchy of the tributaries flowing to a point of interest. https://landscapedna.org/glossary/#s A first order stream has no tributaries, a second-order stream has at least two first-order tributaries, while a third-order stream must have at least 2 second-order tributaries https://www.lawa.org.nz/learn/glossary/s/stream-order/#:~:text=A%20measure%20of%20stream%20or,least%20two%20first%2Dorder%20tributaries.

These actions were tested on nine farms that had waterways present on slopes greater than 10° that are not currently required to be fenced under the national regulations[112]:

1. Farm Class 2, Hill Country farms: SB06, SB12, SB15
2. Farm Class 6, Breeding and Finishing farms: SB01, SB02, SB05, SB09, SB16
3. Farm Class 7, Finishing farms: SB04

It was assumed that the waterways on slopes greater than 10 degrees on Class 1 (High Country) farms were almost impossible to fence due to the steep terrain thus these farms were not included in this analysis.

Further on in this chapter (see Section 2.5.8) other environmental actions were tested to exclude cattle from waterways where fencing is not possible because of the expense and/or topography. These alternatives include excluding cattle from some areas of the farm and removing cattle from the farming system entirely.

For waterway protection, Google Earth[113] was used to identify wetlands (1:50,000 scale) by identifying changes in plant types towards wetland species. Identification of actual species at this scale is difficult so identification was mainly influenced by landform and any historical wetlands on NZ Topo Map. Landscape DNA[114] maps were used to identify on-farm waterways using riverlines and slope (Appendix 2 in this chapter). First-order streams were assumed by KapAg to all be less than one metre in bed width, and only used when testing 'fencing off all waterways'.

Common fencing methods on Otago sheep and beef farms are post and netting on lowland and hill country and a waratah (steel post) and wire (with or without rabbit netting) in the high country. There is some use of electrified wires on some farms to reduce the number of intermediate battens.

Waterway fencing was costed based on a post and netting fence at $15[115] per metre with the landowner providing some labour. Wetland fencing was costed at $22 per metre to allow for the additional strainers needed. A five-metre riparian buffer was assumed around fenced wetlands and waterways, the additional area was removed from the grazing area in FARMAX. In reality, the costs will be considerably more in certain situations in Otago. Many waterways are in steep-sided gullies where a fence line either needs to be created using an excavator (at extra cost and extra risk to sediment loss) or the buffer width is considerably more to find enough flat land to erect a fence (resulting in a loss of more land). The costs of riparian planting are not included the fencing analysis, being presented separately.

When the farms had fenced-off third order and second-order streams it was assumed that livestock could still drink from first-order streams. When all the streams had been fenced it was assumed that reticulated water needed to be provided, however many farms in Otago already have comprehensive stock water reticulation systems. For some farmers, supplying livestock with drinking water means the installation of a new reticulated supply, and others must rely on the expansion of their existing scheme, which can be quite old but usually well maintained. While some farmers would need to pump water, others could use gravity. However, a standard approach was used in this analysis when all streams were fenced, troughs

112 Current regulations state that all intensively grazed deer and beef cattle, deer and beef cattle on low-slope land (5° as identified by the low-slope map or 10° as determined by a certified Freshwater Farm Plan provider) must be excluded (with a three metre setback) from lakes and rivers with a bed wider than one metre *https://www.legislation.govt.nz/regulation/public/2020/0175/latest/whole.html#LMS379905*

113 *https://earth.google.com/web/*

114 *https://landscapedna.org/*

115 Prices in 2022. Prices will fluctuate and the cost of fencing will have a direct impact on the willingness and ability of farmers to pay for fencing.

were added at two troughs per km requiring 200m of 40mm alkathene pipe plus fittings per trough, costed at $1,560/km. No labour was included in this cost. Storage tank costs was not included. On steeper country you also need smaller break tanks. Thus, the cost/km may be greater in reality, especially on farms with steeper country.

Three farms had wetlands, ranging in size from three to 15 hectares with 3 km to 6 km of additional fencing needed to exclude livestock from those wetlands. This action resulted in reductions in profitability (measured as EBITR) of less than one per cent up to 35 per cent across the three farms.

Seven of the nine farms with waterways had second-order or third-order streams and all were either Farm Class 2 or Farm Class 6 farms. Fencing of second-order and third-order streams needed between 2 km and 51 km of fencing, which was between $30,000 and $765,000 capital cost, or an annual cost of borrowing of $2,100 to $53,550. The fencing of these waterways removed 2.4 to 56 hectares from grazing as riparian areas, resulting in reductions in profitability of less than one per cent to 15 per cent for these farms. Four of the farms saw a reduction in livestock numbers to fit the lower feed supply estimated by FARMAX as a result of the smaller grazing area.

Fencing of all waterways and wetlands removed six to 74 hectares from grazing and decreased farm profitability by three per cent to 100 per cent. When the cost of water reticulation was included the reduction in profitability grew to between three per cent and 105 per cent.

2.5.2.1 *Wetland fencing*

Across the three farms (SB06, SB09, and SB15), there were marked differences in wetland size and length of fencing needed to exclude cattle, and profitability. SB06 (a medium-sized farm) had the smallest wetland area but fencing it amounted to six kilometres of fencing. SB09 (a medium-sized farm) and SB15 (a large farm) both had larger wetlands that were already partially fenced and so needed roughly three kilometres of fencing to fully exclude cattle, but farm profitability was influenced by the scale of the farms. In reality, SB09 would be an unlikely candidate for borrowing to fund the capital investment (see Tables 7, 8 and 9).

Table 7: Results of fencing off wetlands for 3 sheep and beef farms in Otago 2020-21

Farm	Farm profitability (EBITR[1] / farm)	Area of wetland	Length of fencing	Capital and annual borrowing cost[2] of fencing	Change in profitability[3]
SB06	$61,000	3.0 ha	6.0 km	$132,000 capital cost or $9,240/yr with borrowing	-15%
SB09	$23,000	14.9 ha	3.5 km	$77,000 capital cost or $5,390/yr with borrowing	-35%
SB15	$852,000	15.0 ha	3.0 km	$45,000 capital cost or $3,150/yr with borrowing	<-1%

1 Earnings before interest, tax, and rent.

2 Assumes an interest rate of 7% per year.

2 EBITR, which includes the cost of borrowing repayments and financial impacts of farm system changes resulting from the fencing (reduction in land area due to riparian areas, stock number changes and associated changes to expenses and income).

2.5.2.2 *Stream fencing*

Table 8: Results of fencing off 2nd and 3rd order streams for 7 sheep and beef farms in Otago 2020-21

Farm	Farm profit (EBITR[1]/ farm)	Length of fencing	Capital and annual borrowing cost[2] of fencing	Change in EBITR[3]	Area removed from grazing	Requires a reduction in stock numbers?	Comments
SB02	$370,000	4.0 km 2nd order	$60,000 capital cost or $4,200/yr with borrowing	-<1%	4.4 ha	No	Capital cost is 16% of EBITR and would require two years to install without borrowing
SB05	$142,000	5.0 km 2nd order	$75,000 capital cost or $5,250/yr with borrowing	-2%	5.5 ha	No	Capital cost is 53% of EBITR and would take six years to implement without borrowing. No change to stock numbers.
SB06	$61,000	4.0 km 3rd order, 5.0 km 2nd order	$90,000 capital cost or $6,300/yr with borrowing	-10%	7.5 ha	No	
SB09	$23,000	2.2 km 2nd order	$33,000 capital cost or $2,310/yr with borrowing	-15%	2.4 ha	Yes	
SB12	$259,000	8.0 km 3rd order, 9.0 km 2nd order	$255,000 capital cost or $17,850/yr with borrowing	-11%	19.0 ha	Yes	Capital cost is 98% of EBITR and would take 10 years to implement without borrowing.
SB15	$852,000	51.0 km 3rd and 2nd order combined	$765,000 capital cost or $53,550/yr with borrowing	-7%	56.0 ha	Yes	
SB16	$297,000	2.0 km 2nd order	$30,000 capital cost or $2,100/yr with borrowing	-4%	2.5 ha	Yes	Cost is 10% of EBITR and could be implemented in 12 months without borrowing

[1] Earnings before interest, tax, and rent.

[2] Assumes an interest rate of 7% per year.

[3] EBITR, which Includes cost of borrowing repayments and financial impacts of farm system changes resulting from the fencing (reduction in land area due to riparian areas, stock number changes and associated changes to expenses and income).

Table 9: Results of fencing off all streams with and without stock-water reticulation costs for 9 sheep and beef farms in Otago 2020-21

Farm	Farm profit (EBITR[1] per farm)	Fencing length by stream order and wetlands	Capital and annual borrowing cost[2] of fencing	Change in farm profit (EBITR3)	Capital and borrowing cost[2] of water reticulation	Change in profitability[3] with water reticulation	Area removed from grazing	Requires a reduction in stock numbers?
SB01	$236,000	5.5 km 1st order	$82,000 capital cost or $5,800/yr with borrowing	-7%	$8,600 capital cost or $600/yr borrowing	-7%	6.0 ha	Yes
SB02	$370,000	4.0 km 2nd order, 11.0 km 1st order	$225,000 capital cost or $15,750/yr with borrowing	-4%	$23,400 capital cost or $1,640/yr borrowing	-5%	16.5 ha	Yes
SB04	$281,000	3.5 km 1st order	$52,500 capital cost or $3,675/yr with borrowing	-3%	$5,500 capital cost or $380/yr borrowing	-3%	3.9 ha	Yes
SB05	$142,000	5.0 km 2nd order, 11.5 km 1st order	$221,500 capital cost or $14,800/yr with borrowing	-12%	$22,000 capital cost or $1,540/yr borrowing	-14%	15.5 ha	Yes
SB06	$61,000	4.0 km 3rd order, 5.0 km 2nd order, 11.0 km 1st order	$387,000 capital cost or $27,000/yr with borrowing	-45%	$31,200 capital cost or $2,185/yr borrowing	-47%	12.1 ha	Yes
SB09	$23,000	3.5 km wetland, 2.2 km 2nd order, 8.1 km 1st order	$231,000 capital cost or $16,070/yr with borrowing	-100%	$16,100 capital cost or $1,125/yr borrowing	-105%	26.2 ha	Yes
SB12	$259,000	8.0 km 3rd order, 9.0 km 2nd order, 6.5 km 1st order	$352,000 capital cost or $24,675/yr with borrowing	-17%	$36,700 capital cost or $2,565/yr extra interest	-18%	19 ha	Yes
SB15	$852,000	51.0 km 3rd and 2nd order, 16.0 km 1st order	$1,005,000 capital cost or $73,500/yr with borrowing	-10%	$104,400 capital cost or $7,315/yr extra interest	-11%	89 ha	Yes
SB16	$297,000	2.0 km 2nd order, 11.5 km 1st order	$202,500 capital cost or $14,175/yr with borrowing	-10%	$21,100 capital cost or $1,475/yr extra interest	-11%	15 ha	Yes

[1] Earnings before interest, tax, and rent.

[2] Assumes an interest rate of 7% per year.

[3] EBITR, which Includes cost of borrowing repayments and financial impacts of farm system changes resulting from the fencing (reduction in land area due to riparian areas, stock number changes and associated changes to expenses and income).

2.5.3 Improving or protecting biodiversity

Following on from the fencing of wetlands and waterways two other environmental actions were tested to promote on-farm biodiversity:

1. Planting riparian areas with natives; and
2. Fencing all areas of regenerating bush.

2.5.3.1 Planting riparian areas

The cost of planting riparian areas is presented separately, and additional to, the fencing costs for the riparian area (see Section 2.5.2). The costs are based on first spot spraying then planting two rows of native trees with tree guards and releasing them from long grass within 12 months. Annually, there is a cost for hand spraying weeds and replacing any dead plants, which is assumed to be one per cent of the initial planting cost. However, this may be higher, especially in drier regions where plant mortality can be high in some seasons. The impact on profitability ranged from a reduction of 1% to 81% and the capital cost of planting ranged from $32,200 to $712,000 per farm (Table 10).

Table 10: Costs of riparian planting and impact on farm profit for 8 sheep and beef farms in Otago 2020-21

Farm	Area (all waterways fenced)	Cost of Planting	Annual Interest on Planting Cost[1]	Annual Repairs and Maintenance	Change in Profitability[2]
SB01	6.0 ha	$48,000	$3,800	$500	-2%
SB02	16.5 ha	$132,000	$10,400	$1,300	-3%
SB04	3.9 ha	$31,200	$2,500	$300	-1%
SB05	15.5 ha	$124,000	$9,800	$1,200	-8%
SB09	26.2 ha	$209,600	$16,500	$2,100	-81%
SB12	26.0 ha	$208,000	$16,400	$2,600	-7%
SB15	89.0 ha	$712,000	$56,100	$8,500	-8%
SB16	15.0 ha	$120,000	$9,500	$1,200	-4%

1 Assumes an interest rate of 7% per year.
2 EBITR, which includes cost of borrowing repayments and financial impacts of farm system changes resulting from the fencing (reduction in land area due to riparian areas, stock number changes and associated changes to expenses and income).

2.5.3.2 Fencing all areas of regenerating bush

Ten of the 16 case study farms included areas of ungrazed bush and scrub. These areas were identified in Overseer as 'trees and scrub' and for the purposes of this modelling were assumed to be unfenced regenerating native. In reality, they may be areas of gorse and broom. In both FARMAX and Overseer, these areas were not grazed so fencing them to completely exclude livestock had negligible impact on the farm system. Fencing these blocks will constrain the farmer's ability to use them to shelter livestock during inclement weather conditions. Often livestock are unable to penetrate far into such an area, depending on the density of regenerating bush and the length of time livestock have access.

As before, fencing costs were assumed to be $15 per metre for a post and netting fence with the farmer providing some of the labour. Annual repairs and maintenance on fencing was assumed to be one per cent of the capital cost. Any weed or pest control expenses were not included. The change in farm profitability was calculated assuming money is borrowed to cover the costs, however in Table 11 the capital cost of fencing as a proportion is shown. It is likely that if the capital cost is less than 10% then the farmer may choose to pay it themselves rather than increase their borrowing.

The areas of regenerating bush range from five to just under 6,000 hectares and fencing costs ranged from $15,000 to $502,500. The range in impact on profitability was between -1 and -180 per cent.

Table 11: Areas of regenerating bush and cost of fencing to exclude stock for ten sheep and beef farms in Otago

Farm	Regenerating Bush Area and Fence Length (ha and km)	Fencing Total Capital Cost	Cost as share of farm Profit	Annual Interest on Fencing Cost[1]	Fencing Repairs and Maintenance	Change in Farm Profitability[2]
SB01	10ha, 1.5 km	$22,500	10%	$1,600	225	-1%
SB02	120ha, 4.5 km	$67,500	18%	$4,700	675	-1%
SB03	5 ha, 1.0 km	$15,000	9%	$1,100	150	-1%
SB05	100ha, 4.0 km	$60,000	42%	$4,200	600	-3%
SB07	20ha, 2.0 km	$30,000	37%	$2,100	300	-3%
SB09	25ha, 2.0 km	$30,000	130%	$2,100	300	-10%
SB10	>5,000 ha, 33.5 km	$502,500	22%	$35,200	5,025	-180%
SB12	130ha, 4.5 km	$67,500	26%	$4,700	675	-2%
SB15	100ha, 4.0 km	$60,000	7%	$4,200	600	-1%
SB16	25ha, 2.0 km	$30,000	10%	$2,100	300	-1%

1 Assumes an interest rate of 7% per year.

2 EBITR, which includes cost of borrowing repayments and financial impacts of farm system changes resulting from the fencing (reduction in land area due to riparian areas, stock number changes and associated changes to expenses and income.

Image 15: A mix of native bush, farm forestry and pasture near Clinton.
Source: Emma Moran

2.5.4 Winter forage crops

A farm's winter forage crop is central to its production system and their management is a complex topic. Otago has long winters with low pasture growth rates, and winter feed crops have become integral to farming systems on many farms. It is a way to transfer high quality feed from the period of high growth rates when feed production exceeds feed demand, to winter when feed production is unable to meet demand.

Four environmental actions were tested in relation to winter forage crops:

1. A maximum winter crop area of 50 hectares or ten per cent of the farm area.
2. Where winter cropping is on a slope >10° provide 20 metre buffer to any waterway and where it is <10° provide a 10-metre buffer to any waterway.
3. Use direct drilling or minimum till for winter crop on all farms.
4. Use a standoff pad and limit cattle-grazing of winter forage crops to a maximum of 8 hours per day.

The following analysis only includes forage crops grown to manage livestock feed requirements. Forage crops are also used in a cropping rotation for weed or pest control, pasture improvement, and/or soil amelioration[116].

116 This topic is covered in some detail in Chapter 4: Arable Farming.

The area of winter forage crop exceeded 50 hectares and more than ten per cent of the total farm area on two of the 16 farms: SB02, SB09. These areas were selected as they are the limits for a farm to be a permitted activity in the National Environmental Standards for Freshwater regulations 2020[117]. Table 12 shows the proportions of forage crop areas for all 16 farms and the changes in profitability of limiting the area of winter crop to 50 hectares for those two farms. For SB02 the cropping area was 62 per cent smaller, which decreased profitability by less than one per cent and nitrate leaching from 9 N/ha/yr to 8 kg N/ha/yr (within the margin of error). On SB09 the cropping area was 52 per cent smaller, which increased profitability by 30 per cent, largely as a result of lower cropping expenses. There was no change in nitrate leaching for this farm.

Table 12: Share of farm in winter crop for 16 sheep and beef farms and impacts on profitability of reducing winter crop area to 50 ha for the two farms with more than 50 ha and 10% of the farm in winter crop

Farm	Winter crop area more than 50 ha?	Proportion of farm in winter crop	Change in winter crop area	Change in Profitability[1]	Comment
SB01	No	11%	-	-	
SB03	No	8%	-	-	
SB04	No	8%	-	-	
SB05	No	6%	-	-	
SB07	No	4%	-	-	
SB08	No	6%	-	-	
SB10	No	<1%	-	-	
SB11	No	<1%	-	-	
SB12	No	<1%	-	-	
SB14	Yes	3%	-	-	More than 50 ha but less than 10% of farm
SB15	No	1%	-	-	
SB16	No	7%	-	-	
SB02	Yes	11%	-62%	<-1%	N loss reduces 7 to 6 kg N/ha/yr
SB09	Yes	15%	-52%	+30%	Change comes from a reduction in cropping expense

117 https://www.legislation.govt.nz/regulation/public/2020/0174/latest/whole.html#LMS376713 Subpart 3 – Intensive winter grazing

2.5.4.1 Cropping Buffers

All 16 farms were previously assessed for the presence of waterways, and stream fencing, including a five-metre riparian buffer, was tested (refer to Section 2.5.2). Four farms had waterways adjacent to crop paddocks and so were included in this part of the analysis: SB02, SB09, SB15, SB16. The riparian buffer was increased from five to ten metres (within the crop paddock) for farms with forage crops grown on slopes below 10°. The buffer was increased from five to 20 metres on the farms with forage crops grown on slopes above 10°. The results for proportion of the crop area lost for grazing by the different buffer widths are presented in Table 13. If the buffer widths increased to either ten or 20 metres (depending on slope), the percentage of the crop area lost for grazing increased.

For example, farm SB02 has 33 per cent of the forage crop area over a 10° slope. When the waterways associated with these areas require a five metre buffer then the forage crop area reduced by four per cent. If that buffer is required to be ten metres for slopes below 10° then the crop area is reduced by five per cent and if buffers on crop areas above 10° slope is required to be increased to 20 metres, then the reduction in crop area a further five per cent on those higher slopes, totalling a ten per cent reduction in crop area.

Table 13: Farms with the largest forage cropping areas and proportions of forage crop area affected by buffers

	Current farm system		With additional buffers		
Farm	**Forage crop area over 10°**	**Change in forage crop area with a 5m buffer**	**Change in forage crop area with a 10m buffer**	**Change in forage crop area with a 20m buffer**	**Change in total area**
SB02	33%	-4%	-5%	-5%	-10%
SB09	40%	-3%	-4%	-1%	-5%
SB15	67%	-26%	-17%	-64%	-81%
SB16	51%	-6%	-5%	-11%	-16%

On two of the four farms, increasing the riparian buffer width to ten metres on slopes less than 10° and to 20 metres on slopes greater than 10°, resulted in less than one per cent decrease in profitability and no change in livestock numbers. A third farm (SB16) had less than one per cent decrease in profitability but had to reduce sheep numbers by one per cent and cattle numbers by three per cent to fit the lower feed supply estimated by FARMAX. The small decrease in profitability, even though livestock numbers (and so revenue) were reduced, was because of lower crop establishment expenses from the smaller crop area. The fourth farm, SB09, had a six per cent decrease in profitability but no reduction in stock numbers (Table 14).

Table 14: Financial impact of creating a buffer area between existing winter forage crops and waterways on four sheep and beef farms in Otago

Farm	Change in Profitability[1] (%)	Share of cropping area used in riparian buffer (%)	Capital Cost of fencing ($)	Annual interest charges on fencing cost[2] (%)	Change in stock numbers to remain viable (%)
SB02	<-1%	10%	$22,000	$1,545	0%
SB09	-6%	5%	$14,100	$985	0%
SB15	<-1%	81%	$35,000	$2,500	0%
SB16	<+1%	16%	$23,200	$1,630	-1% sheep -3% cattle

[1] EBITR, which includes cost of borrowing repayments and financial impacts of farm system changes resulting from the fencing (reduction in land area due to riparian areas, stock number changes and associated changes to expenses and income.
[2] Assumes an interest rate of 7% per year.

2.5.4.2 *Direct drilling and minimum tillage*

Forage crops are generally direct drilled[118] or use minimum tillage[119], except if a paddock needs amelioration to correct a bumpy surface, drainage, or soil structure. No opportunities were identified for further analyses of direct drilling or minimum tillage. Similarly, there were no opportunities for testing the replacement of fallow periods with catch crops on these farm systems. Catch crops are crops planted as soon as practicable after grazing to reduce the period soil is left bare and to take up plant available nitrogen. They reduce the risk of nitrogen leaching and contaminant losses lost via overland flow.

Many farms would cultivate after a winter feed crop before establishing new permanent pasture. Direct drilling can be problematic in areas with higher rainfall because of drowning of sown seed. There is a trend towards direct drilling driven by environmental and GHG concerns, but yields can sometimes be compromised. Some farms use cultivation before sowing crops to avoid using higher rates of herbicide, insecticide, and slug bait.

2.5.4.3 *Standoff areas and cattle grazing time*

Standoff areas are becoming more common on many dairy farms but are seldom used on sheep and beef farms due to the cost of infrastructure, the practicalities relating to the size of the farms and the lower profitability of sheep and beef farms compared to dairy. In a standoff system, livestock need to have easy access from the standoff pad to the crop paddock but crop paddocks are located in different parts of the farm each year and sheep and beef farms can be large. The travelling distance between the crop paddock and a permanent standoff pad may be quite far some years. As well, sheep and beef farms do not have the lane infrastructure that dairy farms have, adding to the complexity, cost and potential for soil damage of this type of environmental action.

118 Direct drill is where the seed is drilled into unploughed soil, often with fertiliser applied at the same time.
119 Minimum tillage covers reduced tillage, conservation tillage and no tillage. It had reduced numbers of passes over the paddock compared to conventional cultivation and has the minimum soil manipulation required for a successful crop.

Standoff areas are not used for feeding livestock. It was assumed that the cattle continue to graze the crop or pasture, as they currently do, for six hours a day and return to the standoff pad for 18 hours a day. The standoff pad was assumed to have a base concrete overlain with woodchip bedding where urine and dung is collected and stored in the bedding. The woodchip is then spread over paddocks at favourable times of the year. Standoff pads for cattle are estimated to cost about $700 a head to construct and $7 a head to maintain each year. A metalled access track between the forage cropping area and the standoff area costs about $7,000 per kilometre to build, plus additional fencing to form a race. In Overseer the woodchip bedding was spread over pasture in spring. Only adult cows and steers were assumed to be suitable for this environmental action.

This environmental action was most relevant to the four of the 16 farms with the highest ratio of cattle to manage.

The percentage of cattle housed on the standoff pad (grazing crop 6 hours a day), ranged between 24 and 68 per cent on the four farms modelled (Table 15). The cost was related to the size of the pad, and for these farms, it ranged between $47,000 and $550,000 for capital cost and between $3,200 and $43,900 for annual interest on borrowing and repairs and maintenance (R&M). The resulting impact on financial performance was a decrease in profitability of between four and 14 per cent. Adding a standoff pad did not result in a change to OverseerFM-predicted whole farm nitrate leaching losses on any of the farms.

Table 15: Cattle standoff pad assumptions, financial and nitrogen leaching loss results

Farm	Sheep: cattle: deer (% of SU)	Cattle on pad as share of herd (%)	Standoff area required (m^2)	Cost of pad and race ($)	Annual interest on borrowing + R&M per animal[1] ($)	Change in EBITR[2] (%)	Change in N loss (%)
SB05	73:27:0	44%	1,250	$102,000	$8,000	-6%	0%
SB09	73:27:0	24%	450	$47,000	$3,200	-15%	0%
SB12	70:30:0	68%	1,700	$147,000	$11,500	-4%	0%
SB15	46:50:4	48%	6,200	$550,000	$43,900	-5%	0%

[1] Assumes an interest rate of 7% per year.

[2] EBITR, which includes cost of borrowing repayments and financial impacts of farm system changes resulting from the fencing (reduction in land area due to riparian areas, stock number changes and associated changes to expenses and income.

2.5.5 Irrigation

2.5.5.1 Overview

Irrigation is not used extensively on sheep and beef farms but, where it is used, it is a vital component of a farm system and is a way of managing the risks that arise from Otago's climatic variability. Irrigation systems are varied - some have on-farm storage, some are run-of-river systems, and some are groundwater sources. Of the 16 case study farms, four include an area of irrigation: one has irrigation on nine per cent of the farm and the other three have around two per cent of the total farm area under irrigation. These farms were SB09, SB11, SB13, and SB14 (SB09 is a medium-sized farm and the remaining three are large farms).

Typical uses of irrigation on sheep and beef farms in Otago are on:

- Winter crop paddocks during the growing season to boost crop growth rates and crop yield;
- New-grass paddocks for good pasture establishment;
- Pasture paddocks identified for hay/silage/baleage production to have reliable supplementary feed production;
- Lucerne crops; and
- Pasture as a reliable source of good quality feed to finish lambs or cattle, or to get replacement livestock up to mating weight.

Irrigation systems on sheep and beef farms are usually pivot, K Line®, borderdyke, wild flooding, Rotorainer, and gun. The most common types of irrigation in Otago across all land uses are pivot (27% of the total irrigated area) and K Line®/long lateral (27% of the total irrigated area). Borderdyke and wild flooding, which are types of flood irrigation, contribute a further 23 per cent of the total irrigated area (border dyke 15% and wild flooding 8%).

A map and discussion of the irrigated land areas by type is included in Report 4 of the Economic Work Programme: An Otago Economic Profile for Fresh Water and Land (Yang and Cardwell, 2023). It shows the irrigated land areas tend to be non-sheep and beef land.

The four case study farms with irrigation included a variety of irrigation types.

Three irrigation-related environmental actions were tested:

1. Upgrading to a more efficient irrigation system, depending on topography because not all areas suit pivot irrigation;
2. Upgrade from borderdyke and increase irrigation area with a more efficient system; and
3. Add water monitoring sensors to more accurately time the application of water.

Specific environmental actions for each farm are shown in Table 16. Irrigation systems were changed on three farms while water monitoring sensors were added to the fourth. There were major impacts in profitability for two of the three farms that had changes to their irrigation system.

- Farm SB09 had a 160 per cent decrease in profit when the K Line® was changed to a pivot and a 316 per cent decrease if the area irrigated was expanded and sensors were added.
- Farm SB11 had less than a one per cent decrease in profit from changing a small area of borderdyke to K Line®.

- Farm SB13 had a 56 per cent decrease in profit changing borderdyke to pivot and when sensors were added it was a 92 per cent decrease.
- The results for these three farms show that the investment needed to change irrigation systems is potentially prohibitive for sheep and beef farms because of the relatively low per hectare and whole farm incomes.
- Farm SB14 had an existing centre pivot irrigation system so the environmental action modelled was to include water sensors, which resulted in a one per cent decrease in profitability.
- All four farms had low base nitrogen losses (refer to Table 4) and, with the small proportions of irrigated area on these farms, the resulting change for each farm was either nil or minimal.

The situations for each of the four farms are described in more detail in the following sections.

While some gains in environmental outcome can be made from improving water use efficiency, major upgrades to irrigation systems are not a sound investment for many sheep and beef farms if the returns are insufficient to cover the costs (which also means finance is unlikely from lenders). The irrigated areas on these farms, while small, play a crucial role in the farm system by providing a reliable feed source for livestock where rainfall is low or unreliable. They are often pivotal to the viability of the farming enterprise and to lose it reduces the options for these farms as they are in locations where other land use alternatives are few. Incorporating water sensors, which is a low-cost solution for irrigated farms, is suitable in some situations but not all. Farmers will need to develop skills for the management and technology. Any reductions in a farm's nitrogen losses depends on the proportion of the farm irrigated, the original water application methods, and the current nitrogen losses.

Table 16: Irrigation actions impact on financial performance, stock numbers and N leaching

Farm	Proportion of farm irrigated (%)	Environmental action tested	Change in profitability (%)	Change in N leaching loss (kg N/ha/yr)	Change in sheep + cattle numbers (%)
SB09	9%	Change K Line® to pivot and add sensors	-160%	-2	0%
	20%	Increase irrigated area and add sensors	-316%	-1	+8%
SB11	<1%	Change borderdyke to K-Line	< -1%	0	0%
	2%	Change borderdyke to pivot	-56%	-1	0%
SB13	2%	All changes + sensors	-92%	-1	0%
SB14	3%	Add water sensors	-1%	-2	0%

2.5.5.2 SB09 – Breeding Finishing Farm

Irrigation on this property is used from October to April and to irrigate mostly flat pasture and some fodder crops. It currently uses a fixed depth of water and return period; no water monitoring sensors are used. In this analysis the K Line® is converted to linear and centre pivot with two moisture sensors. The capital cost is estimated to be $7,500 per hectare plus sensors of $12,500. It was assumed the existing well, pumps, and consents would be used. There is additional annual repairs and maintenance costs of two per cent of the capital value.

The capital costs are $410,000, or $28,700 annually in interest, plus repairs and maintenance of $8,200. Not included is any additional cost for building a storage dam.

Expanding the irrigated area by another 100 hectares using a pivot irrigator will not justify the capital costs required. The model maintained existing levels of animal performance, although it is likely to be possible to optimise the farm system to make better use of the enlarged irrigation area and so increase farm profitability. The cost of either of these actions is financially unviable without increasing animal production or using the irrigated area to produce a product that is more profitable than the current system.

Overall farm nitrogen loss is 9 kg N/ha/yr whereas it is around 23 kg N/ha/yr on the irrigated pasture block and ranges from 35 to 69 kg N/ha/yr on fodder beet crop blocks (however these are only 6-ha and 4-ha blocks respectively).

2.5.5.3 SB11 – High Country Farm

This farm has a small area of borderdyke irrigation, which is used from September to April based on a fixed depth and return period, for growing pasture. The action modelled was to change to K Line® because of the small area (<0.5% of farm area).

The capital cost is $24,500, or $1,715 annually if the money is borrowed. This assumes limited groundwork, a small extension to the existing mainline and booster pump, plus irrigation equipment. On-going maintenance is assumed to be $490/yr. The capital cost is equivalent to less than ten per cent of farm profitability (EBITR) and so a farmer might decide to make the change without borrowing, however additional borrowing was assumed.

This results in less than a one per cent reduction in EBITR and no change to nitrate leaching. Overall, the farm's nitrogen leaching is 4 kg N/ha/yr while the leaching under the irrigated blocks is between 10 kg N/ha/yr and 28 kg N/ha/yr.

2.5.5.4 SB13 – High Country Farm

This farm has borderdyke and K Line® irrigation used between October and April to irrigate pasture. The change introduced was to convert all of this to linear and pivot and introduce three water sensors. The irrigated areas total two per cent of the farm area.

The change from borderdyke irrigation will cost about $821,250, or $57,488 in annual borrowing cost. There are additional annual repairs and maintenance costs of two per cent of the capital value: $16,425. The change from K Line® will cost about $500,500, or $35,000 in interest per year. There are additional annual repairs and maintenance costs of: $10,000.

Installing three water sensors will cost about $12,000, or $840/yr and have an operating cost of $450/yr. At a whole farm level, the use of sensors did not further reduce nitrogen leaching below that of changing to pivot.

The total annual cost is $120,203, which is equivalent to a 92 per cent reduction in EBITR.

This property has multiple blocks. Leaching loss from land that has flood irrigation is 1.1 kg N/ha/yr in one area and 39 kg N/ha/yr in another. Leaching loss from other irrigated areas ranges from 21 to 47 kg N/ha/yr on pasture.

2.5.5.5 SB14 – High Country Farm

This farm operates a pivot irrigator that is used to irrigate pasture and fodder crop. The irrigated area is three per cent of the farm area. The main issue is converting from a visual assessment to determine and irrigation schedule, to adding water monitoring sensors for more accurate timing of water applications.

The capital cost for installing two sensors is about $8,000, and they add about $300/yr to operating costs. The cost of this results in a one per cent reduction in EBITR but reduces overall farm leaching loss from 5 kg N/ha/yr to 3 kg N/ha/ha/yr. Nitrate leaching loss on the irrigated pasture blocks was 17 kg N/ha/yr. Phosphorus loss risk is also reduced from 0.1 kg P/ha/yr to <0.1 kg P/ha/yr.

2.5.6 Nitrogen fertiliser

Nitrogen loss from agriculture is predominantly in the form of nitrate leaching (NO_3) rather than via overland flow pathways. Losses occur when nitrate present in the soil exceeds a plant's needs during drainage or overland flow.

The main drivers of nitrogen leaching are:

1. Urine patches: Affected by stocking rate and stocking density (higher = greater losses), stock class (mature cattle > young cattle > deer/sheep > lambs), concentration of nitrogen in urine (high protein feed increases urinary nitrogen);
2. Effluent: Losses occur via preferential flow pathways, high application depths (>20 mm), ineffective effluent systems, application at high-risk times of the year. Direct discharges to waterways cause increased nitrogen in waterways but not via leaching; and
3. Nitrogen fertiliser: applications that exceed plant requirements, that occur during high-risk months of the year (around winter), and when directly followed by a heavy rainfall event. Unintended direct inputs of nitrogen fertiliser to water are a cause of increased nitrogen in waterways but not via leaching.

The stocking rates of the 16 case study farms (and most sheep and beef farms) are relatively low so environmental actions to reduce stocking rate or stocking density (refer to the start of Section 2.5) were not tested here. Importantly, the stocking rates on sheep and beef farms are generally matched to the pasture that is naturally grown on the land. Typically, there is minimal use of nitrogen fertiliser, irrigation and imported feeds. Thus, to destock causes issues with rank pasture and an inefficient system. The situation differs from an intensive system where it is possible to destock, reduce nitrogen fertiliser applications and imported feed and still have sufficient feed demand for all the pasture that is naturally grown.

The impacts of nitrogen leaching from urine patches are discussed further on in this chapter (Section 2.5.6), although reducing nitrogen was not the main purpose of that section. The application of effluent is not relevant for drystock farms, which leaves nitrogen fertiliser applications. Two environmental actions were tested for managing nitrogen leaching from nitrogen fertiliser:

1. Removing winter nitrogen fertiliser applications and reducing annual applications to 40 kg N/ha/yr or less and replace with the equivalent lucerne baleage[120].
2. Reducing all applications of nitrogen fertiliser to less than 30 kg N/ha/yr, by spreading them out across additional months, without increasing existing winter applications.

Applying nitrogen fertiliser in winter increases the risk of nitrogen losses to water so the removal of any winter application of nitrogen was the first environmental action tested. However, none of the 16 farms (or in fact the 41 farms in the Sheep and Beef Farm Survey) applied nitrogen fertiliser over winter (May to August inclusive) in 2021-22. Therefore, there was no need, or ability, to assess the impact of removing winter nitrogen fertiliser applications.

Of the 16 farms, five were applying nitrogen in such a way that there may be some risk to water quality. Table 17 shows these five farms and the largest amount of nitrogen applied to any pastoral area on each of the farms. Generally, this amount was applied as two or more applications. Only the farm's pastoral areas were included in this analysis – any nitrogen applied for forage crops and/or cash crops was excluded.

In general, all five farms had a feed deficit during lambing around the end of September and early October. The farms had two main strategies to address this: applying nitrogen as early as possible in spring to fill the deficit period with pasture growth; and applying nitrogen in autumn to lift pasture covers over winter and then into early spring. This second strategy needs careful feed budgeting to avoid a 'feed-wedge' created from being consumed between May and August. The five farms applied nitrogen in both spring and autumn.

Table 17: Current nitrogenous fertiliser application to pasture of 5 case study sheep and beef farms

Farm Number (Farm Class)	SB09 (FC 6)	SB05 (FC 6)	SB03 (FC 7)	SB02 (FC 6)	SB01 (FC 6)
Proportion of pasture area to which N applied (%)	52%	77%	67%	77%	53%
Highest total annual amount of nitrogen applied to a pasture block (kg N/ha/yr)	41	51	56	35	44
Highest rate of nitrogen applied on any block (kg N/ha/month)	35	20	40	35	27
Winter application of nitrogen (kg N/ha/winter)	0	0	0	0	0
Months nitrogen used	Sep-Nov, Dec-Jan, Mar-Apr	Sep, Mar-Apr	Sep-Oct, Mar	Sep-Dec, Mar	Oct, Mar
OverseerFM-predicted N leaching loss (kg N/ha/yr)	9	15	9	7	15

120 Equivalence was based on equivalent feed value (dry matter) fed in lucerne baleage to maintain the same farm system.

The first environmental action tested was to reduce annual nitrogen fertiliser applications to 40 kg N/grazable ha/yr and replace the feed deficit caused with lucerne baleage. One of the 16 farms (SB05) had applied over an average of 40 kg N/ha/yr across the whole of the grazeable area and two other farms (SB03 and SB01) had applied more than 40 kg N/ha/yr across parts of their grazeable areas (Table 18). Each of these three farms was able to reduce their nitrogen fertiliser use and replace the feed grown with lucerne baleage at a cost of between $2,000 and $20,000 per farm. However, in a better pasture-growing year the three farms did not need all the replacement lucerne baleage to remain viable. On two of the three farms nitrogen efficiency (kg DM/kg N, calculated on an annual basis), declined and on the third farm it remained virtually unchanged.

Table 18: Results from reducing annual applications of nitrogen fertiliser and replacing with lucerne baleage

Farm Number (Farm Class)		**SB05 (FC 6)**	**SB03 (FC 7)**	**SB01 (FC 6)**
Farm average annual nitrogen application rate (kg N/ha/yr)	Initial	41	32	32
	Final	33	7	17
Block average annual nitrogen application rate (kg N/ha/yr)	Initial	51	44	56
	Final	40	19	27
Nitrogen Efficiency (kg DM/kg N)	Initial	8.1	15.4	11.4
	Final	8.6	10.2	9.9
Additional dry matter needed	Total (kg DM)	19,000	60,500	5,600
	Lucerne bale equivalent (no.)	70	225	20
	Cost of equivalent bales ($)	$6,000	$19,150	$1,700
	Minimum bales needed to maintain existing system (no.)	30	45	0

The second environmental action relating to nitrogen fertiliser was to split applications over additional months so that there were no applications greater than 30 kg N/ha/application. This action was selected because of discussions during regional plan processes around including such a limit in regional plans in other regions of New Zealand. Three of the 16 farms applied more than 30 kg N/ha in a single application (i.e., in the same calendar month). Table 19 lists these farms and shows how nitrogen use was extended across the year (avoiding winter months) to keep applications in any one month to a maximum of 30 kg N/ha.

These changes made little difference in nitrogen efficiency, and all the current farm system models remained viable. Spreading costs are usually estimated as $/tonne and commonly range from $80 to $120 per tonne. For this analysis, it was assumed that extending fertiliser applications over more months may result in additional spreading costs for each farm and an increase of $20/tonne was used. However, often spreading costs per tonne increase as the rate/ha decreases.

Table 19: Results from spreading monthly applications of nitrogen fertiliser above 30 kg N/ha

Farm Number (Farm Class)		SB09 (FC 6)	SB03 (FC 7)	SB02 (FC 6)
Timing and rates (kg N/ha) of nitrogen application	Initial	September 38kg	September 40kg	
			October 37kg	
			March 19kg	March 35kg
	Final	September 20kg	September 16kg	
		October 18kg	October 25kg	
			November 15kg	
			March 17kg	March 13kg
			April 15kg	April 12kg
Nitrogen Efficiency (kg DM/kg N)	Initial	7.6	9.9	-
	Final	7.7	9.9	-
Additional spreading costs	($/farm)	$542	$156	$48

2.5.7 Tussock lands

Tussock lands are unique and form expansive landscapes in Otago and across the South Island. They are considered to be important from a water resource management perspective, as catchments covered in snow tussock have higher water yields than those with pasture grass or forestry land covers (Davey, Fahey, & Stewart, 2006).

In the hill country, tussock areas respond well to rotational grazing and weed control to manage regeneration of matagouri and other invasive species such as wilding pines. The shelter that the tussocks provide livestock, especially during lambing, results in increased lambing percentages. An Otago farmer has reported a 15 point higher tailing percentage from ewes lambing in the tussock country compared to those lambing on the irrigated flats.

Thus, with careful management of stock grazing intensity, tussock cover is maintained in the long term and there is a mutual relationship between the farmer and the tussock lands. The farmer provides weed control to keep out invasive species and the tussocks provide shelter for stock at important times of the year (such as during lambing), which enhances stock performance.

The modelling of the removal of tussock lands from livestock production did not include any changes to livestock performance (e.g., lambing percentages were not reduced as a consequence). Thus, those farms with large areas of the grazable area in tussock (SB10, SB11, SB14) potentially may have reduced lambing percentages as a result of removing the tussock area from grazing. Also, it was assumed there was no additional cost of weed and pest control on the tussock areas removed from grazing. In reality, there may be additional costs of weed and pest control that further increase the impacts of this action.

The modelled financial impact of removing tussock area from grazing reduced farm profitability (EBITR) in all cases, ranging from four per cent to the farm becoming financially unviable.

Whole farm average nitrogen leaching losses predicted by OverseerFM generally reduced by 1 kg N/ha/yr. The exception was SB10 whose losses reduced by 3 kg from 7 to 4 kg N/ha/yr, however, 90 per cent of the grazable area was removed and the number of livestock was reduced by 35 per cent so the result is not surprising. Livestock numbers were also reduced on SB11 – by one-third – but the already low nitrogen leaching figure of 4 kg N/ha/yr was reduced by a further 1 kg N/ha/yr.

Five of the 16 farms included areas of tussock that it was possible to test being retired from grazing (Table 20). Tussock land on one farm was already the subject of a QEII Covenant[121].

- SB02 (Class 6, breeding/finishing farm) had six per cent of the farm area in silver tussock. It was calculated that 2.8 km of fencing was needed to exclude livestock from the area, and the cost of fencing included capital expenditure of $42,000, and an additional cost of $3,000 per year for interest repayments reduced farm profit by four per cent per year.
- SB10 (Class 1, high country farm) had 90 per cent of its grazable area in tussock. This farm had a decrease in farm profit of over 200 per cent from around $25,000, making the property financially unviable if the tussock area was not available for light grazing.
- SB11 (Class 1, high country farm) had 35 per cent of its area in tussock. If livestock were able to be excluded from this area year-round with no additional fencing, then it reduces farm profit by 46 per cent.
- SB14 (Class 1, high country farm) had 32 per cent of the grazable farm area on very steep land. After all tussock land was protected from livestock grazing year-round (35% of the grazable area of the farm), the farm needed around 200 tonnes of lucerne baleage over winter to remain viable in FARMAX. This farm was already operating at a loss and removing the tussock further exacerbates this loss making the farm unviable.
- SB16 (Class 6, finishing and breeding farm) has 18 per cent of the grazable area in red tussock on easy hill. It was assumed that no additional fencing was required to exclude livestock. There was a reduction in EBITR of 13 per cent.

Table 20: Results from excluding tussock areas from year-round livestock grazing on six sheep and beef farms

Farm	Grazeable area in tussock (%)	Change in EBITR (%)	Change in livestock numbers (%)	Change in GHG emissions (%)	Change in N leaching loss (kg N/ha/yr)	
					Before	After
SB02	6	-4	-3	-3	7	6
SB10	90	-244	-35	-35	7	4
SB11	35	-46	-33	-33	4	3
SB14	35	-118	-21	-21	5	4
SB16	18	-13	-13	-13	13	12

121 Queen Elizabeth II National Trust works in partnership with landowners to protect native biodiversity on their properties, forever. The landowner retains ownership of the land they are protecting. The Trust provides the legal protection. https://qeiinationaltrust.org.nz/

2.5.8 Farm system changes

Cattle can pose a greater risk of contaminant loss than sheep. They have a higher nitrogen loading per urine patch than sheep, and cattle urine patches are larger. The amount of nitrogen applied to the soil in urine patches can be nearly 1,000 kg N/ha for a dairy cow compared to 500 kg N/ha for a sheep, with beef cattle somewhere in the middle. There is a higher risk of sediment and phosphorus losses where cattle graze because of the potential for treading damage from larger animals on vulnerable soils, and the resulting erosion.

To address this risk, three environmental actions related to a change in the farm system were tested to understand the impacts:

1. Remove cattle and replace with sheep;
2. Exclude cattle from steeper areas; and
3. Retire some areas to pines or native trees.

Cattle play a vital role within the sheep and beef farm system by improving feed quality for lambs over summer (among other benefits). Their role is hard to model, but in this case, where it was needed, pasture topping over spring and summer was used when cattle were replaced, and the cost was included in farm expenses. Farm expenses were reduced by removing all the applications of nitrogen and the fodder crops that were primarily being grown for cattle (e.g., fodder beet and some kale).

2.5.8.1 Remove cattle and replace with sheep

Seven of the 16 farms had cattle removed as an environmental action. It may be an alternative to fencing waterways where such an option is impractical and/or financially prohibitive.

The range in farming systems across the seven farms was wide. To model the change in system after the removal of cattle the following assumptions were made:

1. Cattle removed and replaced with sheep;
2. No changes to sheep system (e.g., lambing percentage);
3. Any fodder crops grown specifically for cattle were removed;
4. Topping was modelled if needed over spring and summer to maintain pasture quality with the cost included in farm expenses (SB05 had 110 ha topped between November and February, SB15 had topping required on large areas of the farm (in reality it is exceptionally difficult on this farm due to topography, which why they run cattle in the first place), SB07 had less hay made to maintain pasture quality);
5. Nitrogen fertiliser was removed where it had been used to grow feed for cattle (all nitrogen fertiliser applications were removed from SB01, SB05, SB07, SB10, and SB15. SB12 did not apply any nitrogen fertiliser);
6. An attempt was made to keep pasture intakes the same (it was difficult in farm SB10 because of the farm's extensive nature (its total stocking rate was 0.3 SU/ha in the current farm and 0.4 SU/ha when cattle were removed).

Interestingly, three of the four the farms that saw increases in profitability (EBITR ranged from +9% to +44%) were those where no change to the feed crop area was modelled (Table 21). This result suggests that the management decisions associated with removing cattle are important. The range in the change to profitability was from a reduction of 68 per cent to an increase of 44 per cent (i.e., a range of 112%). Greenhouse gas emissions generally reduced except in farms SB10 where they increased 11 per cent, and SB15 where they increased by two per cent. However, farm SB10 was difficult to model, and the result was a 48 per cent increase in sheep numbers and an overall increase in the amount of dry matter eaten. SB15 also had a slight increase in total feed eaten, which has a direct influence on GHG emissions.

There was no change in Overseer-predicted phosphorus loss risk for any of the seven farms when cattle were removed from the system and replaced with sheep. However, five farms had a resulting reduction in nitrogen leaching (between 1 and 3 kg N/ha/yr) while two remained the same (Table 21).

Farm SB15 has some dairy grazers for a period of the year. These animals were also removed in the analysis, which will obviously be an impact the flows on to the dairy farm(s) that rely on that grazing. Similarly, the removal from breeding cattle from the hill and high country properties impacts the supply of young cattle for finishing on the Farm Class 6 and Farm Class 7 farms on the flatter, more productive country.

While the removal of cattle was possible in the FARMAX model with simulated topping to maintain pasture production, in reality much of the land on sheep and beef farms is unable to be topped using machinery. This is one of the main reasons that cattle are such an invaluable part of the system. Removal of cattle and an inability to top paddocks would result in reduced pasture production and quality and the productivity of the sheep flock would decrease in response.

Table 21: Changes in EBITR, nitrogen leaching loss, GHG emissions, sheep numbers and feed crop area when removing cattle from the farming system for 7 case study sheep and beef farms in Otago

Farm	Share of cattle in current system (% of total SU)	Change in EBITR (%)	Change in N leaching (kg N/ha/yr)	Change in GHGs (%)	Change in Sheep numbers (%)	Change in Feed crop area (%)	Change in Feed eaten[1] (%)
SB01	9%	-2%	-3	-4%	+9%	-52%	-2%
SB05	27%	-68%	-3	-26%	+9%	-26%	-21%
SB07	11%	-27%	-1	-9%	+6%	-23%	-5%
SB08	10%	+19%	-1	-3%	+9%	0	-2%
SB10	24%	+44%	0	+11%	+48%	0	+12%
SB12	30%	+9%	0	-8%	+29%	0	-10%
SB15	50%	+20%	-1	+2%	+128%	-32%	+8%

[1] This is a FARMAX output

2.5.8.2 *Exclude cattle from steeper areas*

The combination of heavy animals at higher stocking densities, sloping topography, high-risk or vulnerable soil types, bare soil, and rainfall events causing runoff, can result in losses of contaminants to waterways. Thus, removing cattle from steep slopes was tested as an environmental action. A common management practice that many farmers employ is to remove cattle from steeper areas of the farm during times of increased risk (e.g., winter). This is a management strategy that can be documented in a farm environment plan where soil types and slopes are identified.

For those farms with a relatively high proportion of cattle and an area of steep land, Table 22 shows the proportion of the farm's pasture area that is on steep slopes. On all the case study farms there is enough alternative grazing land available to exclude cattle from the steep land and replace them with sheep without having to alter the livestock ratios. Farm SB10 had 25 per cent of the feed available on its easier land and 25 per cent of its stock units were cattle, the result was that all its cattle could still be kept to the easier country and the rest grazed by sheep.

While it is theoretically possible to not alter livestock ratios on these farms there will be implications for the overall farm productivity. Lamb growth rates will be slower if the high-quality feed on the flatter land is fed to cattle. Pasture quality on the steeper areas is also likely to decrease as cattle are otherwise used as a means of maintaining pasture quality, as will overall farm performance (both animal and financial).

The figures indicate that the most efficient and effective action is to remove cattle from high-risk areas at high-risk times of the year, which is common practice. Nine of the 16 farms were already implementing this practice on steep hill blocks. Another farm had 17 per cent of the productive area grazed by sheep only, although it was not steep land as there was none on that property. A further six properties had no steep slopes so the environmental action was not relevant.

Table 22: Comparison of the ratios of pasture to steep land with cattle to other livestock

	Proportion of Pasture on:		Proportion of total SU that are:	
Farm	**Easy Land (%)**	**Steep Land (%)**	**Beef Cattle (%)**	**Other Livestock (%)**
SB01	90	10	9	91
SB05	100	0	27	73
SB07	85	15	11	89
SB10	25	75	24	76
SB12	100	0	30	70
SB15	85	15	50	50

2.5.8.3 Retire steep Class VI areas from grazing and plant in pines

Slope maps for estimating LUC[122] Class VI land were created using Landscape DNA but soil type, underlying rock type, or erosion susceptibility were not considered. LUC Class VI land is generally over 26°, which is the same slope used to define 'steep hill' in Overseer. There were five farms with 'steep hill' modelled in FARMAX. Three had 'steep hill' and sufficient rainfall (over 1,000mm) to indicate that erosion may be an issue and the environmental action of retiring those slopes was investigated. However, as noted in the previous section, all these farms already excluded cattle from the steep slopes during high-risk times of the year, which is an excellent environmental action to be using to reduce the risk of erosion and contaminant loss to water.

It was assumed for the modelling that the area was planted in Pinus radiata forestry and entered in the New Zealand Emissions Trading Scheme (ETS)[123], however income from carbon credits or forestry is not included in Table 23 below. Areas being converted to forestry were modelled as being destocked and then planted (1,000 stems/ha at $500/ha). An alternative is that landowners may enter joint-venture forestry contracts and obtain an annual return, but this approach was not tested in this research.

Some areas of Otago have restrictions on the type of tree that may be planted (e.g., it is unlikely that consents would be granted for planting some areas in the Upper Lakes and Dunstan [FMU/Rohe]). There are also climatic restrictions on the species of tree that will grow and growth rates in different areas.

Table 23: Planting Class VI land over 26° slope in Pinus radiata

Farm	Proportion of total farm area retired (%)	Change in stock units (%)	Overseer-predicted P loss before and after retiring LUC Class 6 land		Change in EBITR by retiring (not planting) (%)	Capital and annual borrowing cost[1] of planting ($)	Change in EBITR[2] when planting in pines (no ETS income assumed) (%)
SB08	15%	-9%	2.2[3]	1.6	-9%	$21,000 capital cost or $1,400/yr with borrowing	-10%
SB10	57%	-21%	0.6	0.3	+293%4	$5,462,000 capital cost or $382,000/yr with borrowing	Farm is financially unviable
SB15	15%	-14%	0.6	0.5	-16%	$237,000 capital cost or $17,000/yr with borrowing	-16%

[1] Assumes an interest rate of 7% per year.

[2] Includes cost of borrowing repayments and financial impacts of farm system changes resulting from the fencing (reduction in land area due to riparian areas, livestock number changes and associated changes to expenses and income.

[3] Farm not covered by S-map and thus the soil type modelled has a higher level of uncertainty. The podzol soil order used has the greatest influence on this high phosphorus loss value.

[4] Comes from a reduction in expenses.

122 Land Use Capability. This is a classification system based upon a land resource inventory which is an assessment of the physical factors considered critical for long-term management of land. These physical factors are rock type, soil, slope angle, erosion type and severity, vegetation cover.

123 https://environment.govt.nz/what-government-is-doing/areas-of-work/climate-change/ets/

2.6 Research findings

Key observations from the 16 case study farms are:

1. Overall, the use of inputs on these farms, including water for irrigation, and losses of nutrients from them were limited. For example, Overseer-predicted nitrogen leaching losses are low (2-15 kg N/ha/yr) and stocking rates tend to be low, ranging between 0.5 and 17 SU per grazed hectare. Despite this, there was a considerable range in impacts from implementing the same environmental action. Some farms continued to be profitable, while others became unviable.
2. Good progress had been made to meet recent policy changes and thus were not tested in this analysis. Most farms with winter grazing were meeting the NES-F 2020 intensive winter grazing regulations. Those needing to meet stock exclusion regulations have either completed or partial completed this task. It does, however, take time as some farms have considerable lengths to fence. For some farms, the full impacts of meeting recent policy changes are still to be felt.
3. It was unnecessary to test the impacts of some environmental actions (e.g., changing applications of nitrogen fertiliser during winter, removing cattle from steep areas during winter) – because farmers had either already implemented the actions, or they were not relevant and so the risk factors they address were reduced or eliminated.
4. Some environmental actions reduced the area being grazed (e.g., protecting riparian areas). Smaller farms with higher stocking rates tended to fare the worst in the analysis. Other actions reduced livestock numbers (e.g., reducing winter cropping area, retiring land from grazing). These actions mainly affected farms with large areas and low stocking rates.
5. Farms with higher stocking rates tend to have higher financial returns per hectare. This relationship applies consistently across Farm Classes 1, 2, 6 and 7. However, the farms appear to fall into two groups. Even though Farm Classes 1 and 2 tend to have lower overall stocking rates, their profitability is very sensitive to any management changes resulting in changes to stocking rates. Farm Classes 6 and 7 are also sensitive to the impacts of management changes on stocking rates, but they occur at higher stocking rates than Farm Classes 1 and 2.

2.6.1 Phosphorus, sediment and *E. coli*

Phosphorus loss risk (as predicted by Overseer) is dependent on a complex mix of factors, including soil type, topography, and farm system and management. Specific soil types are found on S-map[124], which is a digital soil map for New Zealand maintained by Manaaki Whenua Landcare Research. The goal of S-map is "*to provide precise and accurate soil information to support sustainable management of our soil resource*". However, S-map does not yet cover all New Zealand and coverage is poor for sheep and beef farms in Otago. Six of the 16 case study farms were not covered by S-map and a further three farms were only partially covered. This situation is likely to be similar for deer farms and it places drystock farms in general at a disadvantage for understanding the inherent risk of the soils on a property and when using tools such as Overseer to predict the risk of phosphorus loss.

124 https://smap.landcareresearch.co.nz/

Most sheep and beef farmers appear to aim for maintenance (or below) applications of phosphorus fertiliser because it is a costly product. Farmers are unlikely to apply extra fertiliser if it does not result in increased pasture production. Regular soil testing is key and is a more efficient and generally applicable environmental action than the use of reactive phosphate rock (RPR), which is expensive and can have supply issues. However, regular soil testing is more likely to be suitable for Farm Class 7 and some Farm Class 6 farms than for extensive country and farms with a large number of paddocks and lower stocking rates.

Phosphate, sediment, *E.coli*, and organic nitrogen tend to travel in overland flow into waterways and sediment is signalled by water discolouration. Solutions are most efficient when tailored to the context of the landscape and the farm system. Total stock exclusion has the highest costs where there is a lack of reticulated water for on-farm livestock drinking. Partial or targeted solutions for stock exclusion and riparian planting (e.g., focusing on one side of a waterway or the use of edge-of-field technologies) are two ways of managing impacts. The costs of additional weed and pest control (e.g., for broom and gorse) can be reduced with expert advice and assistance.

2.6.2 Nitrogen

Nitrogen leaching from sheep and beef farms is low relative to some other land uses (although it is similar to that of deer). Nitrogen leaching is a direct response to intensity of land use and sheep and beef farms have low stocking rates as well as low use of nitrogen fertiliser and supplementary feed. The leaching loss figures for the 16 case studies range from 2 to 15 kg N/ha/yr. These results effectively represent the spread for the 52 sheep, beef and deer farms that Overseer Ltd held data for (the mean nitrogen leaching loss for those farms was 8.6 kg N/ha/yr).

Challenges can arise with nitrogen fertiliser when it is used 'strategically' rather than 'tactically'. In other words, when a farm system becomes dependent on nitrogen fertiliser being used every year rather than to cover a seasonal shortfall in pasture production after wet springs and/or dry summers. Strategic use is a reliance on nitrogen to grow grass to enable the farm to carry higher stocking rates, which in turn, increases the nitrogen deposited in urine patches and the risk of nitrogen leaching. Sheep and beef farmers generally use nitrogen tactically, which can see it used one year out of many (e.g., following a drought year), or quite different amounts used in different years. Thus, for sheep and beef farms it is more accurate to consider the use of nitrogen fertiliser over multiple years, rather than just a single year, because of this variable use.

2.6.3 Irrigation

Improvements in irrigation can be more costly (on a hectare basis) because they are often not on contiguous areas of a farm nor at scale compared to more intensive land uses. The cost of using more efficient systems, such as a centre pivot, to expand a farm's irrigated area while keeping the volume of water constant is often not financially viable because of the financing costs involved. It is likely to be the reason why there is still some border dyke irrigation on sheep and beef farms in Otago.

The results suggest that the use of irrigation sensors to apply water at the depths and time needed may reduce nitrogen leaching for relatively low cost. Irrigation water sensors are suitable in some, but not all, situations and need skill development to use effectively.

While there may be some advantages from improved water use efficiency, infrastructure changes to irrigation systems are not a sound investment for sheep and beef farmers if the returns per hectare cannot cover the costs to upgrade. The small areas of irrigated land (as a share of the farm) are vitally important to these businesses in providing a reliable feed source in areas of unreliable rainfall. The environmental risks for water quality and soil quality are minimised by the scale of the operations and the fact that the stocking rates are still relatively low. However, some farms are likely to be in over-allocated catchments for water quantity.

Image 16: Making tracks for home - mustering crossbred ewes in June at the top of Rough Ridge.
Source: Emma Crutchley

2.6.4 Farm system changes

Sheep and beef farms exist in a delicate balance between the physical environment and the specific farming system operated. The farm system has usually evolved over the years work in a unified way, maximising the efficient use of the available pasture production and its supply between seasons. Even within a farm, a farmer must manage differing aspects such as topography, micro-climates, and soils to maximise production and maintain a viable farm system.

Environmental actions that remove sizeable areas of the farm or make the current farming system unviable reduce the productivity of that farm, and sometimes for little environmental gain. Where farmers have few options for how to comply, and they are forced to respond in ways other than what was intended by a regulator, there can be reasonably foreseeable consequences. An example is the fencing of waterways (for the exclusion of cattle) beyond current regulations. For some farms, the extensive nature of the farm, the large number of waterways, and the rotation of livestock, means fencing is impractical and/or financially prohibitive and the only option is for farmers to remove cattle from the system (other than a change in land use). Such a change will disrupt the farm system, resulting in reductions in pasture production and quality, as well as diversity of revenue streams, and so increasing risk.

As sheep and beef farms are low input systems there are few things farmers can change (e.g., use of fertiliser or irrigation) to reduce intensity further other than removing livestock, which can create other issues if it means they are no longer farming to the grass curve. Farmers in the group of 16 case studies, and those in larger B+LNZ Otago Survey appear to be well aware of NES-FW intensive winter grazing rules and are incorporating these into their farm system. Similarly, these farmers are removing heavy cattle from steep hillsides during winter months. These actions have benefits to the farm business, such as not pugging up the land, maintaining pasture growth and soil structure.

Farmers with very low intensity production systems that farm to the pasture grass curve are likely to be most vulnerable to environmental actions as regulation. The impacts, and so their response, will vary from farm to farm. The complex and diverse nature of sheep and beef farms means the most efficient way to contribute to environmental outcomes is through tailored farm environment plans. Such tools allow environmental actions to be targeted to the landscape, location, soils, topography, farm system, and the risks and benefits of each property. This is the best outcome for these farms as it allows the farmer to focus on the areas of risk for both their farm and waterways.

Although historically rural land uses have tended to be cyclical, reflecting changes in fortunes of different primary products, options for alternative land uses to sheep and beef farming are fairly limited. There is a reason that these farms remain sheep and beef farms. Many of the farms that were able to sustain more profitable production systems have already converted to higher value land uses. Most of the remaining sheep and beef farms do not have the option to convert in this way and the only remaining option available to some of them would be to turn to forestry.

2.7 Chapter Appendices

2.7.1 Appendix 1: B+LNZ Farm Class Information

Farm Class	Description
Class 1 - South Island high country	Extensive run country at high altitude carrying fine wool sheep, with wool as the main source of revenue. Located mainly in Marlborough, Canterbury, and Otago.
Class 2 - South Island hill country	Mainly mid-micron wool sheep mostly carrying between two and seven stock units per hectare. Three quarters of the stock units wintered are sheep and one quarter beef cattle.
Class 3 - North Island hard hill country	Steep hill country or low fertility soils with most farms carrying six to ten stock units per hectare. While some stock are finished a significant proportion are sold in store condition.
Class 4 - North Island hill country	Easier hill country or higher fertility soils than Class 3. Mostly carrying between seven and 13 stock units per hectare. A high proportion of sale stock sold is in forward store or prime condition.
Class 5 - North Island intensive finishing	Easy contour farmland with the potential for high production. Mostly carrying between eight and 15 stock units per hectare. A high proportion of stock is sent to slaughter and replacements are often bought in.
Class 6 - South Island finishing-breeding	A more extensive type of finishing farm, also encompassing some irrigation units and frequently with some cash cropping. Carrying capacity ranges from six to 11 stock units per hectare on dryland farms and over 12 stock units per hectare on irrigated units. Mainly in Canterbury and Otago. This is the dominant farm class in the South Island.
Class 7 - South Island finishing	High producing grassland farms carrying about 10 to 14 stock units per hectare, with some cash crop. Located mainly in Southland, South and West Otago.
Class 8 - South Island mixed cropping and finishing	Located mainly on the Canterbury Plains. A high proportion of their revenue is derived from grain and small seed production as well as stock finishing.

Image 17: Pond and ephemeral stream on a farm in the Catlins.
Source: Emma Moran

2.7.2 Appendix 2: Otago rainfall and soil pH maps

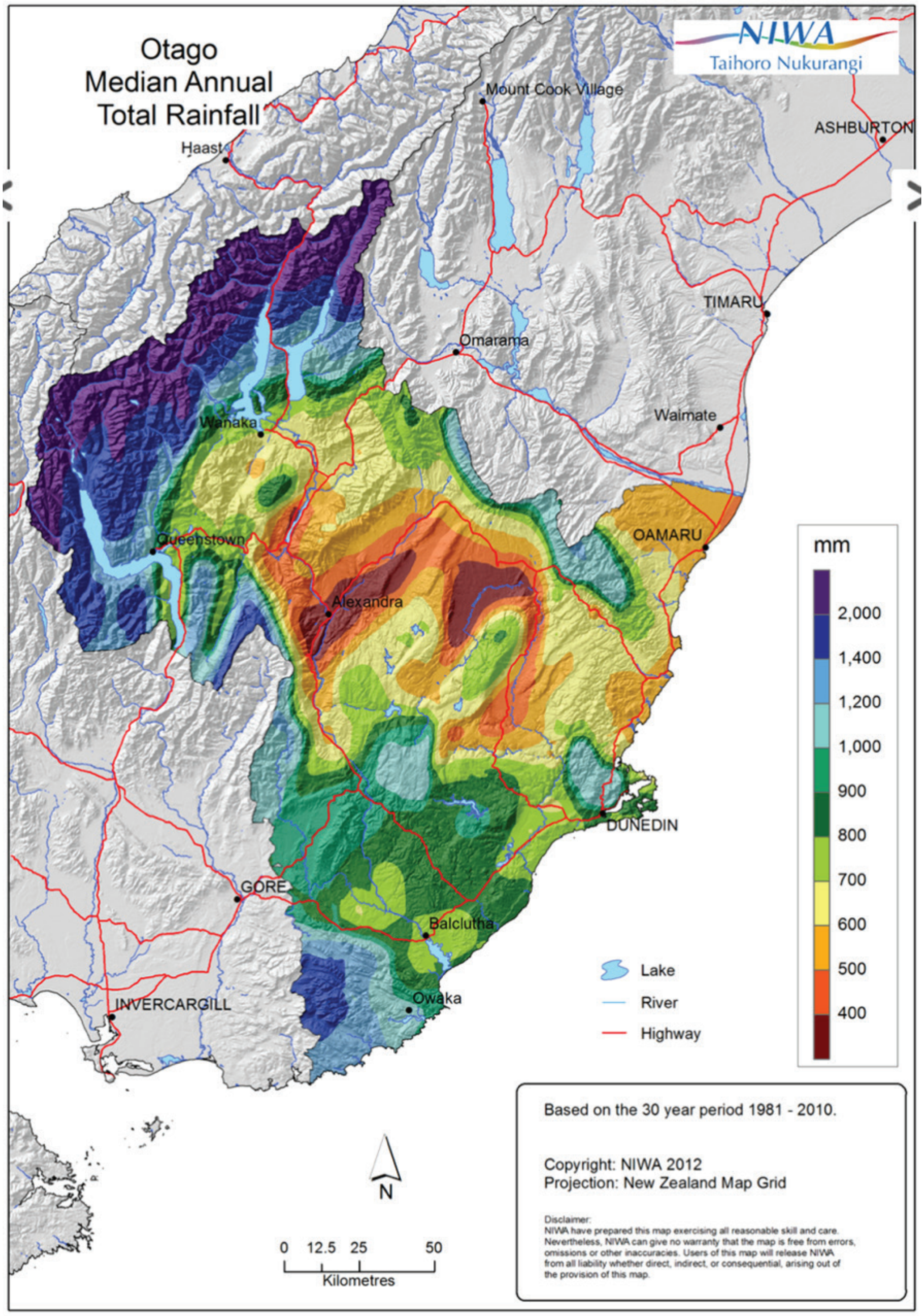

Figure 30: Otago Rainfall
Source: NIWA

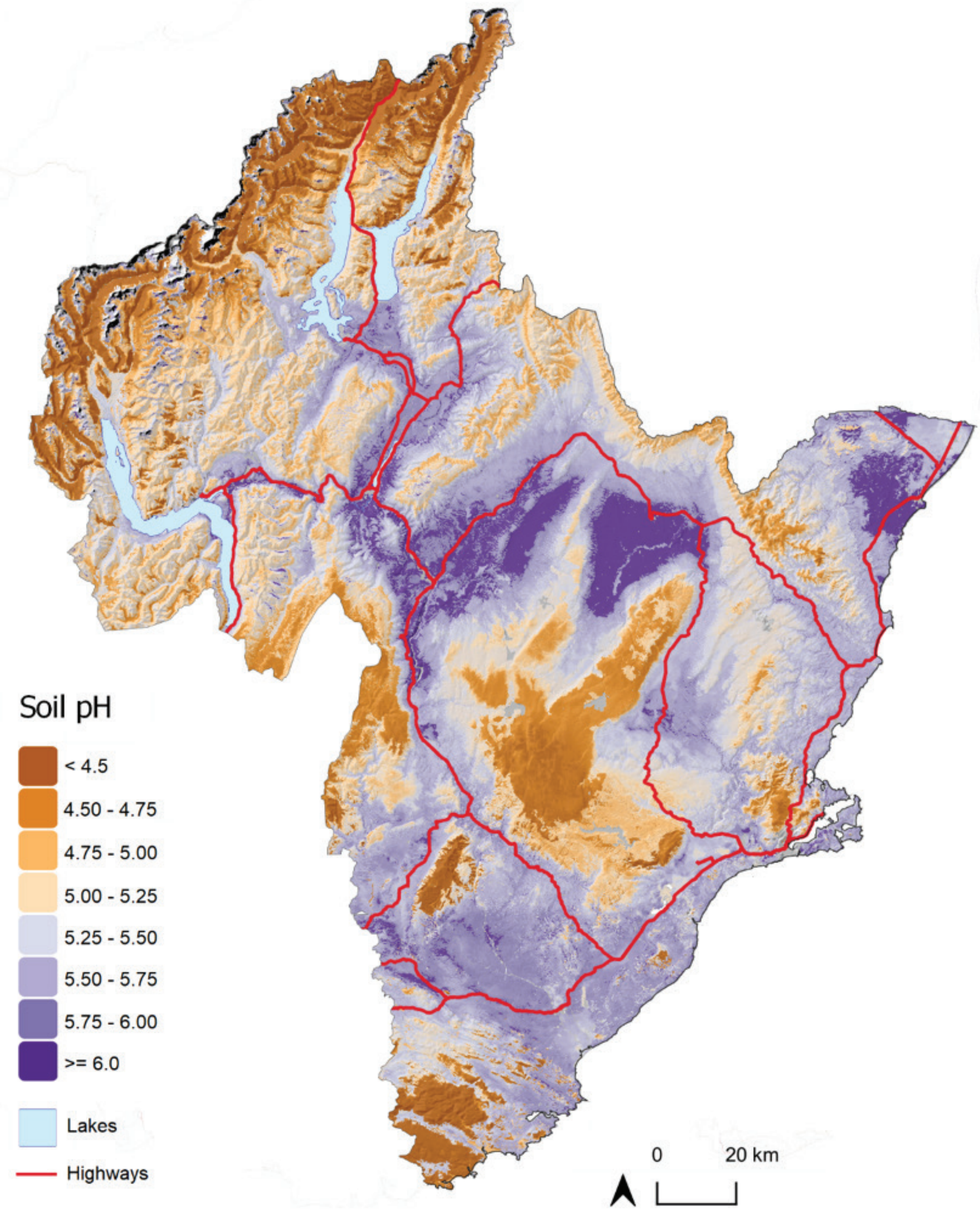

Figure 31: Otago soil pH (Source: S-map)
Source: S-Map Maanaki Whenua Landcare Research: https://smap.landcareresearch.co.nz/

2.7.3 Appendix 3: LandscapeDNA maps

A map of Physiographic Environments of New Zealand for Otago, along with a brief explanation, is available in Section 1.1 of this report.

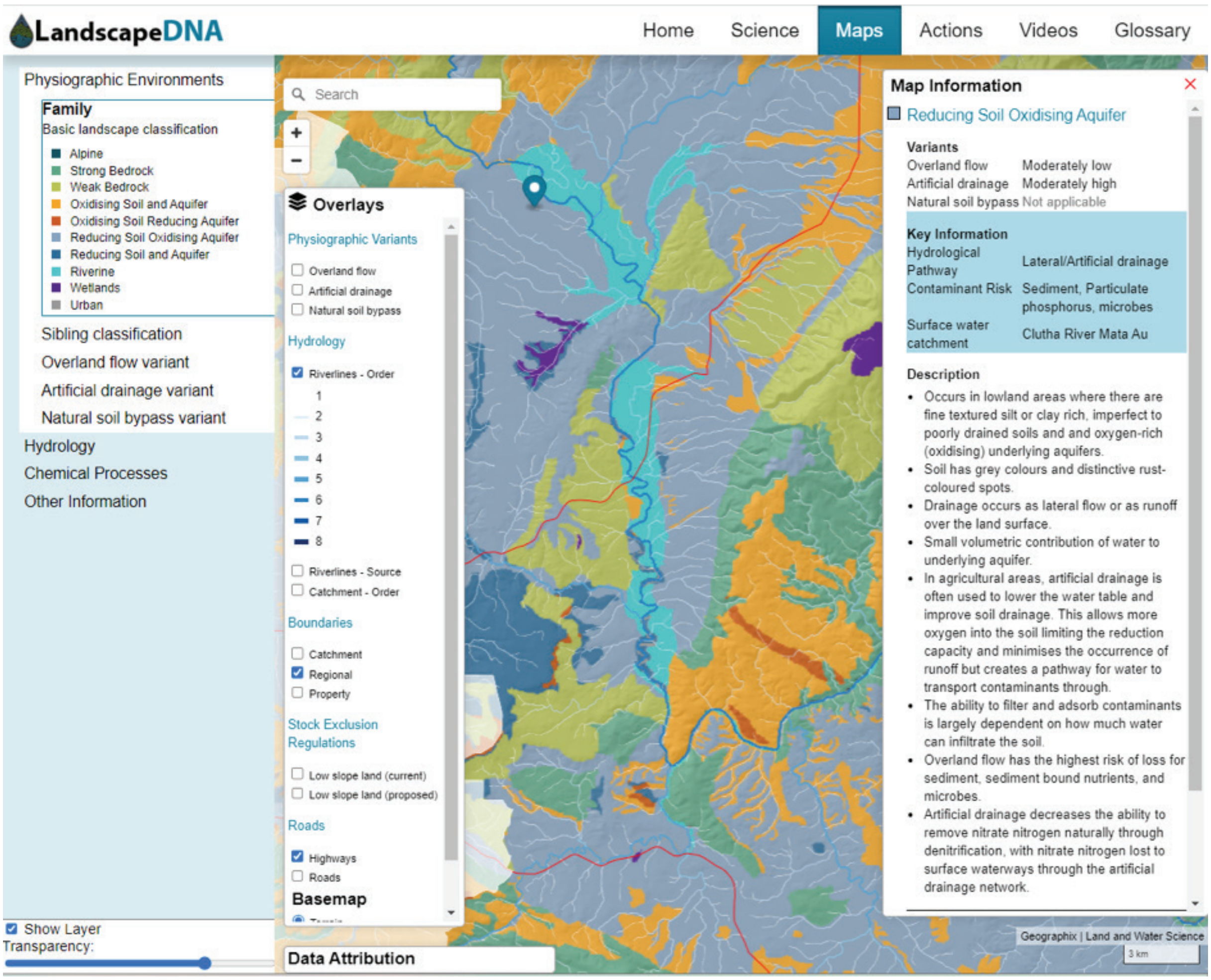

Figure 32: Use of Landscape DNA overlays to identify riverlines and physiographic susceptibility in Otago
Source: LandscapeDNA

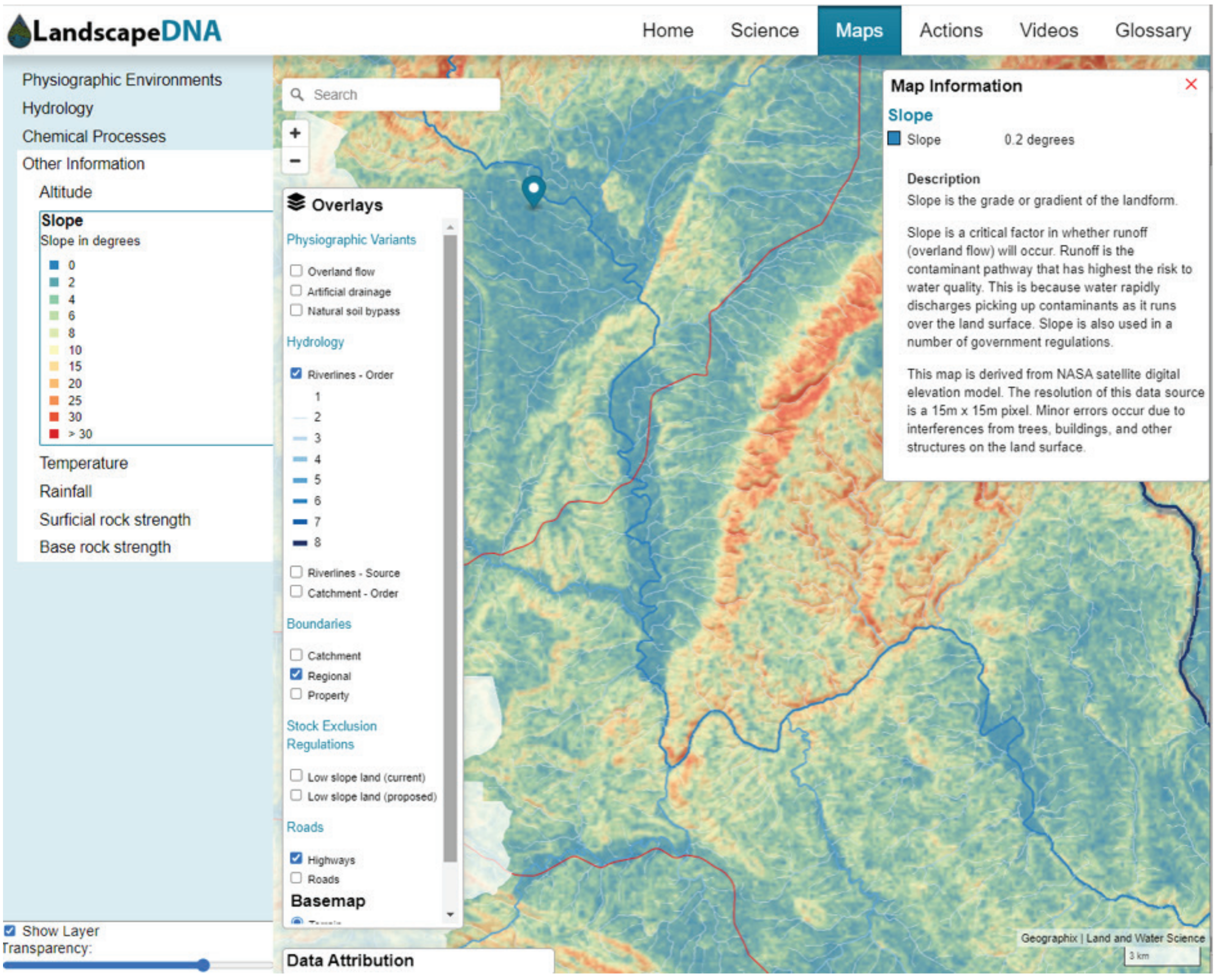

Figure 33: Use of Landscape DNA overlays to identify slope and physiographic susceptibility in Otago
Source: LandscapeDNA

3 Deer Farming

Authors: Tony Pearse (DINZ: Producer Manager – retired), Simon Glennie (AbacusBio), Solis Norton (DeerPRO: Project Manager), and Lindsay Fung (DINZ: Producer Manager). The farm case studies in this chapter are based on an in-depth analysis[125] by Simon Glennie (AbacusBio)[126] of existing primary research for deer farms in Otago. That primary research, known as the 'Natural Knowledge Project', was completed by Deer Industry New Zealand (led by Solis Norton) within the MPI Farm Monitoring and Benchmarking Programme[127]. Editorial oversight by Emma Moran (EM Consulting).

Citation advice: Pearse, T., Glennie, S., Norton, S., & Fung, L. (June, 2023). Deer Farming. In E. Moran (Ed.), *Otago's rural businesses and environmental actions for fresh water* (p.123-163). Otago Regional Council (LWRP Economic Work Programme), Dunedin.

3.1 Summary

Deer farms are usually described in terms of their production system, which place an emphasis on either venison, velvet, or stud, and in some cases include trophy. Some farmers have a fairly fluid production system that tends to follow the market of the day while others maintain their preferred production system through commodity cycles. A two-step approach was taken for this research, reflecting the complex nature of deer production systems across Otago's deer farms.

In the first step, a sample of 17 deer farms in Otago was analysed from the Natural Knowledge Project (the industry 'banner' for the MPI Farm Monitoring and Benchmarking Programme). This is the first time that a dataset of this size and quality has been available for deer farming in the region. The 17 deer farms in the sample were distributed across Otago and ranged in size from around 100 hectares to several thousand hectares. The median farm size was just over 700 hectares, while the average farm size was 1,160 hectares. There was a wide range in herd size on each farm and the relative importance of deer within each of the 17 farms also varied widely.

The 17 farms contained a diverse mix of topography, with any flat land usually being the most highly valued because of its versatility. All the farms included parts that are either not grazed or infrequently grazed but there appeared to be little relationship between the proportion of non-grazeable land and a farm's total size.

Seven farms had some irrigation, and in some cases, several types of irrigation technologies were present on a single farm. All but two farms carried breeding hinds. While general observations can be made, each deer farm has its own combination of biophysical characteristics, farm management, and financial position.

In the second step, a subset of five deer farms was drawn from the sample of 17 Otago farms to develop as case studies to test the impacts of environmental actions on the farm business. The five farms covered an array of deer production systems (i.e., venison, velvet, stud, trophy[128]) and biophysical characteristics (e.g., soil type, rainfall, and contour), which create various opportunities and constraints. On four of the five case studies, uncultivatable hill country areas were used for hinds during fawning. Fawning coincides with summer where pasture growth exceeds demand, and deer survival and welfare was enhanced by access to a more natural environment (offering plenty of cover for the fawns) at lower stocking rates.

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125 This analysis was funded by ORC.
126 AbacusBio is an international agribusiness advisory company based in Dunedin, New Zealand https://abacusbio.com/
127 https://www.mpi.govt.nz/funding-rural-support/farming-funds-and-programmes/productive-and-sustainable-land-use/
128 A description of four main production systems is available in the Deer Chapter of the Farmers and Growers in Otago Report (Pearse et al., 2022).


Image 18 & 19: Hinds (left) and trophy antler stags (right) in the summer dry, Glen Dene Station, Hawea
Source: Tony Pearse
Note: Glen Dene Station won the Elworthy Award (the New Zealand deer industry's premier environmental award) for 2023.

Regular water quality tests and management options that include periodic exclusions are likely to provide the better outcomes in hill blocks that are very lightly stocked and in low rainfall areas. It is seen by farmers as preferable to the replacement of deer with sheep.

Wintering sheds offer an alternative to winter grazing where there is a high risk of pugging and sediment loss to waterways. These are expensive to build. If the shed is used for the hinds, then it is marginal financially but there are still benefits for animal welfare and the improved condition of paddocks. Conversely increasing stag numbers and housing them over winter noticeably increased profit. Stags are the heaviest deer stock class so have the greater risk for pugging during winter grazing.

Irrigation upgrades are expensive and in each of the case studies, the increase in costs (interest, depreciation, and variable costs) was greater than the added revenue. For farms that rely on irrigation for winter crops, any reduction in available water would likely result in reduced deer numbers (i.e., there is less crop to support stock) and their viability as farming business.

Within each of the five case studies, adaptive changes to the farm systems are likely to have wider implications for the deer industry and Otago. The deer industry is particularly vulnerable to adaptive changes and there are already indications that breeding hind numbers are under pressure as farmers consider the implications of meeting recent national stock exclusion regulations (rather than using targeted environmental actions that are better suited to deer farming). On minority deer farms or sheep and beef farms with a deer enterprise, it is the deer enterprise that is increasingly likely to be disposed of or drastically modified due to high costs of fencing, establishment of winter sheds, or upgrading irrigation.

3.2 Introduction

A deer enterprise is a stimulating and challenging addition to drystock farm production systems. They bring diversity and complexity, which create opportunities to refine and optimise a farm's management. Deer are a 'top down' browser like beef cattle and tend to eat fairly evenly over blocks when feed is

129 The deer industry in Otago is described in the Deer Farming Chapter (Pearse, Norton, and Fung, 2022) of the *Farmers and Growers in Otago* Report (Moran, 2022).

in good supply. Deer farms are usually described in terms of their production system, which places an emphasis on either venison, velvet, or stud, and in some cases includes trophy[129]. From its production system, a deer farm generates a range of income streams from either deer products (e.g., velvet, venison, co-products, trophy antler) or the breeding of stock (e.g., 'weaners' for finishing as venison, replacement hinds, and velvet stags and elite sire stags) (Pearse et al., 2022). In Otago (as in other regions) the range of production systems is generally well matched with the region's land use capabilities, climate, and seasonal growth patterns.

3.3 Methodology

A two-step approach was taken for this research to reflect the complexity and breadth of deer production systems across Otago.

3.3.1 Step 1 – farm sample

Information for a sample of 17 deer farms in Otago was analysed to give as wide a view as possible of the industry (Section 3.4). This sample is the complete set of farms that, at the time of this research, had been surveyed from Otago for the MPI Farm Monitoring and Benchmarking Programme. Ultimately, 21 deer farms will be completed for Otago (and 130 across New Zealand). Within the deer industry, the deer component of the MPI Farm Monitoring and Benchmarking Programme is known under the in-house 'banner' of the Natural Knowledge Project.

Within the Natural Knowledge Project, the leadership of regional branches of the New Zealand Deer Farmers Association and Deer Industry New Zealand worked together to identify potential candidate deer farms that typified the deer industry. Once farms were identified, the relevant farmers were asked to participate and the final deer farm samples for each region were selected based on their willingness. A comprehensive data collection process was used, with farm visits and a well-defined farmer interview process taking almost a full day for each farm. The data collected described:

- Biophysical characteristics of the farm (e.g., land types, soil types, topography, waterways);
- Environmental protection and enhancement work planned, in progress, or completed;
- Biodiversity protection and enhancement work planned, in progress, completed;
- Stock reconciliation with types and tallies;
- Farm and animal management practices;
- Stock management metrics (e.g., mating dates, weaning dates);
- Farm production (e.g., meat, wool, velvet, other products);
- Cropping details;
- Fertiliser application;
- Supplementary feed use;
- Irrigation details; and
- Financial accounts

This is the first time that a dataset of this size and quality has been available for deer farming[130]. Within the Natural Knowledge Project, DINZ used this information to create farm environment plans (including Overseer nutrient budgets) for each property. With additional permissions from the farmers involved, it was also used for the case studies described in Section 3.5.

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130 The StatsNZ Agricultural Production Census *https://www.stats.govt.nz/help-with-surveys/list-of-stats-nz-surveys/about-the-agricultural-production-survey/*

Based on the knowledge of industry experts, the Otago sample of 17 farms presented in this chapter is seen as being reasonably indicative of the diverse range of production systems used by deer farms in the region in 2021-22. The sample also broadly reflects Beef + Lamb New Zealand's profiles for high country, hill country, finishing and breeding, and finishing farms in Otago (i.e., Sheep and Beef Farm Classes 1,2,6, and 7[131]). Overall, it represents around 20,000 hectares of farmland in the region.

3.3.2 Step 2 – farm case studies

A subset of five deer farms was drawn from the sample of 17 Otago farms in the Natural Knowledge Project to gain an in-depth understanding of the impacts of environmental actions for the farm business. The five farms were specifically selected to inform a case study approach (rather being chosen at random). They cover the four deer production systems (venison, velvet, stud, and trophy) and a mix of both specialist deer farms and minority deer farms (refer to Figure 36 in Section 3.4.2), as well as a broad geographical spread.

In developing the case studies, an initial exercise was undertaken for each farm to assess its progress in implementing recent changes in national and regional policy as well as longer standing industry guidance. Where needed, environmental actions were 'applied' to the farm as a modelling exercise. These environmental actions included those required through national regulations and regional plan changes as well as those strongly encouraged via the DINZ (2018) Environmental Code of Practice[132].

Once the initial exercise was completed, a second assessment was undertaken to identify any additional environmental actions that may be effective in resolving any remaining issues on-farm in relation to fresh water. This assessment occurred in consultation with the farmer and DINZ to make sure the analysis was both tailored to the farm in question and more generally relevant. When an issue and environmental action were identified, it was then tested to understand its possible impacts on the farm business. The analysis has considered drivers of impacts and, where possible, how impacts may be minimised but not whether it is possible under current legislation.

The testing of environmental actions was based on the following principles:

1. Considered mitigation first, then adaptation, then transformation;
2. Retain elements of the deer enterprise in the first instance to promote the farm's management objectives and maintain the production system's resilience;
3. Approach each case study with a view to its potential wider relevance to other deer farmers farming under similar conditions.

In each case, a base farm system was modelled in FARMAX as a stable long-term system reflecting current numbers, production, and practice. Feed crops and supplements made on farm were fed or sold so that opening stock numbers and feed on hand equalled closing. The FARMAX model was then able to be adapted to mimic consequences of actions that might be taken to mitigate, adapt or transform the farm system to achieve freshwater outcomes.

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131 A description of these Farm Classes in relation to Otago is available in Chapter 3 of the *Farmers and Growers in Otago* Report (2022). More information, economic reports, and interactive tools in relation to Farm Classes are available at *https://beeflambnz.com/data-tools/farm-classes*

132 The Environmental Code of Practice (Gregory, Noonan et al) builds on the 2012 Landcare Manual to provide clear, practical guidance for minimising environmental impacts from deer farming. The Code has had extensive input from deer farmers and experienced consultants and provides farm and in-paddock scale practices for deer farmers to complete Farm Environment Plans required by local authority regulation. *https://www.deernz.org/deer-hub/farm-and-environment/environmental-code-of-practice/*

Revenue from production was generated in FARMAX using long term pricing for venison related sales. Velvet sales values were fixed at $120/kg for all 2-year-olds and mature stags production and $180/kg for the first year or spiker velvet antler. Where an alternative system was included as a mitigation or adaptation, the long-term pricing from the same period was utilised to provide fair comparative revenue.

Farm expenses were generated in FARMAX for feed crops and supplements based on the areas sown or harvested on farm. Each farm was matched to a Beef + Lamb New Zealand farm class that best represented the mix of intensity and land classes farmed. The B+LNZ Economic Service surveys hundreds of farms to produce a benchmark dataset for industry use. Two of the case studies were more extensive in nature and the South Island Hill country data was used while the more intensive farms were matched to the South Island finishing and breeding data. The same base expense data was used for all environmental actions tested.

Where adaptations required investment, the additional capital was calculated, and the interest implication included. Capital investments require bank funding in most cases and a portion of principle is usually required to be repaid on these loans. A standard table mortgage calculator was used to estimate the average annual interest and principal components over the expected life of the investment. Interest rates used were between seven per cent and eight per cent and the life of the assets were between 30 and 40 years. Loan terms were varied between the case studies depending on the likely useful life of the infrastructure in question. Where fencing was included, factors such as slope/erosion or likelihood of flood damage were factored in shortening time frames in some instances.

While labour is included in the benchmark data, the implication of system change on farm labour requirements is often not captured. Where adaptations were marked, the farmers were asked about the potential implications for labour resource. In situations where there is an incomplete additional (or reduced) labour unit required, the system may not be favoured due to inability to resource the change.

3.4 Deer Farm Sample

Note: This section presents individual farm data across a series of graphs. For privacy reasons, the farms are not numbered within each graph and are not necessarily in the same order between the graphs.

All but one of the 17 deer farms in the Otago sample of the Natural Knowledge Project were well established, with consistent management over at least the last five years. The final farm had been purchased recently by an existing deer farmer and its management was in the process of being refined to fit within the wider business. While general observations are made across the sample in this section, the varying combinations of biophysical characteristics, farm management, and financial position make each deer farm unique.

3.4.1 Farm biophysical characteristics

The sample of 17 deer farms were distributed across Otago, and included Queenstown Lakes, the north-eastern basins of Central Otago, the lower Clutha and Catlins, and coastal Taieri and North Otago. The 17 farms ranged in size from around 100 hectares to several thousand hectares. The median farm size was just over 700 hectares, and the farms had an average size of 1,160 hectares. As previously mentioned, the total area in the sample was roughly 20,000 hectares, and three farm businesses included lease land.

Otago's climate is influenced by natural variations including El Niño and La Niña cycles, which vary rainfall across the region both seasonally and annually. Average annual rainfall for the 17 farms ranged from between 400 and 700 mm in Central Otago through to roughly 1,100 mm per year in the Catlins. Seven farms had some irrigation, and these were all located in Queenstown-Lakes and Central Otago. In some cases, several types of irrigation technologies were present on a single farm.

The 17 farms contained a diverse mix of topography (Figure 34) with any flat land usually being the most highly valued because of its versatility (i.e., range of potential uses), particularly if it has sufficient rainfall or is irrigated. For five farms out of the 17, the predominant (> 60%) type of land on the farm was flat land. Four of the 17 farms had very little (2% or less) flat land at all. Ten farms included land classified as steep hill and for five of those it was the predominant (> 60%) land type. Areas of rolling and/or easy hill country were present on most properties. 'Trees and scrub', which includes farm forestry and indigenous biodiversity (e.g., QEII Trust covenanted areas), were present on more than half of the farms and ranged from less than one hectare to well over 100 hectares of the total farm area.

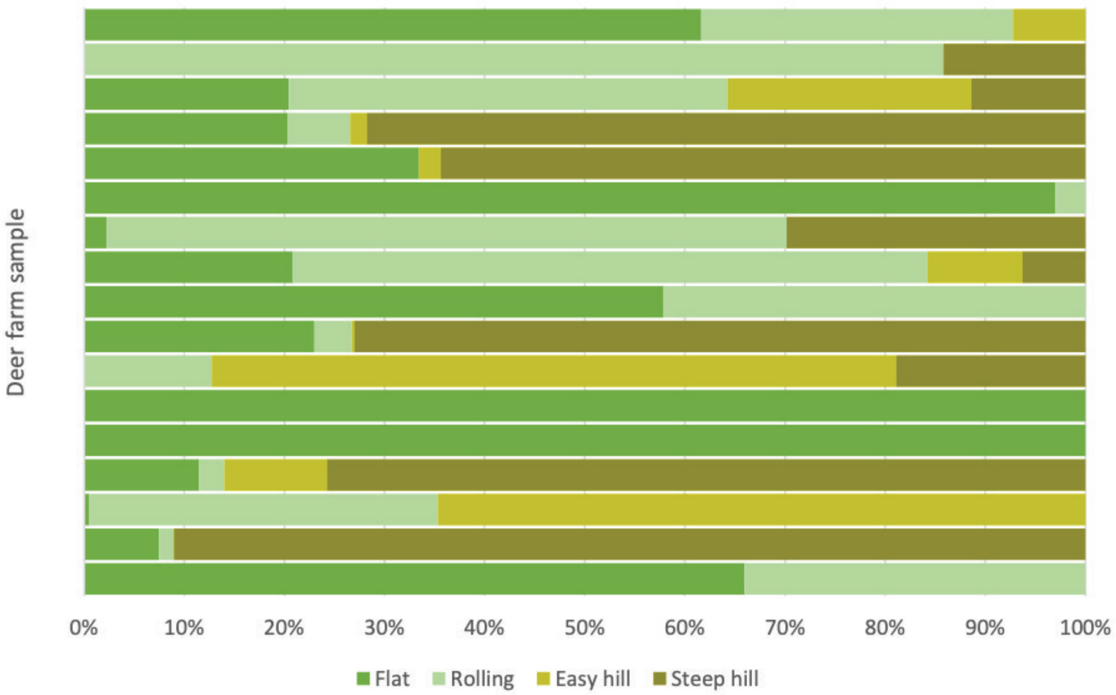

Figure 34: Topography of 17 deer farms in Otago
Source: Deer Industry New Zealand

All the farms included parts that are either not grazed or infrequently grazed – such land is often referred to as 'ineffective' or 'non-productive', but these terms have negative connotations and do not recognise the value of such land for the farm system. The non-grazed areas of the 17 farms tended to be less than ten per cent of the total farm area (an average of 7%). In Otago (unlike Southland for example[133]) there appeared to be little relationship between the proportion of non-grazeable land and a farm's total size.

133 Similar research for Southland found that the proportion of grazeable to non-grazeable land on drystock farms may be related to farm size and slope but it is not always the case. In that research, non-grazeable land ranged from two per cent to 29 per cent of total area for seven deer case study farms and nil to 55% for 39 sheep and beef farms (Moran, 2017).

The relatively low stocking rate on larger farms in Otago means the proportion of 'ungrazable' area is not closely considered. Blocks tend to be large, and fences are erected where practical. Areas of rocky outcrops, scrub and ungrazable areas are often a part of these larger blocks and while animals have access to them, the areas themselves are not effective. The total block area is easily determined from maps but the area that is not effective for stock grazing is less relevant to farmers and as such not closely monitored. Farmers will be more aware of the numbers of animals that can be stocked in the blocks at particular times and intuitively adjust for the areas that are not effective along with the feed types available on the remaining effective area.

The farm sample typified the generally self-sufficient nature of drystock farming in the region in relation to feed. The degree to which a farm is stocked is usually characterised by factors such as the use of winter crops, quantity of fertiliser applied and use of irrigation and/or imported feed. Across the sample, almost two-thirds of the farms grazed livestock at a density of between eight and 14 stock units per hectare (Figure 35). Those farms with stocking rates below eight SU/ha all had grazeable areas in excess of 1,000 hectares.

However, there is strong variability both between farms and within each farm. For example, several farms had lower stocking rates because of large hill block areas with mainly native vegetation, which tend to be very lightly stocked. These properties also have highly productive areas where cropping and irrigation are focused. On deer farms, stocking rates are influenced by stock classes and the time of year (e.g., hinds during fawning or stags during mating, which is commonly known as the 'rut' or 'roar'[134]).

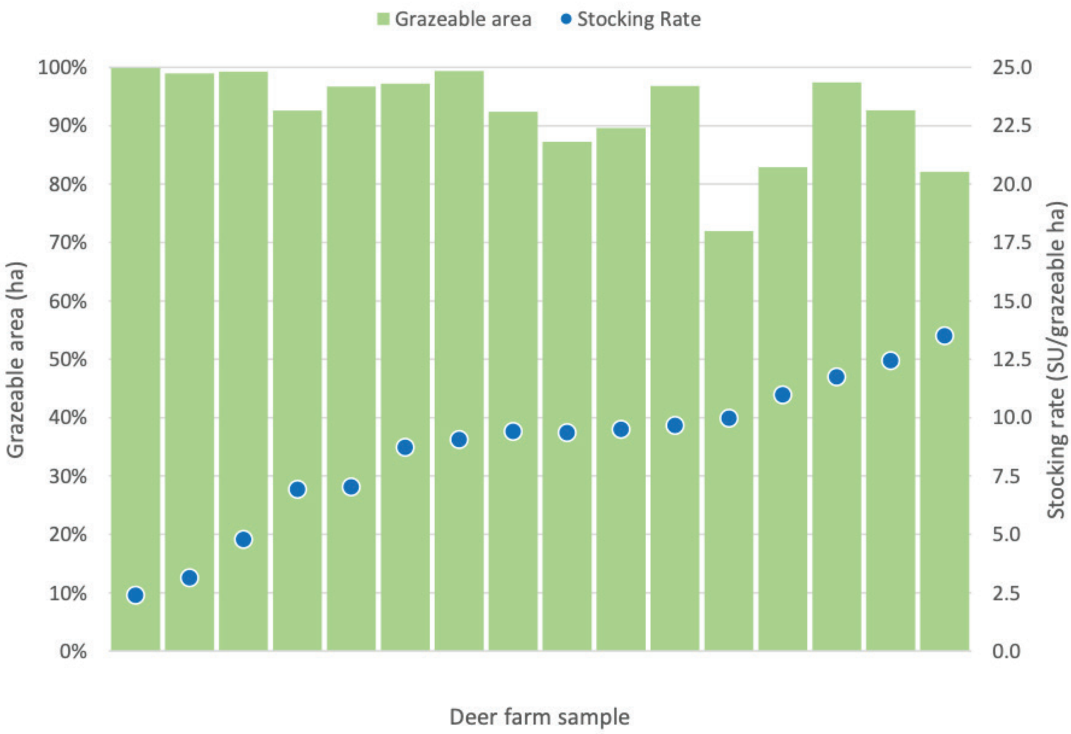

Figure 35: Stocking rates (livestock units per grazable hectare) on 17 deer farms in Otago 2020-21
Source: Deer Industry New Zealand
Note: In this graph the farms are ordered by stock units (lowest to highest), but they are randomly ordered in the preceding graph and the following graphs to help protect individual farmer confidentiality.

134 A period in autumn (late March to late April) when stags actively and aggressively compete for access to hinds for mating. During this period, they exhibit various sexual and combative behaviours, including 'roaring' ('bugling' in wapiti) and territorial defence of harems (hind groups) and rutting areas. https://www.deernz.org/deer-hub/handling-and-welfare/behaviour/mating/

The 17 farms in the sample with larger non-grazeable areas were often made up of a series of flat to gently rolling terraces interspersed by steep-sided but shallow gullies (e.g., Image 20). This type of hill country is common in parts of South Otago (e.g., around Balclutha and Clinton). The gullies drain the terraces during wet periods and remain virtually 'all pasture' covered year-round, including at their base. They can be challenging for farm management being large, irregularly shaped, and usually difficult to traverse without cutting a farm track through them. While they may be seen as non-grazeable in terms of pasture production, their grassy sides are a valuable buffer for sediment and phosphorus loss from crops on the terraces to waterways below.

In some cases, these gully areas are used for hinds during fawning. The more diverse mix of vegetation and more sheltered environment ideally fits the deer's strong natural preference during this critical time of the year compared to the more open terraces above. Feed levels are kept high within the gullies and the deer are at a low density, which improves fawning as the hinds are well fed and do not have to compete for fawning sites. As well as being low density, hinds at fawning tend to keep quietly to themselves. A farm's reproductive rate[135] is the basic starting point for a successful 'breeding unit' so these gully areas are an important and unique asset.

Image 20: Examples of gullies and terraces on a deer farm in South Otago.
Source: DeerPro
Note: Gullies with non-grazeable land are marked in red, waterways marked in blue, and property boundaries in black.

135 https://www.deernz.org/deer-hub/breeding/reproductive-measurements/

3.4.2 Farm management

The 17 deer farms in the sample all had production systems of sufficient size[136] to be viable standalone businesses, but many of the farmers also had off-farm income streams. The farms carried total stock units[137] ranging from around 1,000 to close to 20,000 per farm across all livestock types (deer, sheep, and beef cattle). However, for a venison-based system in the current market environment 1,000 stock units are becoming increasingly marginal for a commercial farm business, which makes any off-farm income crucial during 'leaner' seasons.

Alongside the wide range in herd size, the relative importance of deer within each of the 17 farms was highly variable. As an indicator, deer made up anywhere between 17 per cent and over 95 per cent of each farm's total stock units[138], with the remainder usually consisting of sheep and/or beef cattle (Figure 36). The share of total stock units does not fully reflect the extent to which deer play a leading or supporting role within each farm. Another indicator is the value of revenue streams, which is considered in Section 3.4.3.

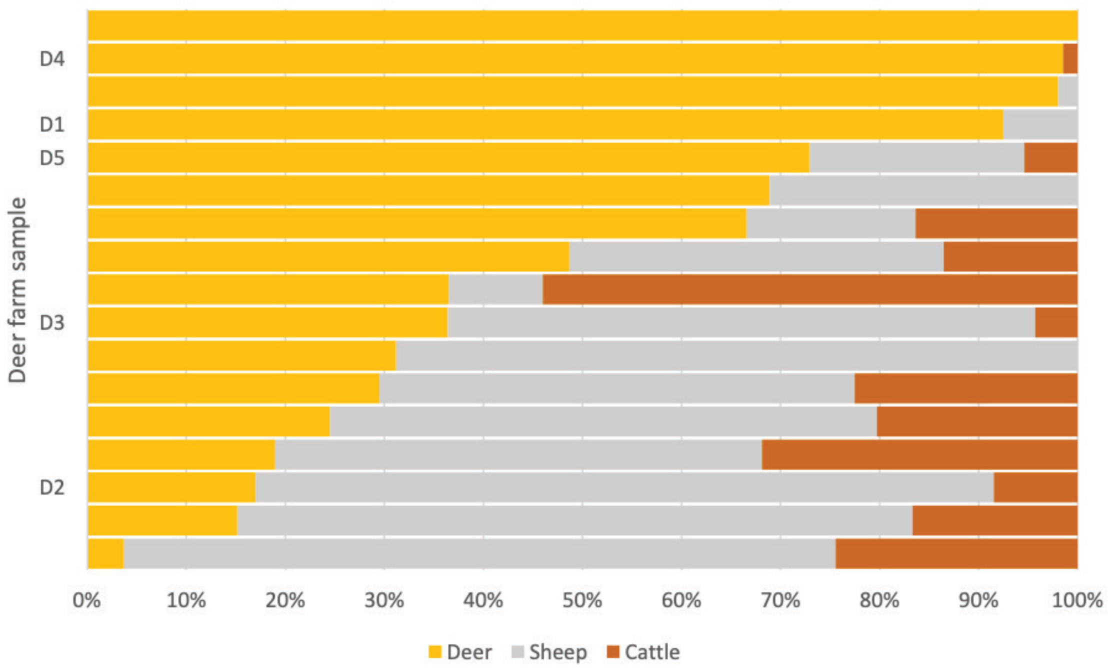

Figure 36: Livestock mix on 17 deer farms in Otago 2022-21
Source: Deer Industry New Zealand
Note: The farms selected to develop as case studies (Deer 1-5) are identified on the vertical (y) axis.

136 Size in this context is broadly a combination of grazeable area and pasture and/or crop production.
137 The stock unit conversion relates the energy requirements of various classes of stock to the requirements of one breeding ewe producing one lamb per year. One stock unit equals one breeding ewe that weighs 55 kg and bears one lamb. The amount of feed consumed by this ewe over a year is around 550 kilograms dry matter (it includes the feed consumed by her lamb up to weaning, at 3.5 months) (Fleming, 2003).
138 The different genotypes of deer in New Zealand mean a large difference in feed requirements. Stock units are dependent on sex, breed and age class: https://www.deernz.org/deer-hub/feeding/feeding-tools/deer-stock-unit-calculator/

Figure 37 shows the composition of deer stock classes within the deer enterprises. All but two farms carried breeding hinds. The two farms without breeding hinds relied on receiving finishing stock[139] from other farms. One farm was solely focused on velvet rather than venison production. Four others had a moderate to strong focus on velvet and the remainder harvested velvet as a by-product of their venison system. The velvet-focused properties clearly have higher proportions of stags while the breeding herds revolve around their hinds. Traders (farmers who buy in livestock to fatten and sell, rather than breeding their own) by comparison will usually have few mature livestock on their farm. They tend to have a period in the year with no deer on the farm at all, from when the last of their fattened animals are processed to the arrival of the next generation of freshly weaned deer.

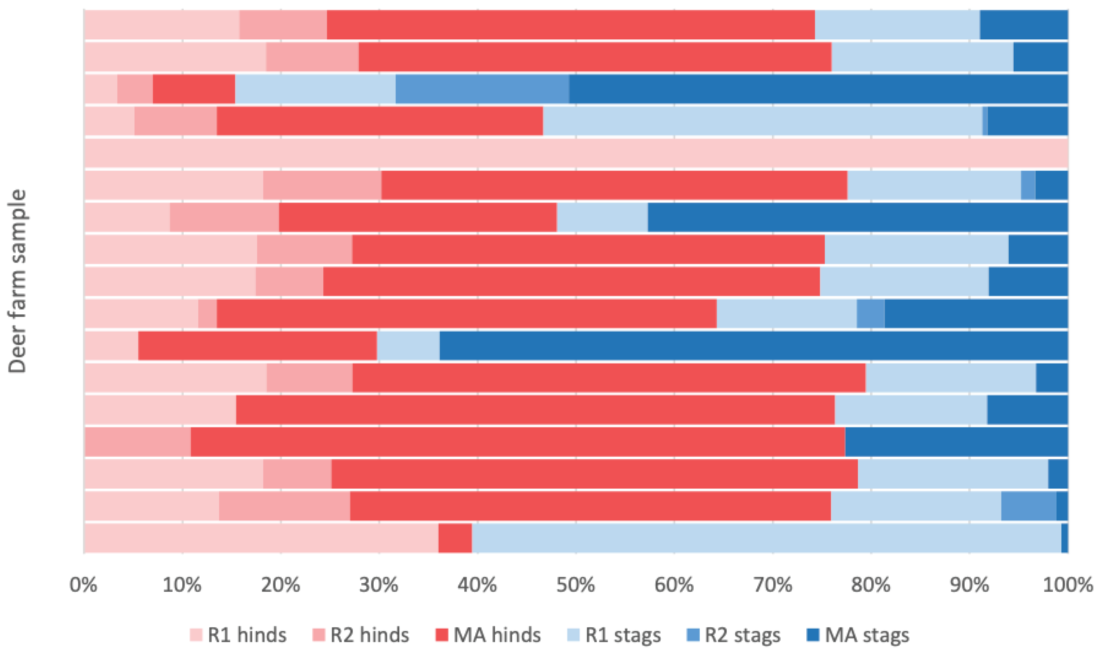

Figure 37: Mix of deer sex and age classes for 17 deer farms in Otago 2020-21
Source: Deer Industry New Zealand

In 2021-22 roughly twice as many deer were processed for venison on each of the sample farms (median of 224 deer and average of 587 deer) compared to all 124 properties that processed deer in Otago in the same year (median of 117 deer and average of 253 deer). Overall, the 17 farms in the sample processed a total of between 7,000 and 10,000 deer annually for the last five production seasons. Their venison productivity is typical of Otago, with young deer being processed at around 100 kg live weight and between 10 and 14 months of age. Figure 38 shows the distribution of venison processing on Otago deer farms that process deer.

The main reason for the difference in processing tallies is that the sample did not include farms that process just a few deer each year for venison, even though such farms are reasonably common. In 2021-22, 18 per cent of properties in Otago processing deer did so for an average of ten animals (and a total of 235, or roughly the equivalent of a single deer farm in the sample). These low-processing properties include lifestyle blocks running less than 100 deer as well as farms with a couple of hundred velvet stags, especially those that are in the process of building up their herd.

139 Finishing stock refers primarily to weaned deer, usually purchased in autumn for the purpose of finishing as venison over the following spring and summer.

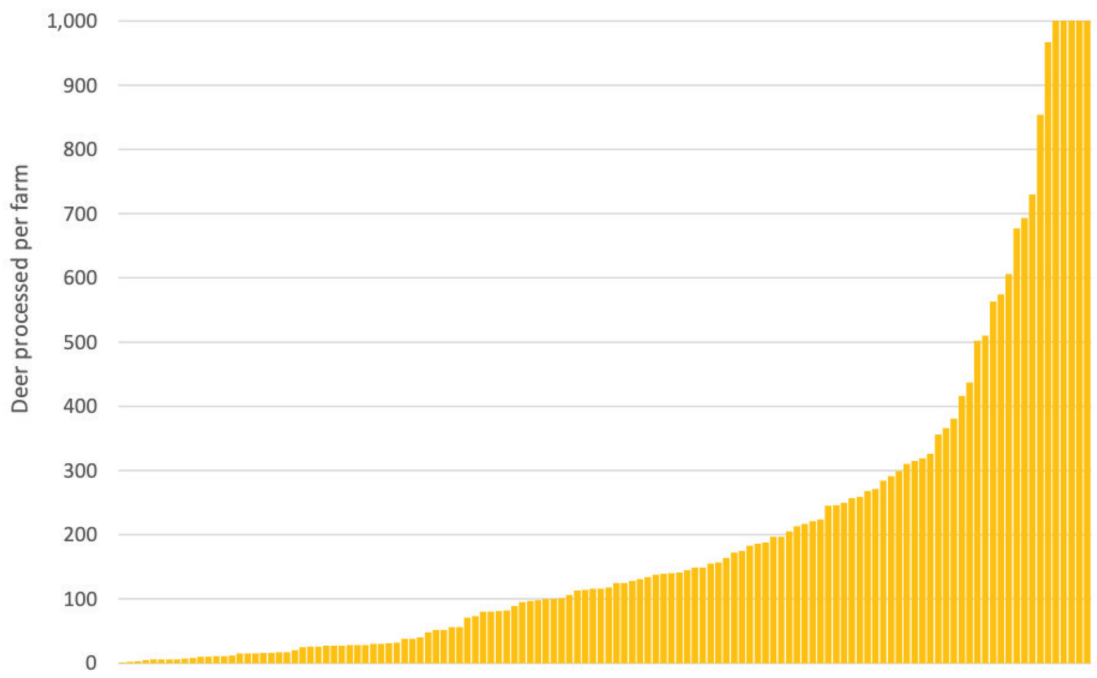

Figure 38: Distribution of venison processing across Otago deer farms 2020-21
Source: DeerPro

3.4.2.1 Deer wintering

The ability to carry livestock over winter is essential for all deer production systems. The annual deer production cycle is strongly related to changes in seasonal daylight length, which influences the onset of the rut and mating in early autumn (March-April) and fawning in late spring / early summer after a relatively long seven-month gestation. In addition, the natural annual biology of velvet growth begins with mature stags initiating growth in early spring and harvest in October-November for peak weight and quality, with harvest from younger stags in late spring / early summer. Consequently, investment and skilled management of overwintering systems and quality spring pastures is essential for the success of all deer production systems.

Fawning is in late November and December (after calving and lambing) and coincides well with the spring flush of pasture in Otago's cooler areas, which is ideal for feeding lactating hinds to get the best start for their offspring but can present additional late summer feed quality challenges in dry summers.

Weaning decisions (both pre or post rut) and autumn feeding of hinds is important to condense fawning spread and reduce numbers of dry or empty hinds. With variable autumn rainfall and long winters, this aspect can be challenging.

Image 21: Hinds and fawns being break fed a paddock of kale, near Mosgiel.
Source: Tony Pearse

Image 22: Hinds (and one stag) winter grazing on a kale crop with farm forestry in background.
Source: Tony Pearse

Young deer and velvet stags have a demand for high quality pasture-based feed early in spring to support their growth. To provide the required areas for these livestock classes, winter supplements are regularly fed through winter as livestock demand for feed exceeds pasture supply at this time. While older breeding hinds can winter on poorer quality feeds, young stock and velvet stags recovering from body weight loss over the rut are typically fed higher quality feeds and supplements.

In recent years, venison markets have developed from being largely traditional European winter restaurant fare, into the United States and China, creating a wider window on-farm for producing premium chilled venison[140]. Velvet market development, together with consistently strong prices, have resulted in growth in velvet production. As these market forces come together, opportunities are opening up for farmers to keep young stags long enough to produce their velvet, then processing them as chilled venison at heavier carcass weights later in the season. The later processing date means farmers can capitalise on the strong growth rates of deer through the spring and early summer, after a slower period during the winter, and benefit from prices that have dropped less from the spring schedule peak (in the past the price drop was 15-20%).

Intensive winter grazing, usually on forage crops, occurred on all 17 sample farms (Figure 39). The area ranged between five and 276 hectares, which was between one and 23 per cent of each farm's total area. On average across the sample, the area of winter grazing was 68 hectares or 8.4 per cent of the farm's total area. However, on six of the farms, more than ten per cent of the total area was used (35% of the sample). Only one of the 17 farms received income from cash cropping during the season surveyed and it amounted to less than two per cent of their gross farm income.

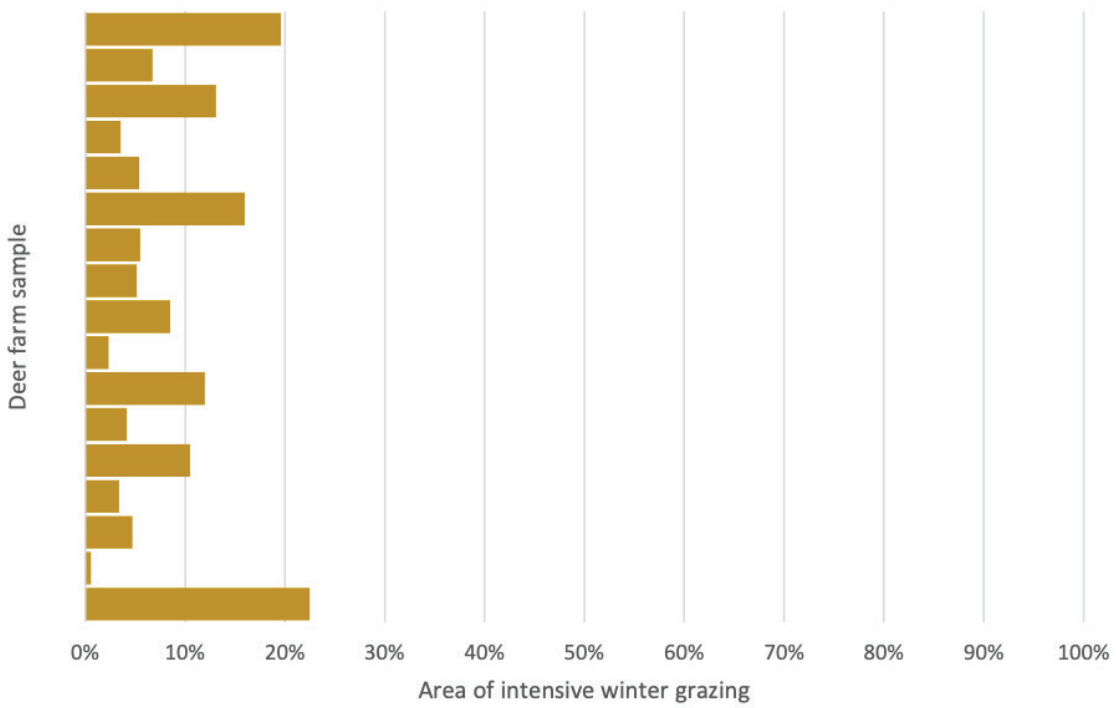

Figure 39: Area of farm used for winter grazing of crop on 17 deer farms in Otago 2020-21
Source: Deer Industry New Zealand

140 Refer to the Deer Production Calendar in Chapter 4 of the *Farmers and Growers in Otago* Report (Pearse et al., 2022).

In total 213 blocks were planted in winter crop on the 17 farms in the sample (Figure 40). Within this total, 130 blocks (61%) were accounted for by four types of feed. Kale was the most common winter crop planted (22%), then swedes (16%), fodder beet (15%) and rape (12%). Other common winter crops were raphno, annual rye grass, turnips, and forage barley. Crop yields varied widely, being influenced heavily by inputs of nutrients and water.

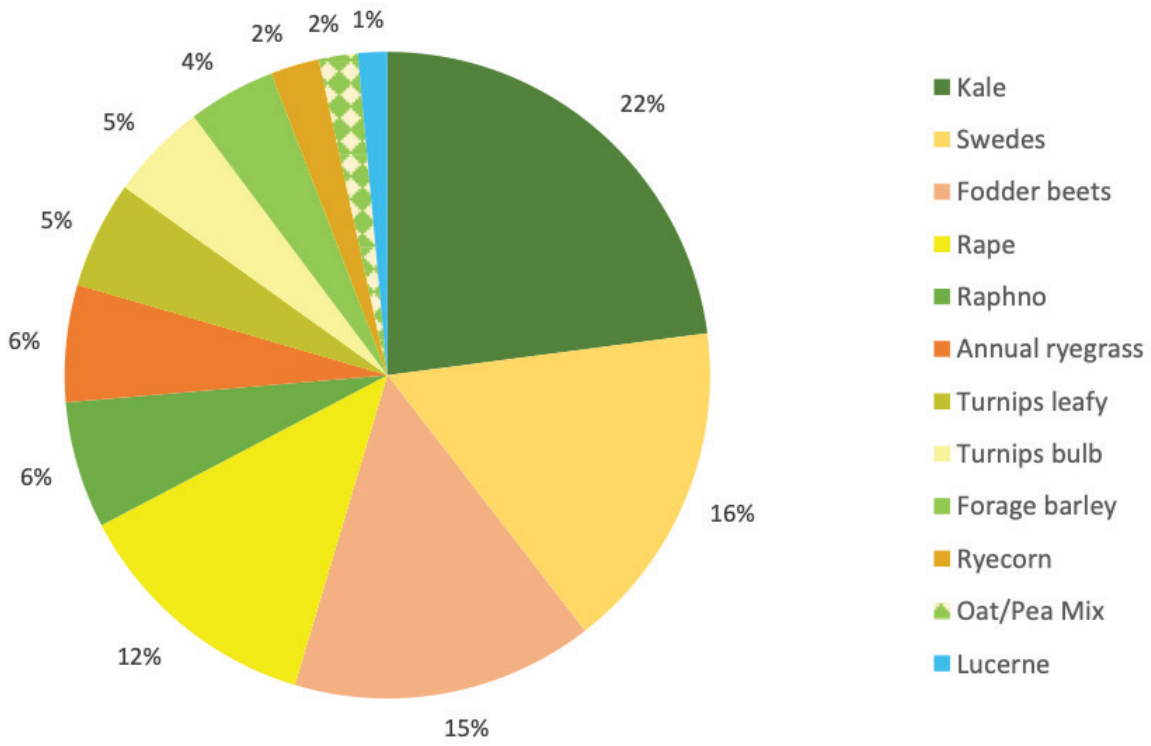

Figure 40: Frequency of crops grown across 17 deer farms in Otago 2020-21
Source: Deer Industry New Zealand

In low rainfall areas of Otago, the parts of a deer farm with irrigation are usually pivotal to the farm business by reliably supporting a comparatively large amount of feed for supplementary use in winter or for finishing stock. Nine of the 17 deer farms used some irrigation, typically the larger operations in drier localities. Total irrigated land across these nine farms ranged from less than 30 hectares to over 300 hectares. The irrigated land tended to make up a small proportion of the total farm area and was concentrated on flat to rolling country. On six farms, between 10 and 40 per cent of their flat to rolling land was irrigated, and on the remaining three farms it was between 50 and 90 per cent of such land. The limited scale and often non-contiguous nature of irrigation on drystock farms can make them expensive to upgrade on a per hectare basis.

Upgrading irrigation systems from border dyke and flood irrigation systems to more technically efficient options can considerably improve a farmer’s ability to grow feed. It is also a substantial investment (and costs have risen sharply in recent years with higher inflation and interest rates). Where large amounts of deer re-fencing are needed to optimise the use of a new irrigation system the expense may mean a farmer replaces the deer in those more productive parts of the farm with other stock types. A general estimate (based on recent actual examples) for the cost of pivot irrigation is $4,750 per hectare for the irrigator, plus items such as the costs of earthworks, power supply, consents, and re-fencing to make the most of the new farm system. Greater certainty, especially around consent term and consented allocations of water, during the period of repayment increases confidence to borrow for this level of capital development.

3.4.2.2 Nutrients

Fertiliser application rates vary from year to year across most drystock farm businesses, sometimes quite substantially. The use of fertiliser is influenced by both financial and biophysical factors as well as a farmer's values and farming policies. Phosphate fertiliser is long established on grazeable areas of drystock farms, dating back to aerial topdressing that started post-World War II, while nitrogen fertiliser tends to be reserved for crops, pasture renewal, and to provide short-term stock feed.

For the 17 farms in the sample, six farmers used phosphorus fertiliser at rates of 3 kg/ha/yr or less in 2020-21, while two farmers applied phosphorus fertiliser at rates over 30 kg/ha/yr (Figure 41). The distribution of results for nitrogen was similar. One farmer did not use any nitrogen fertiliser in 2020-21 and 16 farmers applied nitrogen fertiliser at rates below 30 kg/ha/yr in that year – to put this in perspective, the NES-F Nitrogen Cap for synthetic nitrogen fertiliser on pasture is 190 kg N/ha/yr[141].

Farmers tend to apply phosphate fertilisers to maintain fertility on more productive areas where the financial cost of application can be justified. Nitrogen fertiliser applications are usually more targeted, particularly when addressing feed deficits. The decision to apply nitrogen fertiliser depends on the cost to apply, the farm's cash flow, and the likely response relative to alternative options for feed. In 2020-21, 10 of the 17 farms had application rates of below 10 kg/ha/year for both phosphorus and nitrogen fertilisers.

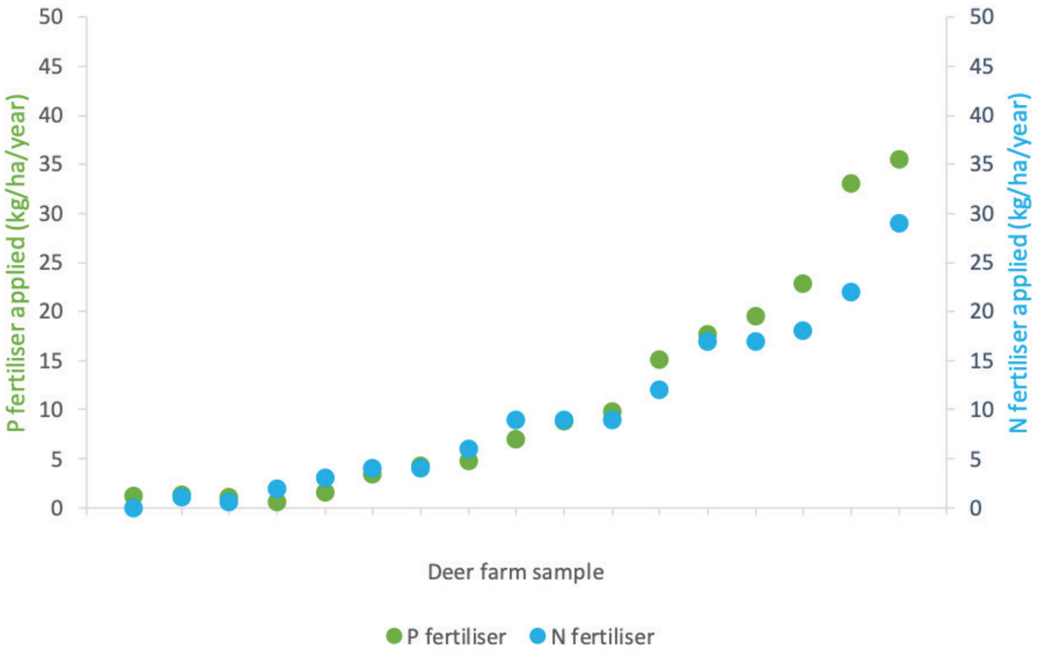

Figure 41: Separate distributions of phosphorus and nitrogen fertiliser use for 17 deer farms in Otago 2020-21
Source Deer Industry New Zealand
Note: Note: Each distribution is ordered from lowest to highest and so is not connected (i.e., a pair of points is unlikely to be for the same farm). The maximum scale of the y axes is 50 kg, and not the 190 kg N/ha/yr NES-F Nitrogen Cap.

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141 The nitrogen cap, for the land in pastoral land use in a contiguous landholding, means the application of nitrogen at a rate of no more than 190 kg N/ha/yr: (a) to all of that land, as averaged over that land; and (b) to each hectare of that land that is not used to grow annual forage crops.

Each farm's estimated risk of phosphorus loss was generally between 0.2 and 0.4 kg P/ha/yr (median 0.3 kg P/ha/yr and average 0.4 kg P/ha/yr) (Figure 42). Overseer estimates of the risk of phosphorus loss do not necessarily consider a farm's management of critical source areas so the actual phosphorus losses may be less than is reported here.

The estimated nitrogen loss on the sample farms was generally between five and 15 kg N/ha/yr (median 12 N/ha/yr and average 13 N/ha/yr) (Figure 42). Both sets of results are fairly typical for drystock farming, at least in southern New Zealand[142]. One deer farm is an obvious outlier for nutrient losses[143]. This property was a medium size minority deer farm with a stocking rate of just over 12 SU/ha, irrigation occurs on around one-fifth of the farm, and just over ten per cent of the farm is used for winter grazing. However, the causes of nitrogen loss are complex, with soil drainage being an important factor, and there was no obvious relationship for the 17 farms between proportions of farm irrigated and/or used for winter grazing and estimates of nitrogen loss.

Generally, there is a weak relationship between estimates of nitrogen leaching and the risk of phosphorus loss because how each nutrient flows in water through a farm differs, but the situation is complex. Deer farms with excessive nutrient losses may be over-applying fertiliser. Improving efficiency in the use of both nutrients within the farm system is likely to benefit the farm business, the industry, and the environment.

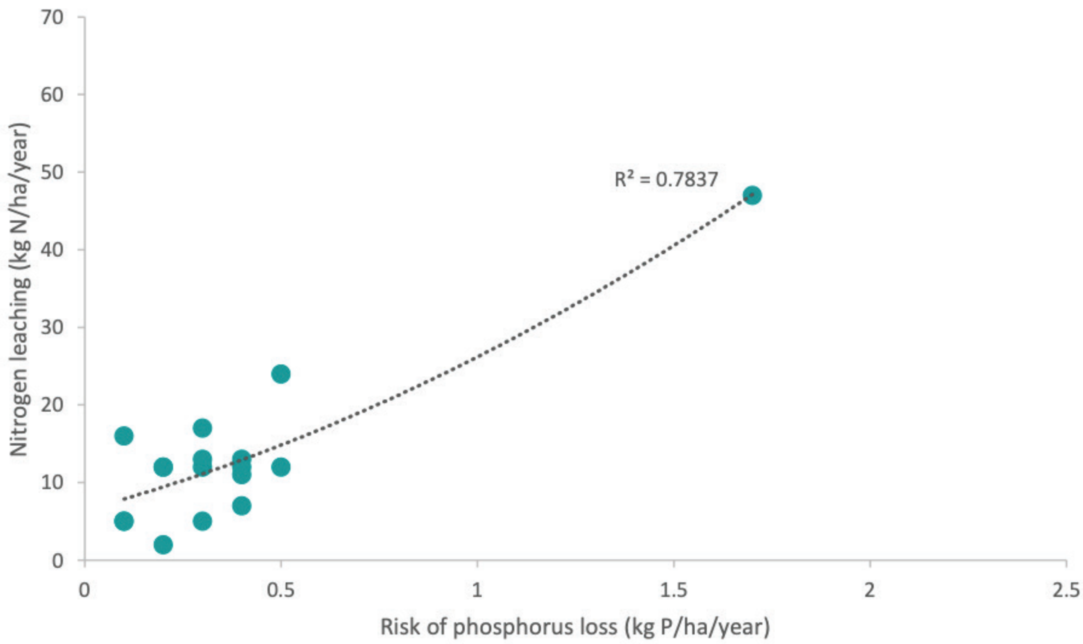

Figure 42: Estimated nutrient losses from 17 deer farms in Otago 2020-21
Source: Deer Industry New Zealand

142 Similar research was undertaken in Southland for the 2013-14 production year and is reported in Part C: Chapter 2 (pages 146 – 210) of The Agriculture and Forestry Report (Moran, 2017). However, care needs to be taken in comparing results because the Southland research used an earlier version of OVERSEER (version 6.2.0).
143 A single outlier was also found in similar research into deer farming in Southland (Moran et al., 2017).

In addition to losses of nutrients to water, greenhouse gas emissions from deer farming were estimated in Overseer. The farm emissions were variable, and the range extended from roughly one tonne CO^2e/ha/yr on two of the more extensive and lightly stocked properties up to over six tonnes CO^2e/ha/yr on one property. Overall, 12 of the 17 deer farms emitted between three and five tonnes CO^2e/ha/yr, with the median being 4.1 tonnes and an average of 3.8 tonnes.

At present, there are no available mitigations to reduce absolute emissions from deer, effectively meaning that the two options available to reduce the impact of emissions are to either offset the emissions through planting trees to sequester carbon or to reduce stock numbers. An alternative approach would be to improve the productivity of the farm (i.e., increase the amount of venison or velvet produced from the same quantity of emissions), but this would not reduce absolute emission levels.

3.4.2.3 Deer behaviour

Deer are a social species that are comfortable living in groups with a hierarchical structure. In nature populations of mature males and females are separated at all times of the year except during the rut. Deer farming systems typically involve stocking densities that are greater than those of wild populations, so care is needed to manage the balance between optimal economic productivity and maintaining the integrity of the environment. The initial adaptation from feral to farmed animal in the 1970s and 1980s has continued with refinement in behaviour and temperament in tandem with improved genetics for growth rates, velvet production and improved animal health. This process of domestication and improvement in livestock management has reduced issues over time[144].

In addition to this social hierarchy, deer have natural needs and behaviours that need to be carefully managed on-farm to reduce the risk to water and soil, particularly from excessive pacing, especially along fence lines, and wallowing[145].

Fence pacing is usually a sign of stress and occurs for a variety of reasons (e.g., weaners separated from hinds, lack of feed, presence of different stock classes in the adjacent paddock). Excessive pacing produces ruts and channels that transport sediment and contaminants down a slope. Its environmental effects vary depending on the soil type, the duration of the pacing and soil moisture/weather at the time. However, the main risk to waterways is whether the flow of sediment will connect to a waterway.

Wallowing is an intrinsic part of natural behaviour in many deer species and all farmed deer need the opportunity to exhibit it for animal health and welfare. Both female and male red deer will wallow, but stags usually wallow more intensively in the rut. Wallowing is thought to benefit deer through tick control, hair removal, cooling, and social interaction.

Deer, like sheep, are less inclined to camp or linger in riverbeds than cattle. Wallowing is a low-risk activity when precautions are taken to address the risk of sediment loss during heavy rain. Strategically located sediment traps offer opportunities to enhance biodiversity while providing shade and shelter.

In more expansive high country environments with low stocking rates, steep slopes, and long stretches of water courses, the cost of fencing off these areas to exclude deer can be prohibitive. The level of direct deposition into waterways is likely to be low due to the low number of animals present (e.g., it is common for unimproved tussock land to carry one stock unit per hectare).

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144 *https://www.deernz.org/assets/Deer-Facts/DeerFact_FencePacing_Web.pdf*

145 Wallowing is where deer bathe and roll around in mud. They create wallow sites in wet depressions in the ground, eventually forming quite large sites (2-3 metres across and up to 1 metre deep). These sites tend to be used by most members of the herd at some stage. It is not uncommon to see deer walking around caked in mud. More information is available at: *https://www.deernz.org/deer-hub/handling-and-welfare/behaviour/wallowing/*

3.4.3 Farm finances

The livestock mix on deer farms is influenced by a complex range of factors. Profitability is a key consideration, but it sits alongside farmer preference and skills, stage of career, and the versatility of the farmland. In recent years, the deer industry has seen the returns from growing velvet surpass returns for venison. This shift is influencing a change in the mix of livestock towards the inclusion of more stags on many properties. A farmer's appetite for change and risk, plus the effort, capital, and infrastructure involved are important factors in decision-making. Some farmers have a fairly fluid production system that tends to follow the market of the day while others maintain their preferred production system through commodity cycles.

As with the livestock mix (refer back to Figure x), the mix of revenue streams within the farm production system is highly variable. Figures 43, 44, and 45 show the revenue mix and main operating expenses for nine of the 17 sample farms. In these graphs the nine farms are numbered so that revenue mix and operating expenditure can be followed. As well, the farms are ordered by the proportion of deer stock units, with Farm 1 being a highly specialised deer farm and Farm 9 being a minority deer farm. For all but one farm, the revenue stream from deer was slightly less proportionally than each farm's deer stock units (Figure 44).

Importantly, the graphs present results for eight of the nine farms from the 2020-21 production season. Demand for venison during that season was severely impacted by a major fall-off in restaurant sales during the Covid-19 pandemic. The results for the remaining farm are from 2019-20, during which the chilled venison season was largely pre-Covid-19. This is the same farm that, proportionally, had a much higher deer revenue stream than its deer stock units.

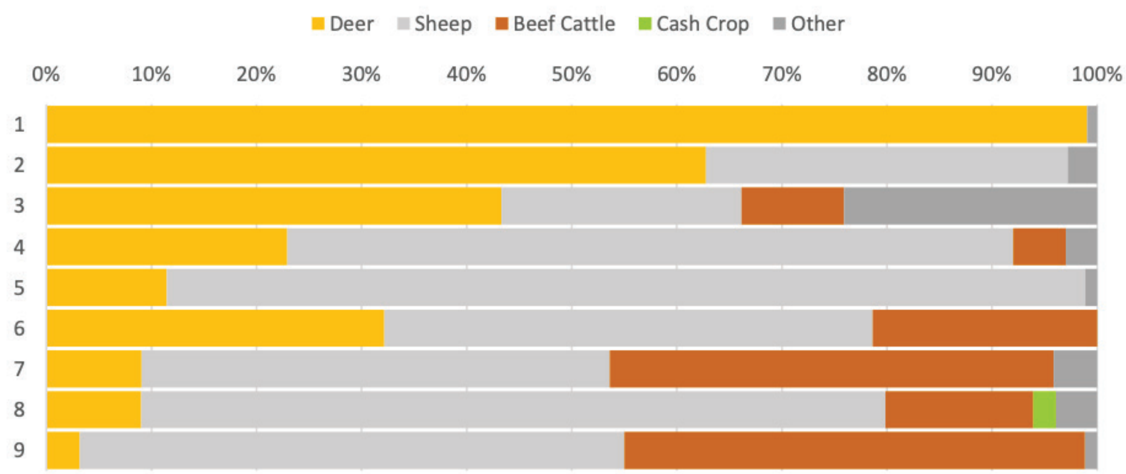

Figure 43: Mix of revenue streams for nine deer farms in Otago 2020-21
Source: Deer Industry New Zealand
Note: The results for Farm 6 are for the 2019-20 production season.

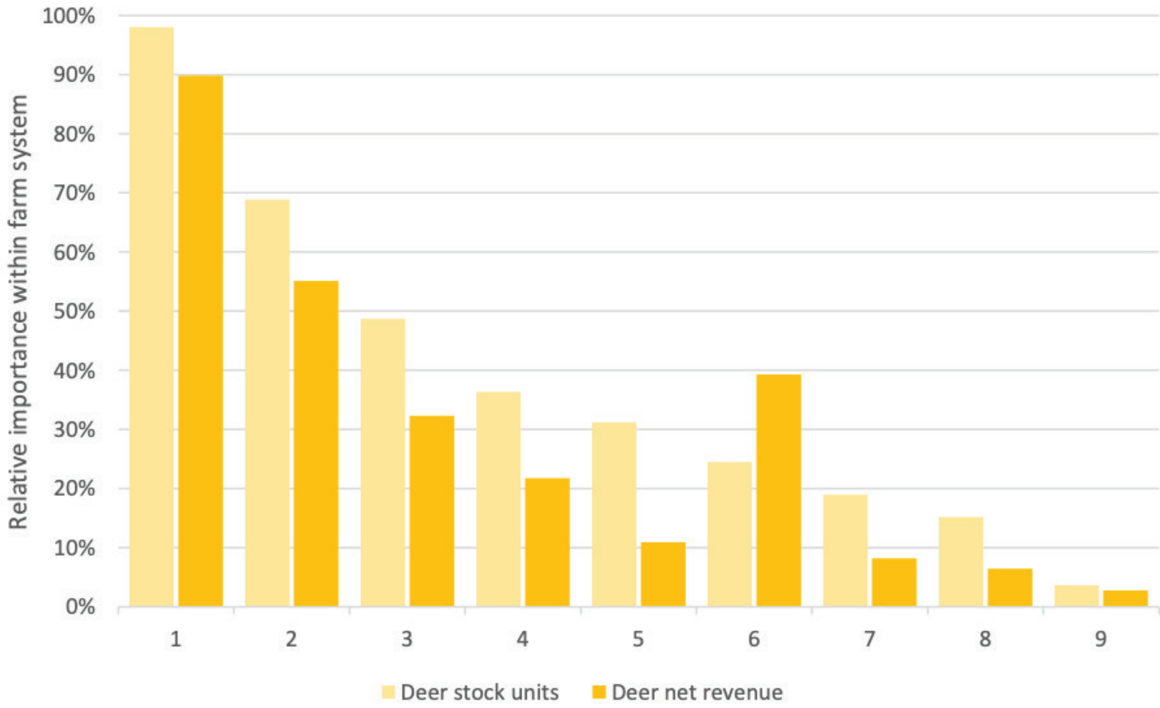

Figure 44: Comparison of proportions of deer and deer revenue stream for nine deer farms 2020-21
Source: Deer Industry New Zealand
Note: The results for Farm 6 are for the 2019-20 production season.

A farm's mix of revenue streams does not necessarily translate into profitability because operating expenses are a crucial consideration. The nine farms' main operating expenses were only available for the whole farm business (Figure 45), so it was not possible to attribute profitability to each income source (e.g., venison, velvet, lamb). Also reported are average expenses across the nine farms (Figure 46). Farm operating profit for the nine farms in 2020-21 ranged from around $30,000 to almost $1 million per year, but the range was not necessarily a simple function of farm size (Figure 47). The median farm profit was roughly $150,000 and the average was around $300,000, heavily influenced by several highly profitable farms.

The cost of 'land', which includes interest, rent and rates, can be a considerable proportion of a farm's expenses. Most, but not all, of the nine farms were carrying debt. On average, interest costs were around $60,000 per year, but for two of the nine farms the interest costs were in the vicinity of $200,000 per year. Interest rates have risen considerably since 2020-21. Electricity is mostly used for reticulated stock drinking water, any infrastructure (e.g., shearing sheds) and irrigation.

The cost of land and water (i.e., irrigation and electricity) and the costs of either growing or supplying feed (i.e., fertiliser, lime, seeds, feed, grazing, cultivation, sowing, weed and pest control) total between roughly 30 per cent and 70 per cent of the main farm expenses, and at least 40 per cent for most of the nine farms. The farms with higher labour costs are likely to be larger farms but one in three farms did not benefit from any additional labour. Shearing is a cost borne by those farms that are not specialist deer farms.

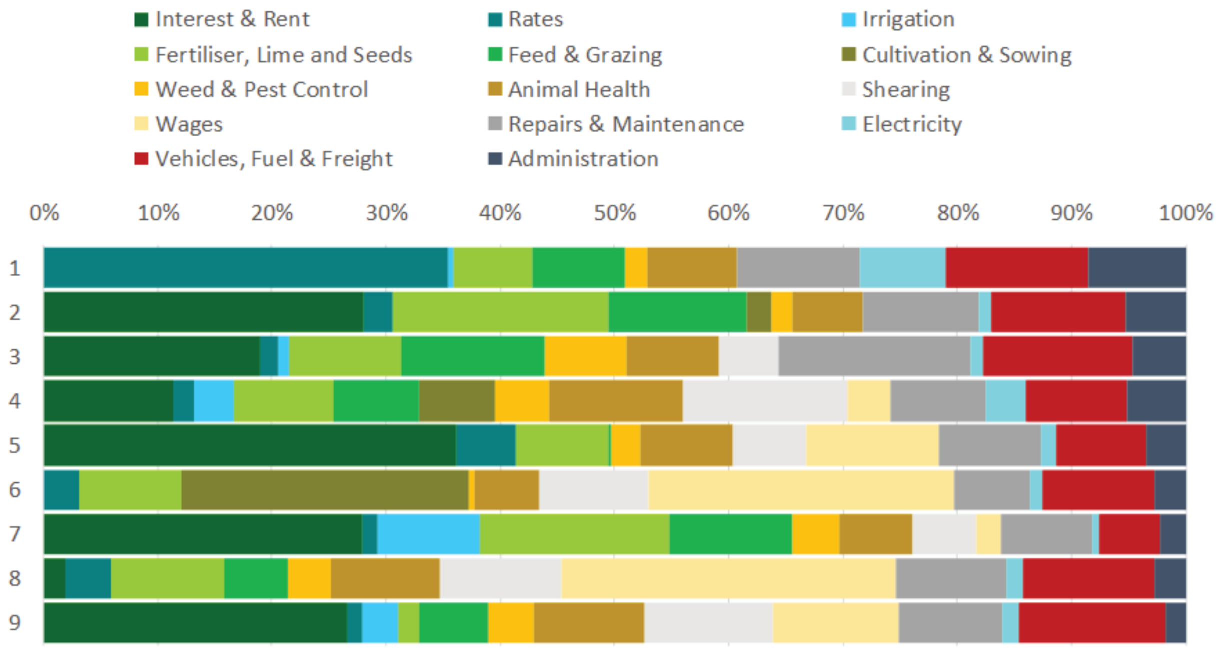

Figure 45: Distribution of farm operating expenses for nine deer farms in Otago 2020-21
Source: Deer Industry New Zealand
Note: The results for Farm 6 are for the 2019-20 production season.

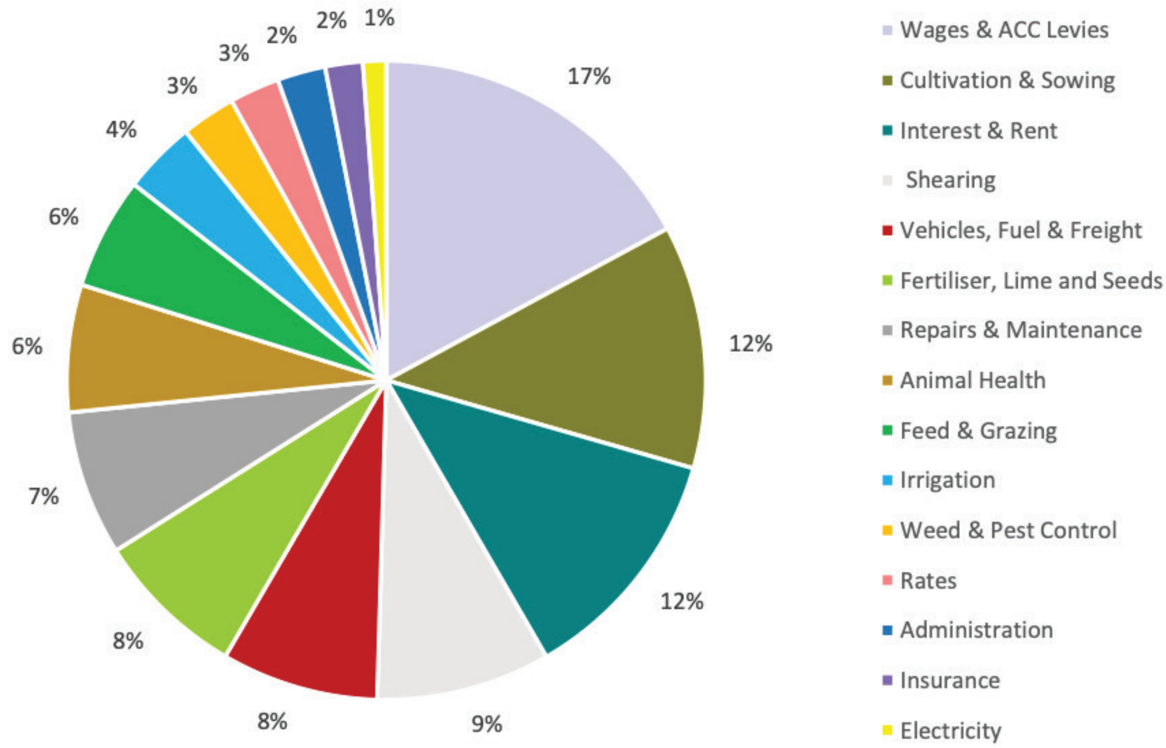

Figure 46: Average farm operating expenses across 9 deer farms in Otago 2020-21
Source: Deer Industry New Zealand
Note: The result for one farm is for the 2019-20 production season.

Figure 47: The relationship between farm size and farm profitability for nine deer farms in Otago 2020-21
Source: Deer Industry New Zealand
Notes: The result for one farm is for the 2019-20 production season. The scale of the x axis (i.e., farm size) is not provided to maintain farmer confidentiality.

Image 23: Variations in topography in the landscape in and around Criffel Station, Wanaka.
Source: Criffel Station

3.4.4 Summary characteristics

Table 24 gives a summary of characteristics across the sample of 17 deer farms within the Natural Knowledge Project for Otago. The data are presented by median[146] (the middle value when arranged from smallest to largest), average (or mean) and range to give a sense of the distribution for each characteristic (i.e., the shape of the dataset). In some instances, thresholds or rounding are used for the minimum and maximum results in the 'range' column to maintain the confidentiality of individual data.

Table 24: Summary of characteristics for 17 deer farms in Otago 2020-21 and 2021-22

Farm characteristic	Number of farms	Median	Average	Rough Range
Flat land (%)	17	21%	37%	0% to 100%
Steep hill (%)	17	11%	27%	0% to 90%
Farm stocking rate (SU/ha)	17	9	9	3 to 14
Deer unit (ha)	17	260	497	30 to 2,000+
Deer stock units (%)	17	36%	51%	5% to 95+%
Sheep stock units (%)	15	48%	41%	0% to 75%
Cattle stock units (%)	12	17%	18%	1% to 50+%
Rainfall (mm/yr)	17	643	671	400 to 1,100
Potential evapotranspiration (mm/yr)	17	799	784	400 to 1,000
Irrigated land (ha)	9	150	161	20 to 300+
Irrigated land within farm (%)	9	5%	8%	0 to 20+%
Mature hinds (%)	16	49%	42%	3% to 60+%
Mixed age stags (%)	16	8%	16%	1% to 60+%
Velvet cut (kg)	15	157	1,387	36 to 5,000+
Velvet cut (kg/deer stock unit)	15	0.10	0.27	0.4 to 1.00+
Winter grazing area (ha)	17	55	68	5 to 200+
Winter grazing (%)	17	5%	8%	1% to 20+%
Other biodiversity areas	6	44	66	1% to 23%
Overseer nitrogen leaching (kg/ha/yr)	17	12	13	2 to 47
Overseer risk of phosphorus loss* (kg/ha/yr)	17	0.3	0.4	0.1 to 1.7
Greenhouse gas emissions (kg/ha/yr)	17	4,100	3,800	925 to 6,000+
Farm profitability**	9	$150,000	$300,000	$30,000 to $1 million

** An estimate of risk as opposed to an estimate of actual phosphorus loss. While Overseer nominally includes grass filter strips, it does not properly reflect the effectiveness of actions such as management of critical source areas and riparian margins.*
*** These results are likely to have been influenced by the impacts of Covid-19 on venison export markets.*
Note: The median is the middle value in a series, with half the data points above the median and half below. Where a data series is skewed by relatively large outliers, the median tends to give a better indication of what is typical than the mean.

146 The median is often used as a measure of central tendency because it is not affected by outliers (extreme values that are far from the rest of the data). Where there is a sizeable gap between the median and the mean it indicates that the dataset is possibly skewed, either towards smaller or larger values. In agriculture, most distributions of physical metrics are 'skewed' rather than being a 'normal' or 'bell-shaped' curve (A. Burtt, Chief Economist B+LNZ, pers. comm., April 2023).

3.5 Farm Case Studies

Five deer farms were selected from across the sample of 17 deer farms described in Section 3.4 to develop as case studies to test the impacts of environmental actions on the farm business. The five farms covered an array of deer production systems (i.e., venison, velvet, stud, trophy[147]) and biophysical characteristics (e.g., soil type, rainfall, and contour), which create various opportunities and constraints. The set of environmental actions tested were discussed and agreed upon with industry representatives based on each case study farm's circumstances and the issues relevant to the wider group of deer farms in Otago.

To help maintain farm confidentiality, this section uses the following farm size categories: 'smaller' = below 500 grazeable hectares, 'medium' = 500 to 1,000 grazeable hectares, and 'large' = over 1,000 grazeable hectares.

Each farm's current practice was modelled in FARMAX with some minor adjustments to reflect a 'steady state' situation (i.e., general 'status quo') rather than a calendar year where stock numbers and farm systems can be in flux. Actual farm expenses were used where they were known. Otherwise, B+LNZ farm system information for Otago was used. The net effect was a hybrid of typical farm current production, pricing, and basic costs as a comparative starting point. The farm models in FARMAX were then modified to reflect the likely farm system adjustments that are needed to implement each environmental action. The results were discussed with each farmer and in a workshop of industry experts to add commentary to the analysis.

3.5.1 Deer 1

A smaller specialist deer farm (87% deer stock units) and a small sheep enterprise within the production system. Young hinds are mated to red stags (selected for velvet antler traits) and older hinds to Eastern Red deer terminal sires as a fast-growth rate venison proposition to produce both stag and hind fawns. Weaners are finished and processed during the premium chilled venison season (September to November)[148]. Some Red stag fawns are retained, and most enter the velvet herd as 3-year-old stags. Eastern weaners are also retained, and some have entered the herd in the past. There is a mixed age velvet herd, and the velvet stags consume roughly half of the feed intake of the whole deer herd operation.

Winter supplements make up roughly half of the feed used over winter. The farm's waterways are already largely deer fenced and include roughly 20 hectares of riparian buffers. Fodder beet is used as a winter feed crop, which can be challenging to both establish a high yield crop and manage winter grazing in the farm's wet conditions. Very few if any of the farm's cultivatable paddocks were under 10° slope.

Given the farm's existing compliance with stock exclusion regulations, two environmental actions were tested for this case study that focused on the winter period:

- A change in winter feed practices from fodder beet to grass silage; and
- Construct a wintering shed for either a) weaners, or b) adult velvet stags, or c) adult velvet stags with an investment in improved genetics.

The FARMAX modelling relied on B+LNZ data for Farm Class 6: *South Island Finishing and Breeding*, rather than using the farm financials, without any irrigation charges because they were not relevant to this farm.

147 A description of four main production systems is available in the Deer Chapter of the *Farmers and Growers in Otago* Report (Pearse et al., 2022).

148 Refer to the Deer Production Calendar in Chapter 4 of the *Farmers and Growers in Otago* Report (Pearse et al., 2022).

The farm had already fenced off the waterways over many years and was compliant in this regard. However, the steeper nature of the cultivated land on the farm posed challenges to effectively mitigate against soil movement from winter crop areas.

3.5.1.1 Change winter feed practices

The first environmental action tested on this farm was to cease growing fodder beet and replace it with grass silage from the late spring growth flush. This action was an adaptation of the farm's existing practices. The aim was to try and sensibly keep deer within the farm system in a way that had the least economic impact.

The yield from grass silage was lower than fodder beet so the farm's stocking rate needed to be reduced from 10.27 SU/ha to 9.79 SU/ha. In total, 60 fewer stags were run, which reduced velvet income. As the hinds numbers were maintained, in each year there are 30 surplus velvet stags selected for culling and sold based on their lower velvet production weights (there is a premium above meat value due to velvet genetics). These surplus stags, sold as stores to other velvet operations, received more than the processor price of $1,500 per head due to superior velvet genetics. The remainder of the stags were sold as usual to retain numbers.

Farm profitability declined by $25,000, mainly as a result of the lower stag numbers. The use of further supplements over winter increased as seasonal feed now only accounted for 35 per cent of demand.

The shift away from a winter feed crop is more complex than simply reducing livestock numbers. The whole production system needs to be considered, including infrastructure (e.g., feed pad or wintering shed), labour, management, and other expenses. For this farm, labour was an important constraint. The farmer is a sole operator, which is challenging when harvesting velvet. They were already facing a decision of either expanding the velvet enterprise to justify an extra labour unit or dropping it from the farm system. Considerations are the extra labour costs and the supply of skilled labour.

Although feeding silage to deer in paddocks was tested, in reality it was not practical for this farm because of its size and the local climatic conditions (generally cold and wet). While the hinds may be able to be put in a farm forestry block, there were no viable options for other livestock.

Image 24 : Established mixed native planting behind deer fencing.
Source: Emma Moran
Note: This photo is used to illustrate a topic relevant to this case study – it is not a photo of the case study farm in question.

3.5.1.2 Construct a wintering shed

As a possible solution, the second environmental action tested was to construct a wintering shed. Initially, the shed was considered for the hinds over winter, but it was eventually tested for the velvet stags instead. This action involved intensifying the farming operation to justify the substantial investment in infrastructure.

The stag numbers were increased, and the hind numbers reduced so that there are only a few culls and fewer hinds bred to larger Eastern Reds as terminal sires for chilled early season venison production. A winter shed was built for 220 weaners at a construction cost of $162,000 over a 20-year period (capital shed cost of shed was $225/m^2)[149]. Additional bedding cost of $25 per weaner and repairs and maintenance of 2 per cent of capital value was included. In Southland, most deer farmers with deer in wintering sheds use a deep litter bedding. They add more woodchips or more straw through the winter and the litter is later spread on the paddocks. However, the practice was not included in this analysis.

The interest and principal for the wintering shed totalled $15,000 per year over 20 years[150]. Profit increased $25,000 because of more velvet stags leading to a rise in antler productivity. However, an extra labour unit was needed, particularly over spring and into summer. The construction of a wintering shed provided the potential of housing a group of stags over winter instead of weaners. Regardless of stock class, it is assumed there are benefits for animal welfare, less feed requirements compared with in situ grazing, and the improved condition of paddocks.

As a variation, all 350 hinds previously mated to terminal sires, along with their weaners for finishing, were replaced by velvet stags. The additional velvet harvested resulted in an improved gross margin, with an increase in farm profitability of $50,000 after the additional costs and debt servicing.

FARMAX calculates the impact of feed costs and makes sure the farm models are viable. In reality, however, there may not be enough room on this farm for both velvet stags and early venison production for the premium chilled market because of the need for high quality feed for both stock classes. While a deer shed might be able to be incorporated, a different deer production system is needed to finance it. As well, there are now fewer operations that run hinds on hills and sell weaners as stores, which increases the risk of availability of livestock to run this system.

The use of conserved pasture supplements in winter increased as winter pasture growth was only sufficient for 37 per cent of winter stock demand. For all analysis where winter crops were replaced with silage, there was a reduction in overall winter supplements from 353 tonnes to 304 tonnes. In the base model, fodder beet provided 154t DM while additional silage able to be taken to replace fodder beet was 105 tonnes.

149 This estimate is based on David Steven's (2022) summary of winter grazing deer on crop versus winter grazing deer in sheds for a Southland Advance Party Regional Workshop. David Steven's figures were adjusted from between $207/m^2 and $214/m^2 to $225/m^2 for this research to reflect rising inflation. The farmers in the Southland Environment Group have put in 14 winter barns across seven farms. Their feedback is positive and there is growing interest from other farms. Financially, it appears to be a more viable option for velvet production systems.

150 Loan terms were varied between the case studies depending on the likely useful life of the infrastructure in question. Where fencing was included, factors such as slope/erosion or likelihood of flood damage were factored in shortening time frames in some instances.

3.5.1.3 Deer 1 Case Study Results

Table 25: Summary FARMAX results for Deer 1 Case Study

	Base Farm Model	No fodder beet	Maintain hind numbers and 60 fewer stags	More stags, fewer hinds + wintering barn for weaners	More stags, fewer hinds + wintering barn for weaners or stags	More stags, fewer hinds, wintering barn for adult stags + investment in better stags
Deer revenue	$542,000	$504,000	$507,000	$588,000	$620,000	$655,000
Total Revenue*	$601,000	$563,000	$566,000	$647,000	$680,000	$714,000
Total Farm Expenses**	$327,000	$318,000	$318,000	$339,000	$347,000	$347,000
EBITR	$274,000	$246,000	$230,000	$308,000	$332,000	$367,000
Interest and rent	$64,000	$64,000	$64,000	$73,000	$73,000	$73,000
Farm profit before tax	$210,000	$182,000	$166,000	$236,000	$260,000	$294,000

Note: the results in this table have been rounded to the nearest 1,000.
** Sheep revenue in the Base Farm Model was $59,000 and remained unchanged.*
***Total Farm Expenses includes depreciation*

3.5.2 Deer 2

A medium minority deer farm (17% deer stock units) on rolling hills with uncultivated steeper gullies. It is a mixed breeding and finishing production system dominated by sheep, with a deer enterprise, and some trading cattle.

The deer enterprise consists of deer-fenced blocks where around three-quarters of the land is rolling, and one-quarter is steep uncultivated gully. Deer are run between the 'tops' and the gullies. The fawning blocks are in the gullies with around half of the hinds being 'set stocked'[151] there with favourable conditions for fawn survival. Hinds can access a stream at the bottom of the gully and the only practical way to prevent it is to exclude deer from these blocks. Another issue is the potential for pugging on winter crops with heavier deer stock classes.

Given the challenge of stock exclusion in the gully blocks and potential pugging on winter crops, two environmental actions were tested for this case study:

- Removal of hinds from the gully blocks to protect the stream; and
- Construct a wintering shed to prevent pugging on winter crops.

The FARMAX modelling relied on B+LNZ data for Farm Class 6: *South Island Finishing and Breeding*, rather than using the farm financials, without any irrigation charges because they were not relevant to this farm.

151 Set stocking is where hinds are spread at an appropriate (usually low) stocking rate across the entire block.

3.5.2.1 Exclude hinds from gullies

The first environmental action tested was to exclude the hinds from the stream in the steep gully blocks, which is non-low slope land[152] (i.e., it is not captured by the National Stock Exclusion Regulations). As it is simply not practical to fence the stream within these blocks, half of the hind numbers were removed from the farming operation. They were replaced with sheep that can use the grazing available in the gully area without exclusion.

It is anticipated that the removal of the hinds out of the gully to fawn on paddocks may create animal welfare issues. Higher paddock stock density and a lack of natural shelter puts more pressure on the survivability of new-born fawns, which are natural hiders in early life (10-15 days) and if disturbed they can be displaced and deserted. Young fawns can easily be lost, and it was estimated the hinds' fawning success may drop by up to seven or eight per cent when fawning occurred in paddocks.

A variation on this environmental action was also tested where the breeding hinds were removed from the farm system altogether. This situation was considered as the farmer's more likely response for this farm as both the difference in gross margins and decline in reproductive efficiency (as well as animal welfare issues) reduce overall farm profitability. The net positive impact on farm profitability is $40,000 per year relative to the base model.

On this farm the deer enterprise is small relative to the sheep operation. If there was a requirement to remove deer from the gullies then, as a second or third enterprise within the production system, the pragmatic decision is likely to be to remove the deer enterprise entirely. Financially, the business was just as (if not more) profitable without the deer, but some of the diversification in the system with complementary enterprises was lost. If this decision is taken across similar farms, then it is likely to have serious consequences for the Otago deer herd (i.e., a reduction in numbers and downstream processing/ employment) and the range of production systems. It would also remove an income stream from those businesses.

Given this situation the farmer would prefer to use the integration of livestock classes to their best advantage and the deer enterprise remained a welcome change from sheep work. However, while running weaner deer is a possible option, it assumes the availability of weaners, which are easier for some farms to source than others.

An alternative environmental action that may allow the hinds to be maintained within the farming system was to modify the management of the gullies with some moderate investment in sediment traps, crossing areas, and water quality testing. A farm visit indicated that the hinds are stocked in these gully blocks during spring when there was pasture growth and no visual sediments or sediment damage.

152 The Resource Management (Stock Exclusion) Regulations 2020 requires (among other things): a) deer on low slope land must be excluded from lakes and wide rivers (except when crossing) and b) deer that are intensively grazing on any terrain must be excluded from lakes and wide rivers (except when crossing). 'Low slope land' means land identified as low slope land in *https://www.mfe.govt.nz/fresh-water/freshwater-acts-and-regulations/stock-exclusion*

3.5.2.2 *Pugging on winter crops*

The second environmental action tested on this farm was to construct a winter shed to avoid pugging on winter crops. The shed was designed to house 600 hinds together with using a gully as a loafing pad. In wet weather the loafing pad was shut off from deer to reduce the potential for soil movement. The swede winter crop was reduced by 20 hectares and the feed replaced by silage taken as late spring surplus. It is anticipated that the hinds may be held in the shed longer resulting in a better early spring outcome for lambing through additional feed available.

Expenses were adjusted to reflect the change in costs as a result of system investment or modification. Where a shed was included as well as sediment traps and strategic exclusion fencing, the capital development expenditure has been calculated and entered into a 30-year table loan. Where these changes altered the farm's running costs, the expense schedule was adjusted accordingly.

Construction of a deer shed was $400,000 based on 600 hinds needing 3m^2 at a cost of $225/m^2. Other costs included: sediment traps $6,000, exclusion fencing $15,000 (500m at $30/m), and annual bedding cost of $10,000. Repairs and maintenance were one per cent of the capital spend on these changes. While overall farm revenue lifted by $13,000, the cost of interest and the added costs to maintain the shed reduces overall farm profit by $33,000.

In reality, the removal of winter crops is complicated as the feed provided as crops that can be fed in situ are replaced by silage often requiring machinery to feed. Trailing silage wagons are heavy and there is increased danger of loss of traction over winter unless they are on tracks all of the time (there is usually gravel tracks to get to and from shed or feed pads). Kale is an alternative winter crop to swedes or fodder beet that can reduce pugging from deer, but it generally requires more area for the same yield.

Deer breeding and finishing operations are at a disadvantage because the feed demand stays relatively constant throughout the year when weaners are retained over the winter months. While holding hinds off pasture in early spring makes sense, the possible options to achieve it (e.g., sheds), are not necessarily financially viable and increase business risk.

3.5.2.3 *Deer 2 Case Study Results*

Table 26: Summary FARMAX results for Deer 2 Case Study

	Base Farm Model	Reduce hinds	No winter crop for deer
Deer revenue	$220,000	$108,000	$220,000
Sheep revenue	$1,468,000	$1,551,000	$1,481,000
Beef revenue	$129,000	$194,000	$129,000
Total Revenue	$1,818,000	$1,853,000	$1,830,000
Total Farm Expenses*	$1,454,000	$1,457,000	$1,480,000
EBITR	$364,000	$396,000	$351,000
Interest and rent	$278,000	$278,000	$297,000
Farm profit before tax	$86,000	$118,000	$54,000

Note: the results in this table have been rounded to the nearest 1,000.
**Total Farm Expenses includes depreciation*

3.5.3 Deer 3

A medium-sized minority deer farm (26% deer stock units) with a mixed breeding and finishing production system consisting largely of sheep, a deer enterprise, and a small number of cattle traded. The property was partly irrigated (border-dyke and K-Line irrigation) and contains multiple soil types from free to poorly drained in heavier clay soils. It also has wet areas, ponds, and other waterways. The ponds are partly filled by irrigation by-wash, as well as being natural watersheds, and are currently unfenced.

While not fully focused on deer, this farm is typical of many operations where investment has been made in deer to diversify the farm production system. The deer enterprise consists of a herd of breeding hinds with around one-quarter of replacements being bought in annually. The deer are all mated to terminal sire with weaners produced for processing in spring. The sheep enterprise consists of over two thousand breeding ewes and replacements with lambs finished to 40 kg and above where there is K-Line irrigation.

The farm system is currently in transition following a decision to shift from border dyke to spray irrigation. The farmer's reasons for the shift are complex but include the thought that further investment in border dyke irrigation is unlikely to find favour with regulators in the future. Overseer modelling estimated a marked reduction in nutrient loss from the property, but it was the financial potential of more efficient use of water (as shown by the K-Line) that allowed the funding and development to progress. The property was modelled as 'prior to' and 'post' development of more efficient irrigation.

Given the lack of stock exclusion and the transition to spray irrigation, two environmental actions were tested for this case study:

- Exclusion of deer from the farm's ponds and other waterways; and
- Improvement of irrigation efficiency.

The FARMAX modelling relied on B+LNZ data for Farm Class 6: South Island Finishing and Breeding, rather than using the farm financials.

Image 25: Unfenced waterway showing natural tortuosity on low slope land.
Source: Simon Glennie
Note: This photo is used to illustrate a topic relevant to this case study – it is not a photo of the case study farm in question.

3.5.3.1 Stock exclusion from waterways

The fencing-off of waterways on low-slope land was the first environmental action tested for the farm to be compliant with current national stock exclusion regulations. The pond perimeters were calculated along with the length of unfenced waterways. The cost to service the additional debt with a total of eight hectares lost from the grazeable area, was then modelled. The cost to fence off deer relative to cattle is high and will prompt a further question for the farmer as to whether deer are run on these areas at all.

Stock exclusion for deer was calculated using the low slope area for the border area and multiple ponds, which totalled 6.1 km of fencing. It was anticipated that exclusion fencing will require more strainers and stays (multiple short strains and corners). The cost of fencing was assumed to be $30 per metre to cover deer fencing of this type, which totalled $183,000. Using an interest rate of seven per cent over 40-year table mortgage, the total investment was $13,650 per year with two-thirds interest and one-third principal repayment over the period.

Breeding hind numbers needed to be reduced because of the grazing area lost around the riparian margins. Although a total of 16 hectares was assumed to be exclusion fenced, only eight hectares of grazing was removed in the FARMAX analysis to reflect the waterway and poorer grazing performance.

Stock exclusion for deer from waterways reduced farm profit before tax by $13,000 or nine per cent.

3.5.3.2 Improve irrigation efficiency

The second environmental action tested was shifting from border dyke irrigation to pivot (and K-Line) irrigation systems. The new development improved pasture growth volumes, which needed to be utilised in the most profitable way to be able to fund the development. As well, the practicalities of managing pivot irrigation on a deer farm, including its passage through deer fencing while maintaining fence security, increased the cost. It led to the removal of the breeding hinds system and the farmer turning to seasonal finishing and trading of deer. The deer numbers dropped slightly as well as some more lamb finishing was included, which was already happening on the farm. In essence, the irrigation development reduced the deer enterprise and changed the livestock ratios.

The cost of the pivots and full cost to build a storage dam, remove existing hedges and conduct earthworks related to pivots along with re-fencing and re-pasturing the area resulted in an increase in borrowings of $1.2million. In reality, the actual costs may have been higher due to circumstances such as the declining exchange rate and additional earthworks in the dam construction. An interest rate of seven per cent was assumed, and the table mortgage calculated over 40 years where two-thirds of the total cost is interest. On an annual basis, there was an additional $86,250 of interest and $43,000 of principle.

Additional farm costs are also incurred post development, which have been included, such as energy cost to drive the pivots and increased repairs and maintenance. Insurance cost was also estimated and included in the analysis. Overall, the economics for the business of improving the technical efficiency of irrigation were marginal but it will improve its productive efficiency in terms of reducing nutrient loss. If a farmer can service the cost of the debt, over time that land is likely to become more valuable.

With more efficient irrigation, an increase in feed supply is anticipated and a more summer safe platform of higher quality pasture on offer. To make the most of the new feed, the farm system was redesigned, including the role of deer within the system. Deer-fencing of areas under the intended path of pivots are extremely expensive and impractical, and so the existing deer fencing was dismantled to re-use along waterways. Both the total deer area and the proportion of irrigated deer fenced area were reduced.

Together with the balance of the farm area changed to better pastures under efficient irrigation, the modelling bought into question the role of breeding hinds on this property. Early spring production on the dryland areas remain strong but later spring and summer dry conditions were least suited to breeding and lactating hinds.

The FARMAX analysis tested the farmer's intended pathway for removing all breeding hinds and increasing numbers of trading lambs and weaner deer. The numbers of weaner deer taken on will vary depending on availability and margin for winter trade lambs, which occur during the same time period. It assumed that weaner deer will be available to purchase of the type and number required, which as noted in the previous case study, may not be realistic for every farm.

Adapting the farm system to make the best use of the extra feed available generated an additional $200,000 of revenue but the additional expenses and debt servicing is such that the farm profit is reduced by around $16,500 per year.

The capital value of the land is expected to hold at a higher value due to the higher stocking rate able to be run[153], but equally there are risks undertaken through the irrigation development and system change process. Of particular note, is the challenge of interest rates, which are already in excess of the interest rate used in the analysis. Increased production, water security and consent tenure were all necessary to gain bank funding to undertake the investment in more efficient irrigation as an environmental action.

This case study is similar to many farms in Otago that have deer as the second or third enterprise. It is these minority deer farms that may be most at risk of transformational change in their production systems and a loss in resilience. In this case, breeding hinds no longer easily fits within the farm system and trading is anticipated, which requires a willing buyer and seller. Any wider trend towards trading could be de-stablising as traders easily enter and depart impacting the returns of breeding properties.

3.5.3.3 Deer 3 Case Study Results

Table 27: Summary FARMAX results for Deer 3 Case Study

	Base Farm Model	Riparian deer fencing	Improve irrigation efficiency
Deer revenue	$147,000	$143,000	$185,000
Sheep revenue	$401,000	$401,000	$568,000
Beef revenue	$14,000	$14,000	$14,000
Crop & feed revenue	$10,000	$10,000	$10,000
Total Revenue	$573,000	$569,000	$777,000
Total Farm Expenses*	$348,000	$348,000	$443,000
EBITR	$224,000	$220,000	$294,000
Interest and rent	$81,000	$90,000	$167,000
Farm profit before tax	$143,000	$130,000	$127,000

Note: the results in this table have been rounded to the nearest 1,000.
**Total Farm Expenses includes depreciation*

153 The debt level and servicing cost increases but so to do farm expenses and it is the combination that pulls back net profit.

3.5.4 Deer 4

A large specialist deer farm (over 90% deer stock units) of flats, easy hill, and hard hill country. The production system comprises some high value animals including sale stags along with hinds and a velvet operation. A mob of hinds are run on the hill with weaners sold prior to winter. Stags are run for velvet harvest and a few additional stags are grown as trophy stags on the hill. As a higher revenue enterprise, the trophy stags allow the farmer to maintain a conservative stocking rate on hard hill country. Commercial (i.e., non-stud) hinds are purchased rather than being bred on the property.

The flats include a stream that is largely fenced along with riparian planning. This stream is a source of irrigation water that is stored on-farm before being gravity fed or pumped for K-Line and fixed grid irrigation systems. Water is also available through an irrigation company. Water security is a key issue for the farm and relates to the consents to irrigate and to store water. There are unfenced waterways on the property, primarily on the hill blocks. There are gorges with waterways passing through some of these blocks. Rainfall is low and at times the streams run dry along some reaches.

Roughly 35 per cent of the farm's feed grown is on irrigated 'flats' that is 7.5 per cent of the grazeable area. The farm's stocking rate and resulting feed demand is very low with a maximum demand of five kilogrammes of dry matter per hectare. The stocking rate in the hills is below one stock unit per hectare and feed utilisation is difficult with a short growing season and low rainfall. When poorer utilisation is accounted for on the hill, the irrigated flats provide approximately half of the feed consumed on an annual basis. High value livestock classes and young animals are supplemented with higher value feed during winter on the flats. Fodder beet is used to increase yield of good quality feed to fill the winter shortfall. The farm's front hill country is important because of its proximity to the flats.

The farm's hills are deer fenced with some blocks larger than 300 hectares. Deferred grazing is an important source of winter feed for commercial hinds where spring growth, particularly on shady faces, is left ungrazed during summer and autumn. During winter and into early spring these areas provide a feed source for the hinds. While pasture feed covers[154] are short in some places, most of the hill country has good native and introduced grasses. The low stocking rate means there are long grass covers that gives a degree of filtering near waterways and reduces nutrient and sediment run off. During autumn, trophy stags are run on large hill blocks while hinds and fawns are on lower blocks. Large blocks, remote location and natural cover mean very little fence pacing occurs. Low rainfall and high covers also protect the soil from erosion.

The farm's mixed topography and water security issues pointed towards three environmental actions to test for this case study:

- Riparian management of a partial hill block;
- Improve irrigation efficiency; and
- Fertiliser use on hill blocks

The FARMAX modelling relied on B+LNZ data for Farm Class 2: South Island Hill Country, rather than using the farm financials.

154 Pasture feed covers is a term that relates to the amount of feed present and available to grazing livestock. Farmers use the term to describe the feed available for animals but equally a good cover supports a reduced overland flow in most cases.

3.5.4.1 Riparian management of partial hill block

The first environmental action tested was to further improve the farm's riparian management. The stocking rate is very low, and the contour of the land is not well suited to riparian fencing. In some instances, creeks run over rock in deep ravines and the exclusion of livestock, particularly deer, is not practical in any sense. The only course of action available is to exclude deer and run sheep. This step would require a re-think of the entire operation, including a new set of skills and infrastructure. The transformative change in production system for this situation was not tested.

There are waterways on low slope land adjacent to irrigated areas. These waterways are being progressively fenced off and riparian planting undertaken. The main cost in this situation is the fencing, which is estimated at $22 per metre (as a minimum) along a length of 3.6 kilometres, or $80,000 for a single side. The fencing equates to a $8,000 reduction in farm profit (added interest cost). A further cost to consider is investment in riparian planting, some of which has been completed. As well as amenity value, the native planting will, over time, help suppress competing brush weeds.

3.5.4.2 Improve irrigation efficiency

The second environmental action tested was shifting from K-Line irrigation to spray irrigation. The development needed a capital investment of $2 million, which includes an allowance to complete the farm's water storage and fixed grid installation. The farm system was changed to utilise the additional feed generated via retaining weaners from commercial deer. Also needed was an increase in the winter feed area to cater for additional wintered stock.

For this farm the development of more efficient irrigation reduced farm profit by $42,000 per year. The large increase in debt servicing was not able to be covered by the subsequent increase in farm production.

In this situation, the farm can generate $150,000 of additional revenue by finishing weaners but the cost to service debt was also greatly increased.

3.5.4.3 Fertiliser use on hill blocks

For the farm's extensive run hill blocks, the annual contribution to production is on average roughly 600 kg of feed eaten per hectare at 13c per kg of dry matter (kg/DM) gross margin, or $78 per hectare for commercial hinds.

At times, these blocks also provide the potential to run trophy stags and velvet stags. The aerial application of fertiliser is marginal at this level of return but there are some blocks with better soils and contour that support better than average production. Any application of fertiliser is limited to these areas.

Lower blocks and where paddock subdivision is better are targeted as grazing management can support the proliferation of sub clovers[155] in a favourable season. The periodic seed set of sub clovers delivers a surge of fixed nitrogen that is important for productivity on the hill block, but these events are neither annual nor able to be anticipated with any degree of certainty.

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155 The grazing behaviour of livestock in spring is crucial to perpetuate sub clover seeding and annual regeneration. Deer grazing patterns and behaviour are well suited to the production of sub clover, with its spreading stolons not grazed or damaged as the plants grow and seed in the spring (stolons are a horizontal plant stem or runner that takes root at points along its length to form new plants). In contrast, sheep favour clover in their diets and will target sub clover runners in spring reducing the ability to set seed. As a result, the sub clover becomes sparse and, in some cases, re-seeding is needed.

Deer have been run for many years on this farm and the seeding of sub clover has created a substantial hard seed bank in the soil. In a season where rainfall is adequate, the sub clover germinates through autumn and dominates in spring fixing nitrogen and allowing a large abundance of standing feed to be pushed forward as a result. In this situation, the system has greater pasture cover and may reduce overgrazing and soil loss at similar stocking rates.

While some phosphatic fertiliser is needed to support this legume, sulphur is also likely to limit production. Tactical applications based on financial return is not new but the technology to apply the fertiliser to specific areas on hill country is advancing. In this situation, the higher application cost is likely to be countered by the pasture growth response and a slight reduction in leaching will be achieved without affecting the system overall. A cessation of fertiliser application will result in lower production and may well be forced over time as the pricing of fertiliser and the expense of its application has risen.

In the interest of maintaining farmer confidentiality, the results of this analysis are not able to be reported in full.

The completion of riparian fencing was capitalised and there was no marked impact on production. The additional debt servicing resulted in a farm profit decline of one per cent relative to base.

The major change to more efficient irrigation resulted in a ten per cent increase in farm revenue but also required a 12 per cent increase in farm working expenses. When an additional $91,000 of annual debt servicing to undertake the irrigation development was included, farm profit dropped by five per cent. Farm working expenses increased in line with extra stock carried. More winter crops were made and fed to carry the extra stock and while run off and leaching losses while irrigating would be reduced, the net effect was not tested.

Image 26: Sub-clover growth measured by a gumboot on a deer farm in Otago.
Source: Simon Glennie
Note: This photo is used to illustrate a topic relevant to this case study – it is not a photo of the case study farm in question.

3.5.5 Deer 5

This is a large specialist deer farm (91% deer stock units) with small sheep and beef enterprises. Irrigation occurs over roughly one-sixth of the farm's total area. Annual pasture production from the hills matches that from the irrigated land, with a 15 per cent contribution from lucerne and semi-developed hill. A mix of breeding hinds (mostly on hill) and finishing and trading deer are utilised to fit the pasture curve.

To improve the farm's productive efficiency, feed is shifted into winter, through the use of crops and other supplements. The additional feed allows high margin trading weaner deer for venison to be purchased in autumn and carried through winter with sufficient stock on hand to utilise a portion of the spring feed surplus. The result is high numbers of finished deer processed for premium prices in the chilled venison export season.

The farm's production system is designed around winter supplements for good reason as the winter feed deficit is very predictable due to being temperature related. Conversely, summer deficits are very unpredictable due to being soil moisture related. As rainfall is far more variable than winter temperatures, the system with least risk is one where stock demand is low when dry conditions are likely to prevail.

Around 70 per cent of winter supplements are attributable to the irrigated area with most forage crops being grazed in situ by both young stock and trading stock. The property's deep stoney fans are used for winter feeding because they are predominantly dry, and pugging is less of a concern than in other localities. However, livestock spend time on bare ground post-grazing and there is nitrate leaching from urine. Reductions in winter crop area were not considered for this farm.

Image 27: K-Line irrigation showing up as greener pasture growth on light soil.
Source: Simon Glennie
Note: This photo is used to illustrate a topic relevant to this case study – it is not a photo of the case study farm in question.

All the farm's trades, including winter lambs and beef cattle, are timed to finish going into the summer reducing the demand for feed through this season. By February, breeding hinds are consuming almost all the feed demand for the farm, which is at an annual low. The breeding hinds suit the lower stocking rate environment on the hill, offering a better fawning as long as hind body condition in autumn is not compromised and young hinds are sufficiently grown. The trading components of the production system allow this by weaners leaving the property over spring and summer allowing the best possible outcome for the hinds.

Given the importance of water in producing winter supplementary feed on this farm, two environmental actions were tested for this case study:

- Improve irrigation efficiency; and
- Reconfigure irrigation infrastructure

The FARMAX modelling relied on B+LNZ data for Farm Class 2: South Island Hill Country, rather than using the farm financials.

3.5.5.1 Improve irrigation efficiency

The environmental action tested on this farm was to improve irrigation efficiency from a K-Line system, which is not well suited to the land. K-Line irrigation is usually shifted between paddocks on a 24-hour basis with more than 14-day return periods. Where soils are shallow and 'leaky' applying water for 24 hours is excessive and can cause run off or leaching. Over 14 days, high evapotranspiration can lead to soil moisture deficits and lower growth. Using a 12-hour shift helps as some of the applied water is unable to be held in the soil profile with a 24-hour shift frequency.

On this farm, stoney alluvial soils are present on the main terrace and sizeable soil moisture deficits are evident in summer. This situation is evident in the pasture production curve for the irrigated area as well as visually.

The economics for the business of upgrading to a more technically efficient irrigation system are challenging. The pasture and crop production are expected to be improved by around four tonnes per hectare. The additional revenue from running more velvet stags is estimated at $230,000 from an extra 1,940 kg of velvet. Yet once the increase in silage and animal costs for the stags are considered, then the change is close to breakeven. Any change in labour was not included in the calculations but the shift from K-Line is expected to free up labour, which will then be used to handle the additional stock.

The cost of change is considerable. The farm's layout is not ideally suited to pivots and an original plan proposed a total of seven pivots, including five half circles that increase the cost per area of irrigation. The analysis allowed $6,500 per hectare for the pivots over 250 hectares. The largest pivot was over 95 hectares and may struggle to improve irrigation efficiency in the outer spans because of the higher instantaneous rate of application on very light soils.

The deer fencing needed to be fully re-designed along with stock water at an estimated cost of $840,000, bringing the total cost of the upgrade to just under $2.5 million (just under $10,000/ha). On an annual basis at seven per cent interest over a 40-year term, the farm pays an average of $196,000 debt servicing every year (interest and principal).

Fixed grid irrigation was also looked at and had the advantage of not having to re fence. The capital cost was greater than the pivot option and production benefits are likely to be similar.

3.5.5.2 *Reconfigure irrigation infrastructure*

An alternative environmental action tested for this farm was to make use of all the water granted through its consent and re-configure the existing infrastructure by re-purposing K-Line and including a single pivot of around 100 hectares of land. More efficient application of water under current systems and installation of efficient spray in new areas is likely to reduce the farm's nutrient loss and manage the impacts on the business. The piping of water allows precise delivery of allocated rates to scheme users, which makes the farm's water allocation (and all users) more efficient. The cost to pipe the water is high but in the longer term it improves irrigation with the potential to deliver a greater area under gravity. If hydro generation is included, then it may be possible to pump water using the farms own power and to generate from the full irrigation take over winter when no irrigation is needed.

There is also potential to integrate a sub clover system on the lower hill. This step will involve subdivision, to smaller, more manageable areas, which could also be in line with the 'fencing off' of terrace faces as higher value biodiversity sites. Stags can be used to promote the desired cover to introduce sub clover seeds and manage the plants during the first spring seed set. The result is a new area of high-quality early feed that will allow the velvet stag enterprise an added area of feed at a pinch point for the farm system.

3.5.5.3 *Deer 5 Case Study Results*

Table 28: Summary FARMAX results for Deer 5 Case Study

	Base Farm Model	Improve irrigation efficiency
Deer revenue	$833,000	$1,018,000
Sheep revenue	$20,000	$15,000
Beef revenue	$69,000	$69,000
Crop & feed revenue	-	-
Total Revenue	$921,000	$1,107,000
Total Farm Expenses*	$604,000	$727,000
EBITR	$317,000	$380,000
Interest and rent	$94,000	$208,000
Farm profit before tax	$223,000	$172,000

Note: the results in this table have been rounded to the nearest 1,000.
**Total Farm Expenses includes depreciation*

3.5.6 Case study summary results and commentary

Table 29 gives a general summary of the impacts of environmental actions across the five deer case studies discussed in Sections 3.5.1 to 3.5.5 while Table 30 summarises the specific details for each of the deer farm case studies.

Table 29: Summary of impacts of environmental actions across five deer case studies in Otago

Impacts	Reduce winter crop	Exclude hinds from gullies and extensive hill	Fence off low slope waterways	Upgrade irrigation to efficient spray
Farm profit / business viability	Moderate	High	Low (as most have complied already so impacts occurring now)	High
Other implications on farm	Business risk – more borrowed, difficulty to feed silage	Poor welfare outcomes, loss of diversification, change of enterprise or exit	High cost to replace or repair flood damage	Business risk – more borrowed, Enterprise mix change to pay
Wider industry	Enterprise mix change to velvet, industry exit and new entrant decline	Industry exit and new entrant decline	Most impacts are already being felt in the industry	Enterprise mix change to velvet, industry exit
Industry preference for policy mechanism	Certified Freshwater Farm Plans	Certified Freshwater Farm Plans	Certified Freshwater Farm Plans	-

The five deer case studies are divided into wetter rolling South Otago type properties and dry, more extensive Central Otago properties. The wetter properties typically rely on winter feed crops and fawning areas that include waterways that can be difficult to fence. Winter feed crops can be replaced by sheds and silage, but the stocking rate is typically lower and capital cost is difficult to cover without enterprise change.

Blocks with gullies that are saved for fawning are impractical to fence and are typically used over the November to January fawning period where they can be stocked lightly. Feed covers and good pasture growth during this time reduce the risk of adverse effects on water quality and provide very good stock welfare outcomes through natural shelter and less disturbance. The seasonal nature of the use and value to the farm system make them well suited to being considered in certified farm plans, where stock crossings, sediment traps and strategic periodic exclusions can be detailed.

The more extensive Central Otago farms have two main areas of concern. The hill areas are usually very lightly stocked and in low rainfall areas where effects on waterways tend to be minimal. The financial cost of fencing these areas is prohibitive and, in many cases, not possible because of the challenging terrain. Exclusion of deer and replacement with sheep is a possible option but was not favoured by the case study farmers due to the different grazing habits of sheep and the additional skills and infrastructure needed. Certified Freshwater Farm Pans with regular water quality tests and management options, including periodic exclusions, are likely to help minimise the impacts for these farms.

Irrigation upgrades are expensive and in each of the deer case studies, the increase in costs (interest, depreciation, and variable costs) was greater than any additional revenue. While there may be water quality benefits where it reduces nitrogen losses, there is risk for the business, particularly where existing farm debt and cash flow mean a farm is more vulnerable. For farms that rely on irrigation for winter crops, a reduction in available water will likely result in reduced deer numbers, because there is less crop to carry livestock, and a less viable farming business.

In all situations, there was an underlying assumption that the same quantity of water was used, but it was used more efficiently. The use of spray irrigation reduces the loss of water through the soil profile and at the same time, reduces soil moisture deficit between irrigation events. The result is more pasture production, more livestock, more revenue and while a similar amount of water is irrigated, inefficient overwatering (and associated leaching) is removed. However, the results of the case studies show that the cost to change to efficient spray proved too great to fund by the increase in production alone.

In Deer 3 where border dykes are changed to spray irrigation, there is a shift of land use where heavier soils previously irrigated by borders become dryland and some lighter soils that were previously dryland can be irrigated efficiently. The wetter, deeper soils that become dryland still perform due to good natural moisture holding, and the light soils becoming irrigated is useful in funding the upgrade. Less water is needed to fully irrigate the same area, but the additional area of irrigation is used to help pay for the investment.

In the instances where the deer enterprise is a relatively small part of a larger, diversified business, the easiest option may be to remove deer altogether from the system. For the wider deer industry, the prospect of a herd reduction or the loss of smaller operators is exacerbated by the concurrent barrier to new entrants through the same issues. New entrants are essential to hold numbers where farmers exit the industry for other reasons, such as retirement and aging infrastructure. Nationally, the venison enterprise is already under pressure because of the relative profitability of velvet stags, and continuing declines in sale volume has the potential to impact economies of scale in processing and marketing of the venison crop.

The five case studies described here are largely simulating responses to environmental actions that are either required by recent policy changes or may be required in the future. As such they show the impacts of an action rather than the impacts of addressing risks. There are many industry good management practices that can be put in place to achieve similar or even better environmental outcomes, while maintaining the viability of the farm business. These practices can be described and documented in a certified Freshwater Farm Plan, along with measures of success in contributing to environmental outcomes.

3.6 Research Findings

Within each of the case studies, adaptive changes to the farm systems are likely to have wider implications for the deer industry and Otago. In this research it was assumed that the industry will be in a position to provide what is needed, be it knowledge, infrastructure, labour or availability of stock. However, the deer industry is particularly vulnerable to adaptive changes as the already reduced regional herd is affecting economies of scale and it needs a critical mass to maintain value chains.

There are already indications on-farm that breeding hind numbers are under pressure as farmers consider the implications of the National Environmental Standards for Freshwater and Stock Exclusion Regulations. On minority deer farms or sheep and beef farms with a deer enterprise, it is the deer enterprise that is increasingly likely to be disposed of or drastically modified due to high costs of fencing, establishment of winter sheds, or upgrading irrigation.

There are situations where deer are ideally suited to farm environments. Of the five case studies there were four examples of hinds on uncultivatable hill country areas during fawning. Fawning coincides with summer where growth exceeds demand, and deer survival and welfare are enhanced through access to gullies and a more natural environment at lower stocking rates. The current trend to increase velvet stags at the expense of breeding hinds may increase wallowing behaviours in some situations.

Table 30: Specific summaries for five deer farm case studies in Otago

Case Study	Environmental Action Tested	Change in Farm Profit (EBITR)	Notes
Deer 1: 87% deer stock units Smaller farm	Reduced winter grazing Result: less deer on farm.	-$25,000 (-12%)	Change from 50 tonnes of fodder beet to 100 tonnes of grass silage, lower stocking rate.
Venison breeding and velvet Steeper cultivated land in higher rainfall area – intensive winter grazing risk.	Winter shed for 220 weaners Result: less deer on farm.	+$25,000 (+12)	Result is fewer hinds and more stags on farm. $163,000 borrowed and repaid over 20 years at 7% interest. Extra labour unit needed but not included in financial analysis Conditional on access to capital.
Deer 2: 13% deer stock units Medium-large farm Mixed finishing and breeding	Remove hinds from fawning gully for stock exclusion from stream Result: less deer on farm.	+$32,000 (+37%)	Roughly 30% of deer unit is in gullies, half hinds mob replaced with sheep. Poorer welfare outcomes for remaining deer.
Pugging risk in winter, deer access to waterways in gullies.	Winter shed for 600 hinds with careful gully use Result: static deer numbers.	-$33,000 (-38%)	$421,000 borrowed and repaid over 30 years at 7% interest. Plus sediment traps and strategic exclusion fencing.
Deer 3: 26% deer stock units Flat farm with some irrigation	Fencing to exclude deer from water Result: less deer on farm.	-$13,000 (-9%)	Recycled deer fencing from new pivot area, 8 ha grazing lost. $183,000 borrowed and repaid over 40 years at 7% interest.
Unfenced ponds and waterways, inefficient border dyke irrigation.	Upgrade to more efficient irrigation Result: less deer on farm.	-$17,000 (-12%)	2 pivots, earthworks, re-fencing/pasture, system optimisation. $1.2 million borrowed and repaid over 40 years at 7% interest. Deer breeding unit removed from farm.
Deer 4: Over 90% deer stock units Large farm with some irrigation	Riparian management on remaining low slope land Result: static deer numbers.	-$8,000 (-1%)	Exclusion and riparian planting on low slope flats, no real change in grazeable area. $183,000 borrowed and repaid over 40 years at 7% interest.
Access to hill block waterways, hill block sub clover system, small amount of exclusion fencing on low slope land.	Upgrade to more efficient irrigation Result: more deer on farm.	-$42,000 (-5%)	Water storage and fixed grid irrigation system, more winter grazing for additional livestock. Intensive flats are only 7% of land area but generate half of the feed eaten on farm. $2 million borrowed and repaid over 40 years at 7% interest.
Deer 5: 73% deer stock units Large farm with some irrigation on well-drained soils.	Upgrade to more efficient irrigation Result: more deer on farm, enterprise shift to velvet stags.	-$51,000 (-23%)	Irrigated flats needed to grow large proportion of winter feed for weaners, replace K-Line with 7 pivots over 250 ha, re-fence and new stock drinking water system, more velvet. $2.5 million borrowed and repaid over 40 years at 7% interest.

Observations of deer grazing behaviour show the browsing of grassland can favour the retention of biodiversity. The interaction of deer with water is more like sheep than cattle even though deer and cattle are often treated in a similar way in stock exclusion regulations. In extensive situations, fence pacing is often minimal and, when noted on the case study farms, it occurred on the cultivated areas where paddocks are smaller and contain less natural cover. At times when hinds are in larger mobs on hill country, they are very mobile and spread throughout a block.

Deer are a 'top down' browser like beef cattle and less likely to overgraze than sheep, tending to eat more evenly over blocks when feed is in good supply. In the extensive grazing blocks observed in the case study farms, the grazing of deer was well understood and the visual effects on waterways appeared to be minimal. Hinds were able to perform well with large feed mass carried into winter and again available at fawning. This deferred grazing may reduce the potential for soil loss.

The sub clover system in Deer 4 is a prime example of the advantages of deer grazing. Deer have been run for many years and the seeding of sub clover has created a substantial hard seed bank in the soil. In a season where rainfall is adequate, the sub clover germinates through autumn and dominates in spring fixing nitrogen and allowing a large abundance of standing feed to be pushed forward as a result. In this situation, the system has greater pasture cover and as such, has the ability to reduce overgrazing and soil loss at similar stocking rates.

In Deer 5, the farm's production system is designed around winter supplements because the winter feed deficit is very predictable as it is temperature related. Conversely, summer deficits are very unpredictable due to being soil moisture related. As rainfall is far more variable than winter temperatures, the production system with lowest risk is one where stock demand is low when dry conditions are likely to prevail.

Image 28: Boundary deer fence with track, Glen Dene Station, Lake Hawea.
Source: Tony Pearse
Note: Deer fencing in hill country usually needs the development of the farm track alongside it.

4 Arable Cropping

Authors: Abie Horrocks (Research Manager – Environment, Foundation for Arable Research) with contributions from Chris Smith, Ivan Lawrie and Andrew Pitman (Foundation for Arable Research). This chapter is based on in-depth analysis[156] by Macfarlane Rural Business[157] of primary research for arable farms in Otago. That primary research was completed by the Foundation for Arable Research within the MPI Farm Monitoring and Benchmarking Project[158]. Editorial oversight by Emma Moran (EM Consulting).

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4.1 Summary

Continuous, flexible crop rotations that extend over a period of years, and the combination of crop and livestock enterprises within a production system make research on arable farming extremely challenging. This chapter reports on the characteristics of a sample of 16 commercial arable farms in Otago that the Foundation for Arable Research surveyed as part of the MPI Farm Monitoring and Benchmarking Programme. It then looks in-depth at four case study farms selected from this sample to test the impacts of environmental actions.

'Steady state' farm models were created to help manage the complicated task of modelling each farm's arable crop rotations (with various levels of livestock integration) over multiple years. These models were then adjusted to make sure the farms complied with current environmental actions stemming from recently introduced regional plan changes and national regulations. They were then used to test the impacts of the most relevant additional action for each of the four case study farms (one per farm). The four environmental actions tested were:

1. Changes in nitrogen fertiliser regime
2. Overland flow management options
3. Variable rate nitrogen capability
4. Management of winter grazing options

A key finding of this research was that a flexible approach, based on a risk assessment that matches environmental actions to risks, had fewer impacts on the farm business than a fixed approach. A flexible approach utilised rotation as a mitigation tool. Rotations are an important tool in arable farming because although the crops grown need to be marketable, the rotation itself is used to manage a range of agronomic and environmental issues within a farm's physiographic constraints.

A comparison of the impacts on a case study farm of a fixed approach and a flexible approach to manage overland flow resulted in over a seven per cent difference in the reduction in profitability compared to the steady state. A comparison of a fixed and flexible approach on a case study farm looking at winter grazing showed over a 32 per cent difference in the reduction in profitability compared to the steady

156 This analysis was funded by ORC.

157 Macfarlane Rural Business (MRB) is a farm advisory company based out of Ashburton in Mid Canterbury, New Zealand. https://www.mrb.co.nz/

158 https://www.mpi.govt.nz/funding-rural-support/farming-funds-and-programmes/productive-and-sustainable-land-use/

state. These results are expected to differ depending on the business because of the diversity in arable farming in Otago. The benefits of robust risk assessments are that mitigations can be targeted to give the most desired environmental outcome for a farm.

The suitability of using technologies that allow for variable rate application of fertiliser was shown to vary depending on economies of scale. The impact of reducing nitrogen application rates where it is already being applied efficiently will also depend on the business (absolute nitrogen rates do not correlate well with nitrogen surplus on arable farms). For the case study farm looking at adjustments in the nitrogen regime (for all crops on that farm in one year), an eight per cent reduction in nitrogen application rates (on average) resulted in reaching the break-even point for growing that crop (beyond which it is grown at a loss).

The impact of not being able to apply nitrogen fertiliser in September to spring sown crops was financial unviability for these crops even without any rate reductions. An unintended consequence might be that it inadvertently encourages farmers to apply fertiliser prior to 1st March to 'front load' before winter when they are 'allowed' to apply nitrogen. Although environmentally risky due to risk of nitrogen leaching over winter, their hope may be that the nitrogen will still be available in the soil to support strong spring growth necessary to optimise yields.

Other than a farmer's skills, there is no simple explanation for a farm's viability as a business or its environmental footprint. In the worst-case, the impacts may push arable farmers in Otago towards pastoral farming, either through land sales and purchases. The outcome may be a loss of diversity in land uses and critical skills in the region. The impacts are likely to flow on to other industries dependent on arable cropping. The experience overseas is that many cropping industries have become less integrated with livestock, and although this may simplify management, it has generated new challenges (e.g., related to weed management and soil quality).

4.2 Introduction

The Foundation for Arable Research estimates that there are close to 100 commercial arable farms in Otago, each with their own individual crop rotations and (in most cases) a mix of crop and livestock rotations (Horrocks, 2022). These farms grow many (but not all) of the arable crops in the region as well as some of the forage crops used to graze livestock over the winter months. The area of crops harvested in Otago reported in the StatsNZ 2017 Agricultural Production Census[159] was around 23,000 hectares (or roughly 8% of arable land in New Zealand). The area of forage brassicas and lucerne was on a similar scale. This current extent of arable farming is far less than it once was in Otago, and it only partly indicates the central importance of the industry within the agricultural sector (Horrocks, 2022).

159 There is some evidence to suggest that the area of crops harvested may have changed markedly since 2017 (Horrocks, 2022). However, at the time of writing, the 2017 Agricultural Production Census was the latest finalised census released. The 2022 provisional Agricultural Production Census was available but is based on data from 67% of expected respondents, a lower response rate than usual (in the 2017 census it was 84%). This response rate has impacted on the accuracy of the release, compared with previous years. StatsNZ is working with data received since mid-November 2022, and to better understand the quality of all the data for the final agricultural production statistics release, which will be published on 5 May 2023. https://www.stats.govt.nz/information-releases/agricultural-production-statistics-year-to-june-2022-provisional/#:~:text=The%202022%20provisional%20agricultural%20production,release%2C%20compared%20with%20previous%20years.Accessed 8/2/23

This chapter reports on a sample of 16 commercial arable farms from across Otago that the Foundation for Arable Research surveyed for the MPI Farm Monitoring and Benchmarking Programme. Four farms from this sample were developed as case studies using modelling and analysis by Macfarlane Rural Business. The next section summarises the methodology used in this research. Sections 4.4 and 4.5 are an overview of the 16 arable farms and more in-depth analysis of the four case study farms. The final section reports the findings of this research and their relevance to freshwater management in Otago.

4.2.1 Waitaki (North Otago)

Arable farms in this district are mixed, but typically have a higher proportion of income derived from arable crops than livestock. Grains are usually sold into the feed market (poultry, dairy, pig) within the Otago Region. Partly irrigated farms in the Waitaki District typically grow some greenfeed used for finishing of sheep and beef classes or sold to dairy farmers.

4.2.2 Queenstown Lakes / Central Otago (Central Otago)

Arable farms typically have fairly recent irrigation developments in a historically dryland area. At around 600 millimetres average rainfall per year, dryland arable farms in these districts would encounter yield plateaus as soil moisture runs out in December. Recent irrigation developments have led to high livestock stocking rates (whether red meat/finishing, or dairy support systems) where landowners are looking to increase the arable crop proportion of their farms overall. While arable farms in these districts are mixed, they tend towards a higher proportion of income derived from livestock rather than arable crops. Grains are usually sold into the feed market (poultry, dairy, pig) within the Otago Region. Irrigated farms in Central Otago would typically have short-term pasture and grow summer and winter greenfeed that would be used for finishing of sheep and beef classes or sold to dairy farmers.

4.2.3 Clutha (South Otago)

The income of arable farms in the Clutha district is driven by grain production, allowing an economy of scale to target investment on specific plant and machinery. Growing livestock feed is still part of the rotation, but may be exported off farm (e.g., bales), or sold to other farmers whose livestock grazes in-situ on the farm. Many farms graze beef or dairy cattle over winter, but in relatively small areas as they prefer to minimise soil quality impacts such that grain and seed yields (i.e., their core business) can be maximised.

These types of farms are on ‘rolling’ topography. In terms of farm policies this means livestock, and therefore pasture, are still an important part of the farm system. While these farms are considered mixed, they have a higher proportion of income derived from livestock compared to the other three model farm types. These farms often supply supplementary feed and grazing to the dairy market.

4.3 Methodology

The Foundation for Arable Research surveyed 16 commercial arable farms in Otago in 2022 to collect financial and environmental data as part of the MPI Farm Monitoring and Benchmarking Programme. This data included financial accounts, Overseer files ((V6.4.3 (4.3.3.3)), and Farm Environment Plans. In addition, farmers were interviewed to gain their thoughts on what they see as the catchment environmental issues where they farm and how they would characterise arable farming, both in their catchment but also across Otago.

With close to 100 commercial arable farms in the region, the sample of 16 farms from the MPI Farm Monitoring and Benchmarking Programme equates to roughly 16 per cent of the industry in Otago. These farms totalled just over 6,000 hectares of the land planted in arable crops (including forage brassicas and lucerne) in 2020-21. Within the sample, eight farms were in South Otago, seven farms were in North Otago, and one in Central Otago (this farm is included in the North Otago group).

The number of farms sampled in each region represented regional distribution of arable farming in Otago where most cropping farmers are situated in North Otago and South Otago (Lower Clutha Rohe) with a smaller proportion in central/west Otago. Table 31 gives results for a set of key metrics as averages for the 16 arable farms. However, each arable farm is completely distinct, and none are likely to come close to fitting more than one or two of these results.

Table 31: Average results across key metrics for a sample of 16 arable farms in Otago 2020-21

Geographic area	Farm size (total ha)	Effective area (ha)	Non-effective area (ha)	Average annual rainfall (mm)	Synthetic nitrogen fertiliser use (effective ha)	Nitrogen surplus (Overseer) (kg/ha/yr)	Nitrogen loss to water (Overseer) (kg/ha/yr)	Crop cash income (% of Gross Farm Revenue)
South Otago	398	361 (91%)	38 (9%)	863	94	59	35	57
North Otago	411	388 (94%)	23 (6%)	572	130	77	32	64
Otago	405	374 (93%)	31 (8%)	718	112	68	34	61

The national definition used in the MPI Farm Monitoring and Benchmarking Programme for arable farms was “at least 50 per cent of income comes from cropping”. However, this definition was not well suited to Otago where there is so much integration between cropping and pastoral. Only a small number of large cropping farms are solely oriented around cropping (with many others more aligned with pastoral sectors but still growing sizeable areas of crop). Therefore, farms were selected to represent the range of integration (Figure 48) as well as the spread of dryland and irrigated farms (both farms that have recently converted to having irrigation and those that have been under long-term irrigation). The farm sample is described in more detail in Section 4.4.

From the sample of 16 farms, the Foundation for Arable Research selected four farms to develop as case studies (identified within Figure 48 as A1, A2, A3, and A4). This research was led by the Foundation for Arable Research and involved farm modelling carried out by Macfarlane Rural Business. Continuous, flexible crop rotations that extend over a period of years and the combination of crop and livestock enterprises within a production system make arable farming extremely complex and diverse. These features make any research task for the arable industry particularly challenging.

The total number of farm case studies was limited to four, despite the diversity in arable farming, because of the effort involved where there is a high level of complexity. In selecting each farm, the main consideration was to reflect the broad distribution of arable farming in Otago. Two other considerations were to capture both dryland and irrigated farms, and to cover the varying degrees of integration with livestock farming typical in Otago. While the case studies are fairly typical of certain types of arable farms, a much larger set of farm types is needed to come close to fully representing the industry as a whole.

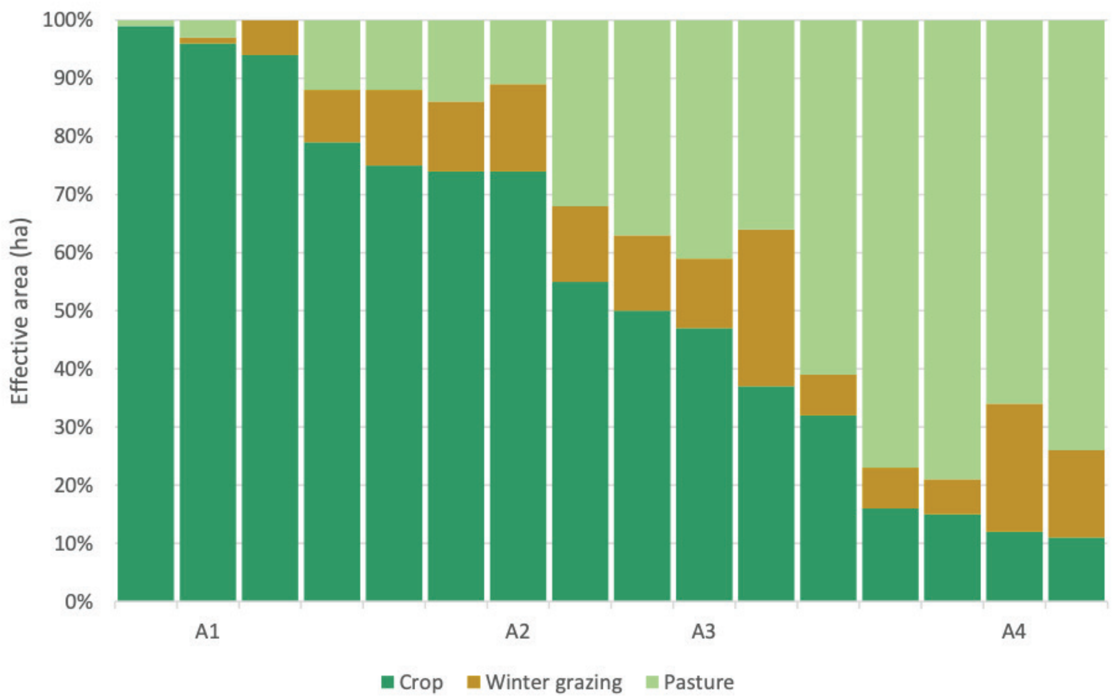

Figure 48: Proportion of arable crop sown on 16 arable farms in Otago 2020-21.
Note: The farms selected as case study farms (Arable 1-4) are identified on the horizontal (x) axis.
Source: Foundation for Arable Research

The four case study farms (described in Section 4.5) are referred to as:

- Arable 1 – Mixed, predominately arable (partly irrigated)
- Arable 2 – Mixed, predominately arable (dryland)
- Arable 3 – Mixed, an even mix of arable and pasture (dryland)
- Arable 4 – Mixed, some arable (mostly irrigated)

The Foundation for Arable Research chose Macfarlane Rural Business to model the impacts of environmental actions on these four farm businesses because of their local experience and existing investment in analytical tools relevant to the arable industry. In general, the modelling was a detailed desktop exercise (i.e., without specific farm visits) but the farms were known to MacFarlane Rural Business through other work. The modellers were supplied with financial data, base Overseer files, and Farm Environment Plans, and they liaised with the farmers and the Foundation for Arable Research to gain further information where needed.

Macfarlane Rural Business undertook the modelling task in two main parts, which are described in Sections 4.3.1 and 4.3.2. Part 1 developed 'steady state' farm models and, where necessary, made sure ***current environmental actions*** were in place to meet recent policy changes. Part 2 focused on understanding the impacts of possible additional ***possible additional environmental actions*** relevant to the development of Otago Regional Council's proposed Land and Water Regional Plan.

4.3.1 Current environmental actions

In Part 1 of this research, Macfarlane Rural Business created 'steady state' farm models to help manage the complicated task of modelling each farm's arable crop rotations (with various levels of livestock integration) over multiple years. More specifically, these 'steady state' farm models were detailed farm management and financial analyses developed using existing arable farm financial spreadsheets alongside FARMAX[160]. FARMAX is evidenced-based computer software that is used to monitor livestock feed demand and performance against feed supply on a monthly basis. The 'steady state' farm models closely aligned with, but were not identical to, each of the farms on which they were based (Arable 1-4).

Assumptions of crop and livestock prices and various expense items were based on everyday-working knowledge of mixed arable farms. Rather than current market prices (at the time of writing), prices and expenses used were a medium-term 10-year average that are more relevant to the steady-state (status-quo) situation that the models were based on. Livestock programmes were based on discussions with the farmer and then modified to match the supply of feed provided by the steady-state rotation.

For permanent fences, lamb-proof cyclone netting fences were costed at $18 per metre, allowing for a high proportion of posts, strainers, and angle-stays, to allow for the fact that the CSAs seldom involved long straight-line fences. For temporary electric fencing three-wire 'lamb-proof' temporary electric fencing were costed at $1.76 per metre.

160 FARMAX is a modelling and decision support tool that AgResearch launched in 2003 for pastoral farmers in New Zealand following 20 years of development. The tool allows the user to build a model of a unique farm system and use it to record actual farm performance data, forecast future expectations and investigate potential changes to the farm system. It is now owned by FarmIQ. http://www.farmax.co.nz/

Once the 'steady state' farm models were built, they were then adjusted to make sure the farms complied with current environmental actions stemming from recently introduced regional plan changes and national regulations (i.e., recent policy changes) as of mid-2022. More specifically, changes relating to the farm system and infrastructure on-farm were assessed and reworked to implement rules and regulations (as a bundle) included in the Regional Plan: Water for Otago, National Environmental Standards for Freshwater 2020 (NES-F), Stock Exclusion Regulations 2020, and National Policy Statement for Freshwater Management (NPS-FM). The impacts from Part 1 are not the full impacts of the recent policy changes because each of the four case study farms were at different stages of implementing the required actions.

The modelling task included:

1. Various detail and assumptions regarding crop management and financial budgets;
2. Farm physical and economic performance, before and after recent policy changes, and the various impacts to the businesses;
3. Steady-state (status-quo) cash budget detail for each farm, before and after policy changes;
4. Key financial indicators, including EBITR and EBITRD[161] for comparison of pre and post policy changes, and for comparing the scale of relative change for each farm, and between farm types; and
5. Return on capital and estimated asset value, before and after policy changes. The change in Return on capital associated with the actions was calculated and the relative asset value loss to maintain 'steady state' return on capital was determined.

4.3.2 Additional environmental actions

The research outputs from Part 1 were then used in Part 2 to test the impacts of the most relevant additional action for each of the four case study farms (Arable 1 to 4). The four environmental actions tested on the four case study farms (one per farm) were:

1. Changes in nitrogen fertiliser regime
2. Overland flow management options
3. Variable rate nitrogen capability
4. Management of winter grazing options

161 EBITR= Earnings before interest, tax and rent. EBITRD= Earnings before interest, tax, rent and depreciation (where rents are short and long-term lease transactions for the farm business).

4.3.2.1 Changes in nitrogen fertiliser regime

This environmental action was tested on ***Arable 1 – Arable, some livestock (partly irrigated).***

Arable 1 was already applying nitrogen fertiliser efficiently (using tools such as soil testing and variable rate applications). The purpose of this action was to analyse:

- the extent to which nitrogen fertiliser reductions could be made before it was no longer financially viable to grow each crop (the profit bottom-line became breakeven); and
- what impact a nitrogen fertiliser withholding period between 1st March to 30th September would have on yields and profitability.

Nitrogen fertiliser application rates and timings were adjusted crop-by-crop (relative to yield expectation while considering amounts of plant available nitrogen already in the soil) and the resulting reduction to crop and livestock performance was modelled. In this case, the crop rotation was kept the same, but the yields and livestock carrying capacity were adjusted. The amount the crop yields were adjusted by was based on agronomic knowledge of input/outputs (nitrogen mass balance budget) of relative crop offtake to nutrient amount (from the literature and expert opinion).

4.3.2.2 Overland flow management options

This environmental action was tested on ***Arable 2 – Predominately arable (dryland).***

This environmental action built on the outputs of Part 1 for Arable 2 where a 3-metre setback of permanent fences from the edge of waterways was tested as part of the current environmental actions ('steady state + recent policy'). This was compared to a fixed approach and a flexible 'risk assessment' approach.

The fixed approach modelled a permanent setback area (with no pasture, forage or grain and seed crops drilled within the setbacks) of ten metres where the adjacent land has a slope of less than or equal to 10°, and 20 metres where the adjacent land has a slope of greater than 10°. For permanent fences, it was assumed the farmer uses lamb-proof cyclone netting fences costing $18 per metre with a high proportion of posts, strainers, and angle-stays, to allow for the nonlinear nature of the waterways. In the fixed approach, the crop rotation had to be adjusted as did the yields and livestock carrying capacity. The FARMAX model was modified to reflect the reduction in effective area and feed produced, and this had a direct impact on the number of livestock farmed. There was no change in nitrogen application per hectare, however, the total area of nitrogen application was reduced in proportion to the reduction in effective land area.

The flexible approach modelled increasing the permanent setback from three metres to five metres from waterways and qualitatively discussed customised additional actions that could be identified via a farm plan and risk assessment. These may include identifying areas where setbacks need to be greater than five metres. Other actions that fit the scale and character of the risk would be identified from a tool kit of mitigations (interception drains, culverts, diversion bunds, benched headland, swales, sediment traps, silt fences etc).

4.3.2.3 Environmental Action 3 – Variable rate nitrogen capability

This environmental action was tested on ***Arable 3 – Even mix of arable and pasture (dryland)*** and was carried out internally by FAR.

This environmental action aimed to determine how the suitability of variable rate technologies is affected by economies of scale. It carried this out by looking at the suitability of investing in variable rate nitrogen capability on two farms with different areas in crop (102 ha for Arable 3 and 429 ha for Arable 1).

Most fertiliser spreaders sold in New Zealand have variable rate (VR) ability in some form. Five options were costed depending on varying levels of infrastructure that may already be available on farm. These options were:

- The grower has GPS in the tractor already and just needed to purchase N Sensor technology.
- The grower has a VR capable spreader but needs GPS and N Sensor technology.
- The grower has GPS on his tractor but needs to upgrade his spreader and purchase N Sensor technology.
- The grower needs to upgrade his spreader, purchase GPS and N sensor technology.
- The grower is going to apply VR fertiliser from prescription application maps not using N Sensor technology but needs a VR capable spreader and GPS.

Depending on site variability, the reduction in fertiliser use from adopting VR technology has been shown to range between four and 37 per cent (Fastellini & Schillaci, 2020). The first four options were based on a 14 per cent reduction in nitrogen fertiliser use, while the fifth was based on ten per cent reduction in nitrogen fertiliser use. Calculations were made on actual grower application rates for all crops on both case study farms. The saving was calculated on the savings in product per hectare over the total area the technology could be used for on the two case study farms. The number of years for each farm to repay this investment was then calculated by dividing the cost of the investment by the annual saving.

4.3.2.4 Environmental Action 4 – Management of winter grazing options

This environmental action was tested on ***Arable 4 – Mixed, some arable (mostly irrigated).***

This environmental action built on the outputs of Part 1 for Arable 4 where a steady state farm was modelled. This steady state was then adjusted in one of two ways. Firstly, it was adjusted so the farm operated as a fixed 'permitted activity' approach). Secondly, adjustments were made to accommodate a flexible 'risk assessment' approach where effects were mitigated either via the consent process or with an audited farm environment plan (which was assumed to have the same administration cost).

The set of permitted activity conditions were based on (but not identical to) a recent Environment Court decision on the Southland Water and Land Regional Plan. The permitted activity was assumed to include:

- Not more than 50 hectares or ten per cent (whichever is the greater) of the effective farm area is sown in annual forage crops.
- Brassica forages are under sown with species that can regrow to maintain ground cover.
- Stock is excluded from critical source areas (CSAs) during grazing of annual forage crops. ten metre setbacks on land less than 10° slope.
- 20 metre setbacks on land more than 10° slope.

The permitted activity approach was achieved by removing fodder beet from the rotation. It was also achieved by keeping 26 hectares of triticale sown after wheat for silage rather than grazing and changing the sowing of milling oats to autumn rather than spring (following maize in the same way spring oats followed fodder beet). The permitted activity conditions resulted in a reduction of winter grazing areas from 156 hectares to 50 hectares (-68%). The area no longer in forage crops was replaced with silage maize, milling oats, and silages. The reduction in both winterfeed area and crop yields resulted in a sizeable reduction in livestock farmed. Management was adjusted so there was an understorey that resulted in constant ground cover.

The risk assessment approach focused on managing adverse effects. It aimed to maintain the use of the rotation as an important tool for weed and disease management and made alterations to grazing management so that sediment loss risks were managed.

The risk assessment approach made the following changes to the steady state farm model:

- 10 metre by 10 metre grassed CSA termination points (to capture sediment contained in runoff from winter grazing from entering waterways), back fencing, portable water troughs and down-gradient grazing management.
- Reduced the winter grazing area by just over three hectares.
- Excluded livestock from additional CSAs, which equated to 2.4 per cent of the effective area of the farm (the major critical sources areas on farm already excluded from arable crops).
- The terminal sections of some awkward ‘gully’ type paddocks were kept in forage crop over winter to complete a ‘last bite’ of that area at the very end of the grazing period, immediately before establishing the next crop. In this way an overland flow buffer is maintained.

CSAs were managed with temporary electric fencing when in forage crops for grazing. This fencing would be removed when those areas were established in grain and seed crops or pasture during the rotation. For temporary electric fencing it was assumed the farmer uses 3 wire ‘lamb-proof’ fencing costing $1.76 per metre. The temporary fencing removed just under seven hectares from the potential winter grazing area and included approximately 728 metres of temporary fencing at a cost of $1,764 (includes an extra labour component).

Image 29: A young barley crop in December, Māniatoto.
Source: Emma Crutchley

4.4 Arable Farm Sample

There is a high degree of flexibility in cropping rotations, even for those farms in close proximity to each other, and it is challenging to attempt to describe a typical arable production system. The 16 Otago arable farms in the MPI Farm Monitoring and Benchmarking Programme in 2020-21 were all well-established mixed growing operations with varying degrees of livestock integration in their crop rotations (Figure 48 in Section 4.3). This section explores the biophysical and farm management characteristics of the farm sample, including their financial position.

4.4.1 Farm biophysical characteristics

The starting point for all arable production systems is the nature and extent of the land and the local climatic conditions.

An arable farm's total area consists of its 'effective' area and its 'non-effective' area. The average total farm size in the sample 16 farms was just over 400 hectares, although it ranged from around 200 hectares to well over 700 hectares. The effective area for these farms was around 93 per cent and non-effective area was seven per cent. Figure 49 shows the range in size of growing area across the sample, with the reasonably even distribution indicating the high quality of the sample. Growing area rather than total area and a maximum size of 700 hectares is reported to help maintain confidentiality.

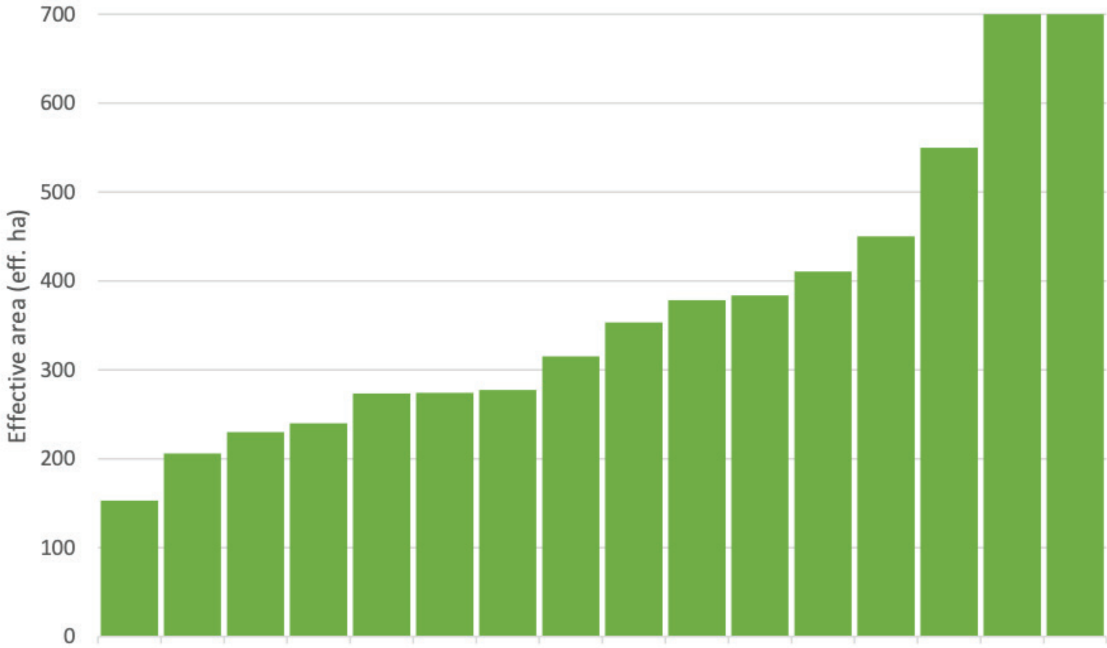

Figure 49: Production area of 16 arable farms in Otago in 2020-21
Source: Foundation for Arable Research

Of the sample of 16 arable farms in Otago, only five farms are located entirely on flat land (most of these farms are in North Otago). Six of the farms include easy hill country, and three farms also include steep hill country. For farms with hill country, arable crop rotations are most likely to occur on the parts of the farm that are more easily cultivated. Figure 50 indicates the variation in topography across the sample of 16 farms.

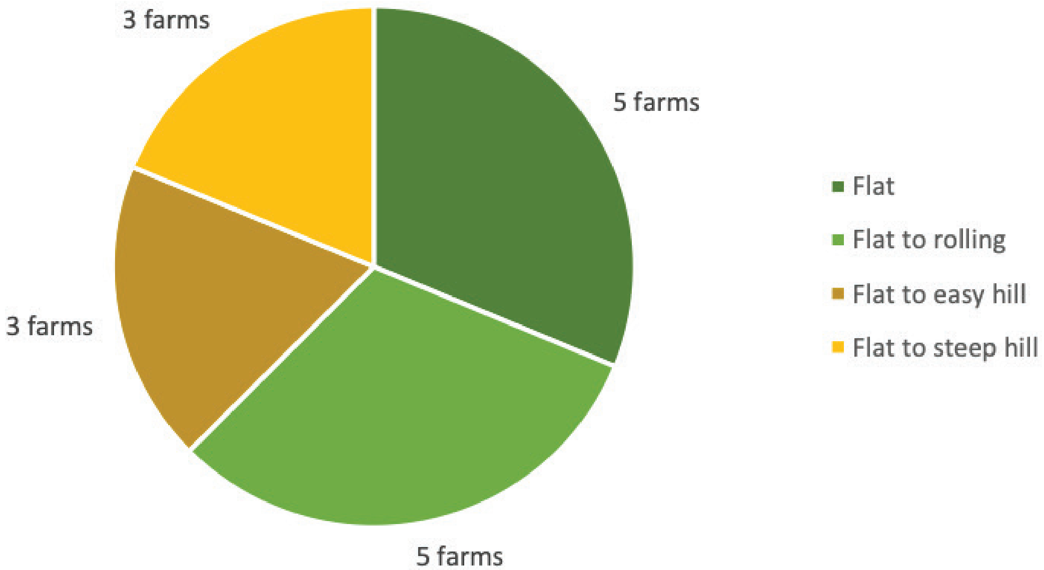

Figure 50: Topography of 16 arable farms in Otago in 2020-21
Source: Foundation for Arable Research

As with topography, there are marked differences in natural soil drainage between arable farmland in South Otago (Figure 51) and that in North Otago (Figure 52). On average, the eight South Otago farms tend to have a roughly equal mix of 1) poorly drained, 2) imperfectly drained and 3) moderately well to well drained soils. However, there is strong variability even within this sample, with four farms having little to no well (or moderately well) drained land and four having little to no poorly drained land (i.e., 10% or less). The eight farms in North Otago are, on average, likely to be two-thirds moderately well to well drained, while the remainder of the farm is imperfectly drained and possibly poorly drained. Again, the sample points towards variability, with five of the eight North Otago farms being almost entirely well drained or moderately well drained land (i.e., more than 80%).

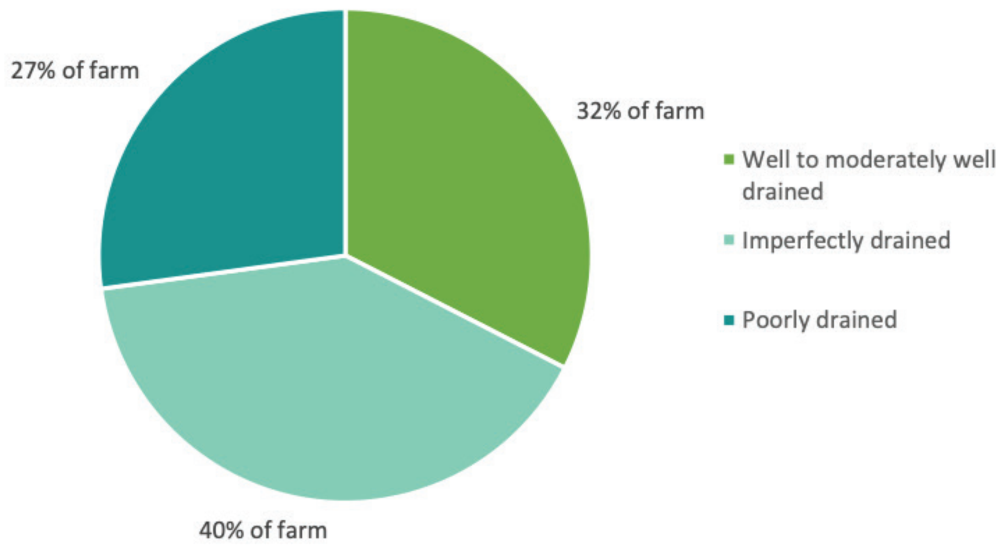

Figure 51: Average mix of soil drainage for 8 arable farms in South Otago in 2020-21
Source: Foundation for Arable Research

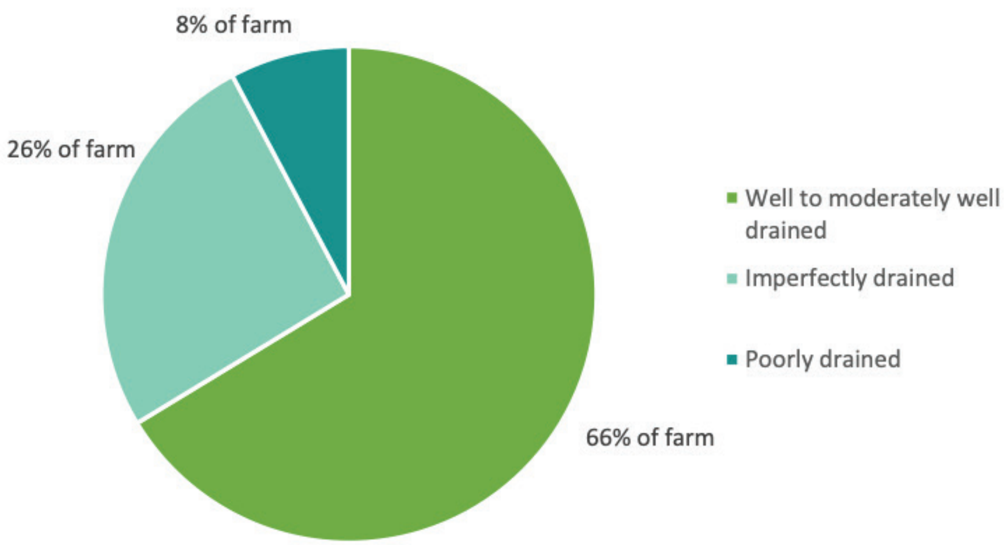

Figure 52: Average mix of soil drainage for 8 arable farms in North Otago in 2020-21
Source: Foundation for Arable Research

4.4.2 Farm management

A central characteristic of a mixed arable farm is its combination of crops and pasture with varying degrees of more intensive winter grazing within its production system. The 16 arable farms in the sample ranged from almost entirely cropping through to predominantly pastoral, as was shown in Figure 48 in Section 4.3. Within the area sown in crop for each farm, including the area used for winter grazing, there is an extremely broad range of crops and varietals. At least 36 different crops were grown on the 16 farms in 2020-21 (Figure 53). The most common crops grown on these farms at the time are shown in Figure 54 (noting that frequency and extent of a crop is not necessarily indicative of its value). The pasture and winter grazing components of a farm are used to raise and graze livestock, and may either be part of the rotation and/or sit outside of the rotation (e.g., on steeper slopes that cannot be cropped).

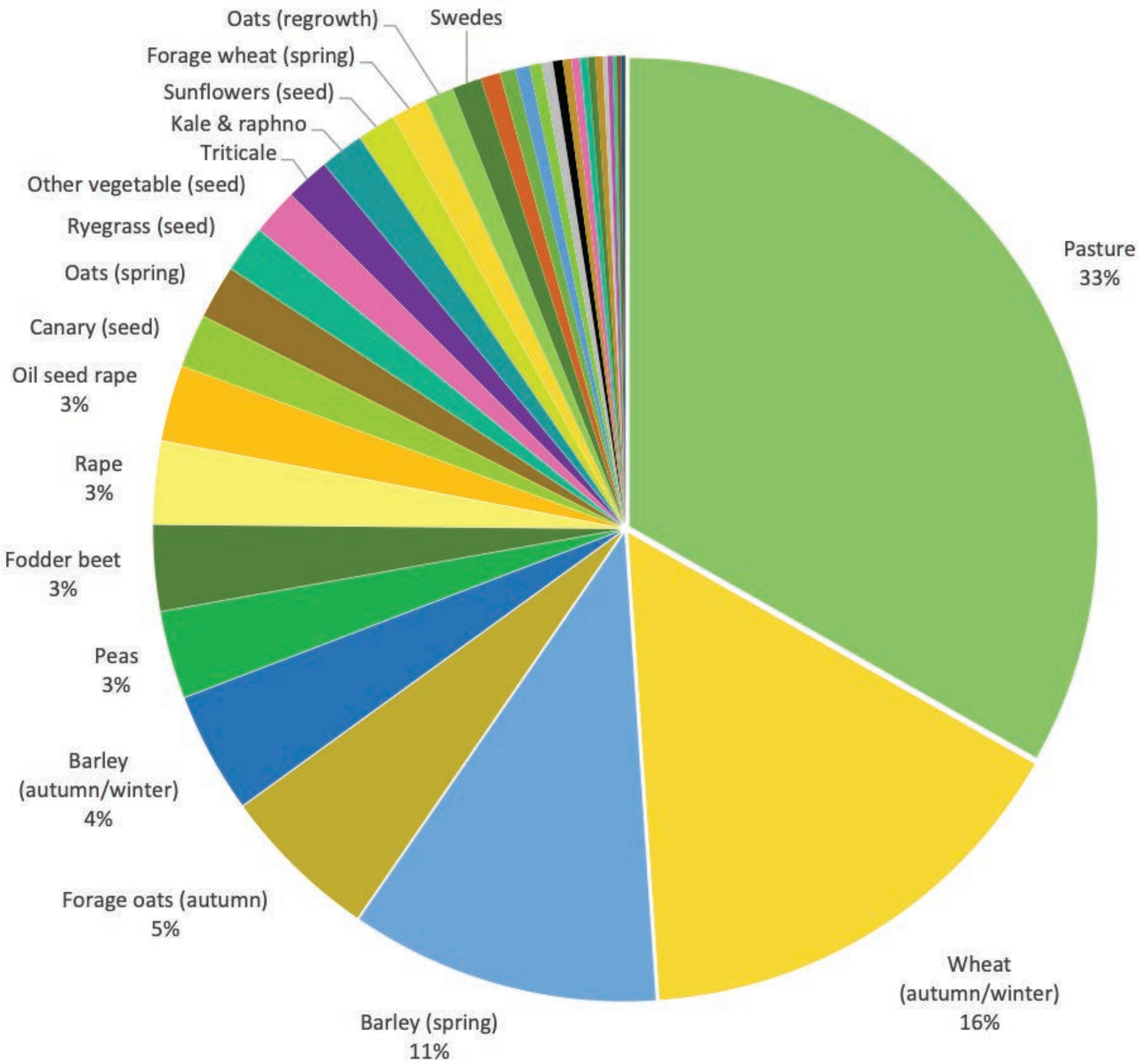

Figure 53: Distribution of 36 crops by area grown on 16 arable farms in Otago 2020-21
Source: Foundation for Arable Research
Note: Not labelled on the graph are at least 16 crops, which were each less than one per cent of the cropping area: these included hemp (seed), lucerne, forage barley (spring), whole crop, clover (seed), black oats, oats and peas, Asian brassica (seed), crested dogstail (seed), maize (silage), oats and grass/clover, phacelia, radish (seed), kale (seed), yarrow, vetch, and potatoes. A crop's value is not necessarily indicated by the area planted.

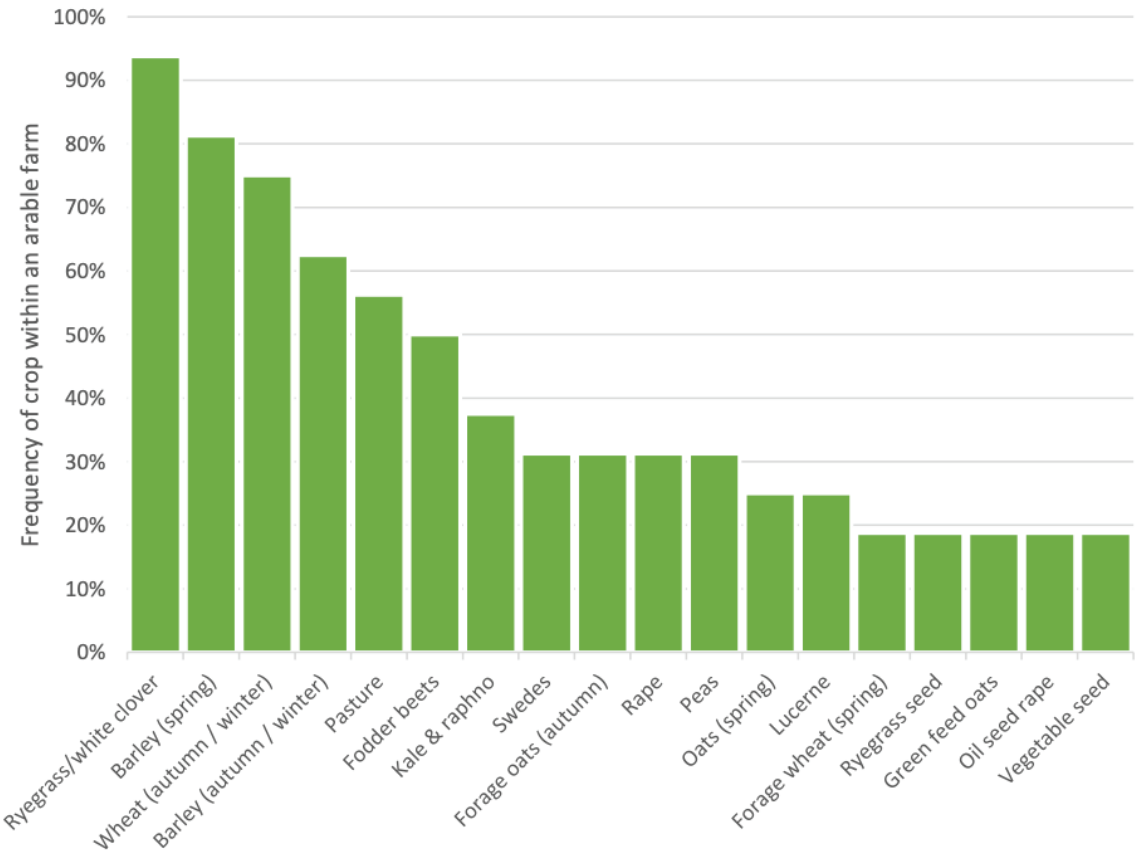

Figure 54: Frequency of crops grown on 16 arable farms in Otago 2020-21
Source: Foundation for Arable Research

Image 30: Post-harvest ryecorn in February, Māniatoto.
Source: Emma Crutchley

The farms in all the graphs in the rest of this section are ordered by the proportion of crop sown in 2020-21 (from highest on left to lowest on right)[162].

Most runoff and riparian studies in New Zealand have been conducted in pasture systems, with very few studies on cropped land, studies that have been carried out generally show that sediment loading in runoff is less than other land uses. However, sediment loads in runoff events reaching waterways pose the greatest risk of sediment and phosphorus loss from a cropping farm. Grazing can introduce the risk of *E.coli* contamination and pugging and surface capping can be a problem after intensive grazing increasing restricting infiltration of rainwater and exacerbating runoff. Managing soil quality on cropping farms is important to reduce compaction, which can also decrease infiltration and therefore runoff loading.

Turning to nitrogen, the nitrogen cycle on a mixed arable farm is multi-faceted. Synthetic nitrogen fertiliser is an essential input for plant growth, but its usage is influenced by the level of livestock integration (via winter grazing and pastoral phases) (Figure 55). It highlights the fact that synthetic nitrogen fertiliser is not the only source of nitrogen on-farm.

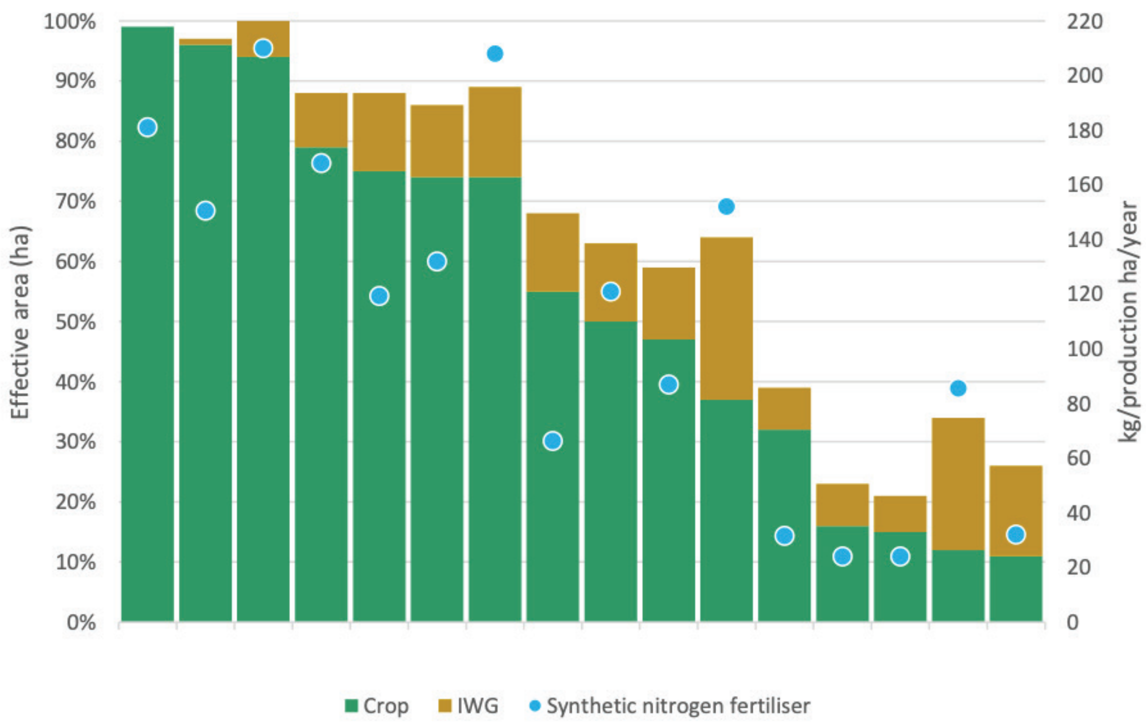

Figure 55: Use of synthetic nitrogen fertiliser for 16 arable farms in Otago in 2020-21
Source: Foundation for Arable Research

162 The order of the farms is slightly different when arranged by total area (i.e., including non-production area). For example, the second and third farms (from the left) swap positions because the second has more non-production area.

Arable farms with higher use of synthetic nitrogen fertiliser use are not necessarily those with higher nitrogen surplus or higher nitrogen loss to water — it is a matter of nitrogen efficiency (Figure 56). Nitrogen surplus is a calculation that focuses on inputs, either as feed or fertilisers, and outputs as products, and does not fully capture biological nitrogen (i.e., nitrogen fixed into the soil through plant growth). Consequently, it does not tend to work well as a tool for cropping.

Estimates of nitrogen surplus in Overseer[163] can be useful for tracking an individual farm's change over time, but it does not consider a farm's physiographic limitations (e.g., soils, rainfall) and so is not accurate when making comparisons between farms that are dissimilar. In Figure 56 the four farms with the smallest proportion of arable crops, which are the four on the furthest right-hand side of the graph, all have estimates of nitrogen surplus in excess of their use of synthetic nitrogen fertiliser.

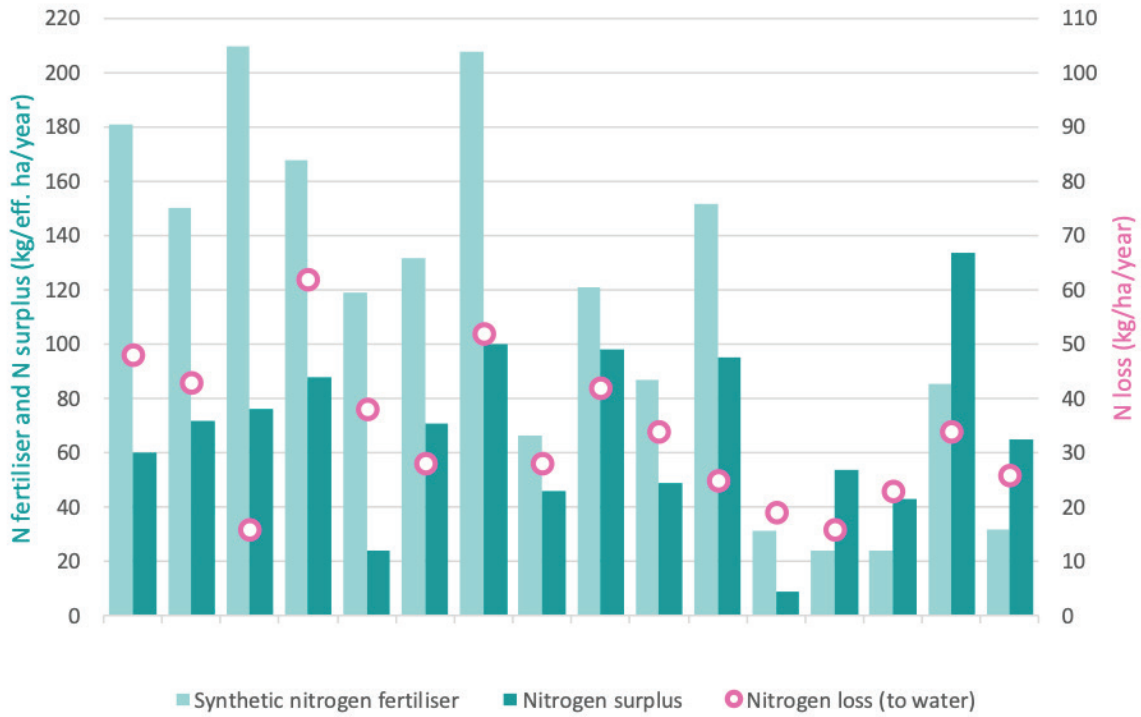

Figure 56: Comparison of nitrogen metrics across 16 arable farms in Otago in 2020-21

Source: Foundation for Arable Research

Note: The results are presented on two different scales. Synthetic nitrogen fertiliser and nitrogen surplus are shown in relation to the left-hand vertical axis and nitrogen loss is shown against the right-hand vertical axis.

163 Estimates of nitrogen surplus are also available in FARMAX and other tools but there is no industry consensus on which is the most appropriate (if any).

4.4.3 Farm finances

An arable farm's profitability is determined by its cash income from both crops and livestock set against its wages and general expenses, and the value of stock on hand. The drivers of profitability, like arable farming itself, are complex. The investment in plant and machinery can be a substantial proportion of the total business assets, especially for more specialised seed production farm types. The plant and machinery involved in growing grain and seed crops is at work constantly, with subsequent high wear and so high rates of depreciation[164].

Another major component of an arable farm's expenses is the land itself, which is either owned or leased. A sizeable share of the arable farms in the sample leased part or all their land. However, it is difficult to determine whether the area leased occurs on a one-off basis or there are longer-term arrangements and contracts in place. Anecdotally, an arable farmer suggested that most the leases are likely to fall into a three to five year arrangement, however some may still be more ad-hoc. It is unusual for the whole farm to be leased though not impossible, such as when a farmer is entering into cropping. In some cases, a lease may be from a family trust.

> *Although new entrants are uncommon, some mixed cropping farms are looking to increase their cropping enterprise (e.g., if they were 30:70 then they may be shifting towards 40:60): "We are trending towards more cropping and the driver for this is financial". However, "big decisions can mean large capital outlay. If we want to put more grain in to increase the cropping part of the business, then we need to update the combine harvester and put in more silo storage."*
>
> ***Arable Farming (Horrocks, 2022) in Otago Farmers and Growers Report***

Image 31: A crop of irrigated peas in mid-November, Māniatoto.
Source: Emma Crutchley

164 MacFarlane Rural Business noted in their analysis for this chapter that farm accountants and advisors in arable areas of New Zealand monitor plant and machinery investment benchmarks. If reinvestment is too low from year to year, then the farm is at risk of a burden of repairs and maintenance or new purchases all happening at once, causing lending and cashflow issues. Depreciation is usually a large expense on arable farms, and that if under-represented, can be a large risk to the sustainability of the business.

Figure 57 shows the variability in profitability across the 16 farms in the sample, with the arable farms ordered by the proportion of area planted in crop (highest to lowest). It highlights that there is no obvious relationship between profitability and the relative size of the cropping enterprise. Figure 58 compares proportionally each farm's area of arable crops planted (including those for intensive winter grazing) with its cash income earned from crops. Figure 59 compares each farm's cash income with their use of synthetic fertiliser (noting that nitrogen is also sourced from the pastoral component of the farm).

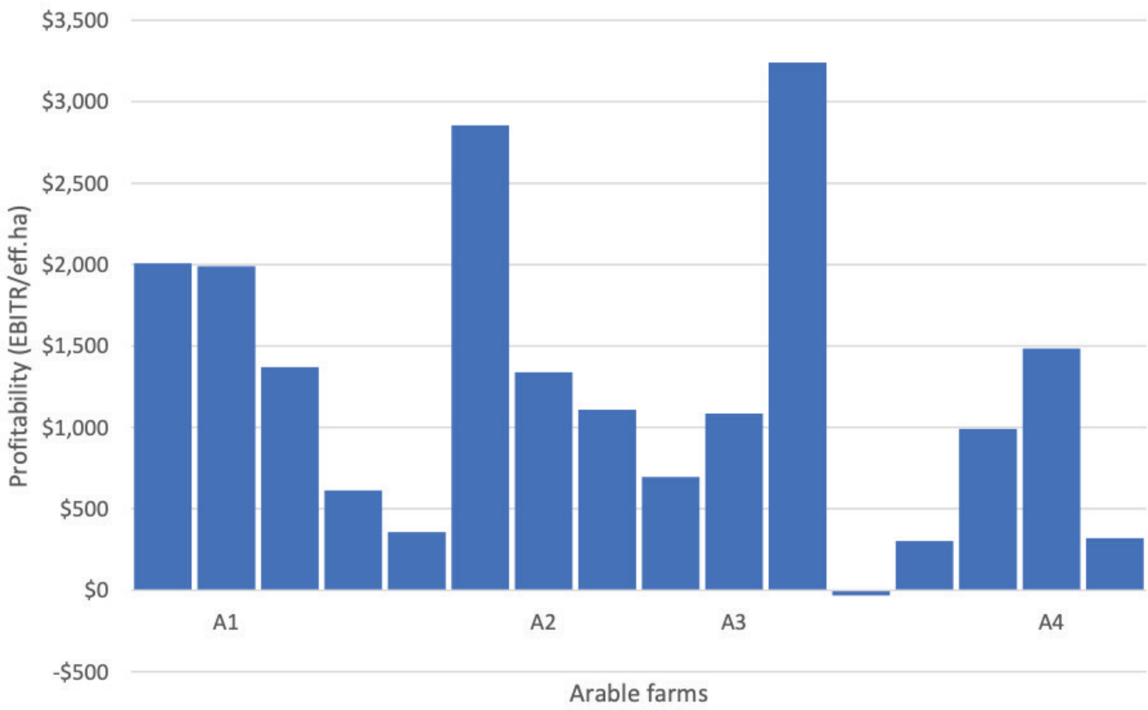

Figure 57: Operating profit per hectare for 15 arable farms in Otago 2020-21
Source: Foundation for Arable Research
Note: The farms selected as case study farms (Arable 1-4) are identified on the horizontal (x) axis.

Figure 58: Proportion of crop and crop income for 16 arable farms in Otago in 2020-21
Source: Foundation for Arable Research

Figure 59: Synthetic nitrogen use and crop income for 16 arable farms in Otago in 2020-21
Source: Foundation for Arable Research

4.5 Farm Case Studies

Four arable farms were selected from the farm sample described in Section 4.4 to develop as case studies: two irrigated farms and two dryland farms. The farms were also fairly evenly distributed between predominantly arable and mixed arable / livestock (as shown in Figure 48 in Section 4.3). For convenience, the case studies are named from Arable 1 to Arable 4.

The case studies involved transforming the four real arable farms in Otago into 'steady state' farm models to simplify the complex crop rotations using the methodology outlined in Section 4.3. Each case study is presented in this section and describes:

- the farm's crop rotation,
- its livestock enterprises,
- the environmental actions needed to meet recent policy changes,
- before finally testing additional environmental actions that may be relevant to the development of the new LWRP.

The additional environment actions tested relate to the following topics (one per case study):

1. Nitrogen fertiliser regime
2. Overland flow management
3. Variable rate fertiliser
4. Intensive winter grazing

While robust calculations were used in this research, the results in this section are rounded so as to not give a false sense of precision.

4.5.1 Arable 1 – Predominately arable (partly irrigated)

Arable 1 is a large model farm consisting of non-contiguous properties (including leased land) with an average annual rainfall of around 600 millimetres. Just over 40 per cent of the farm is irrigated, applied by centre pivots or hard hose guns, and just under 60 per cent is dryland. The investment and operating expenses of irrigation influences the production system, creating more certainty of higher value production crops (but at a higher production cost).

Arable 1 was selected to test additional environmental actions for its nitrogen fertiliser regime. Before this analysis occurred, the farm model was adjusted to be compliant with recent policy changes relating to fresh water that have occurred nationally and specifically for Otago.

4.5.1.1 Crop rotations

The dryland part of the farm has a six-year rotation of harvests. This rotation was simplified into similar sized blocks as steps in a 'steady state' farm rotation for ease of modelling (Figure 60). The irrigated part of the farm has a five-year rotation (Figure 61).

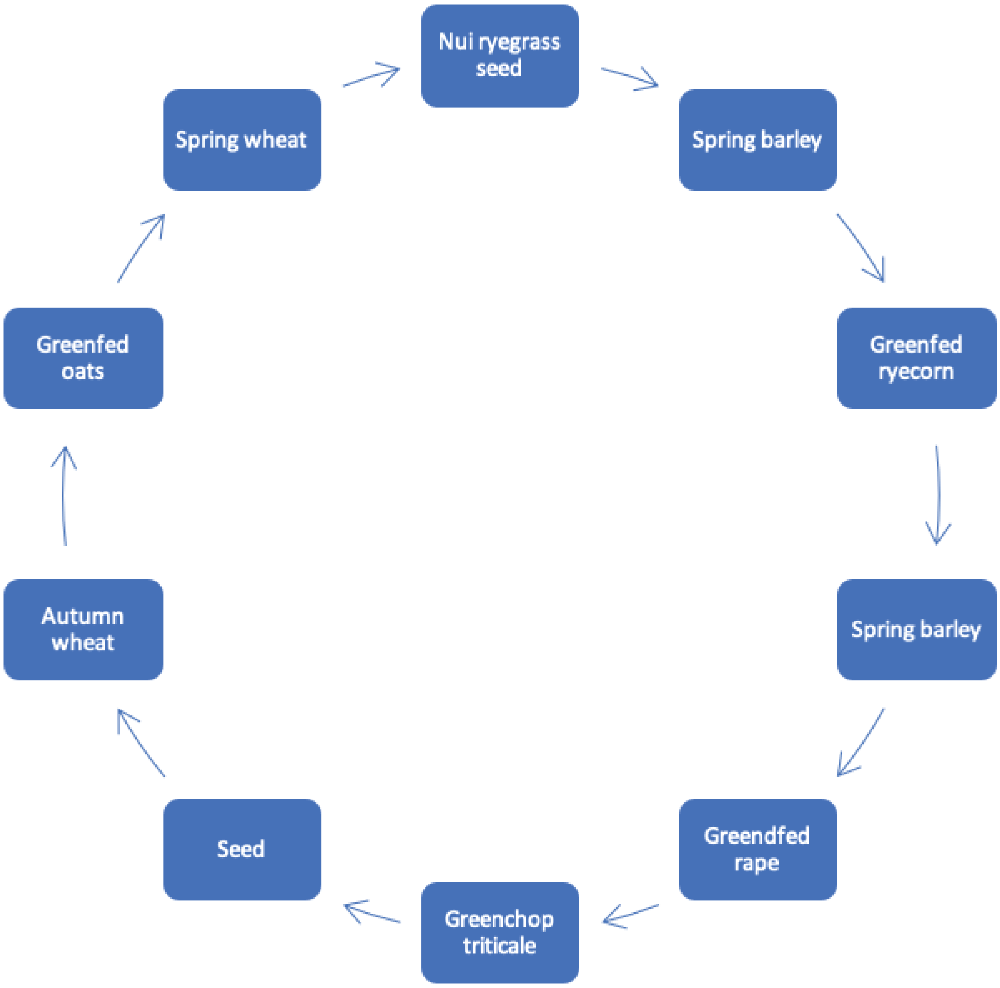

Figure 60: Six harvest year dryland mixed arable crop rotation
Source: Macfarlane Rural Business

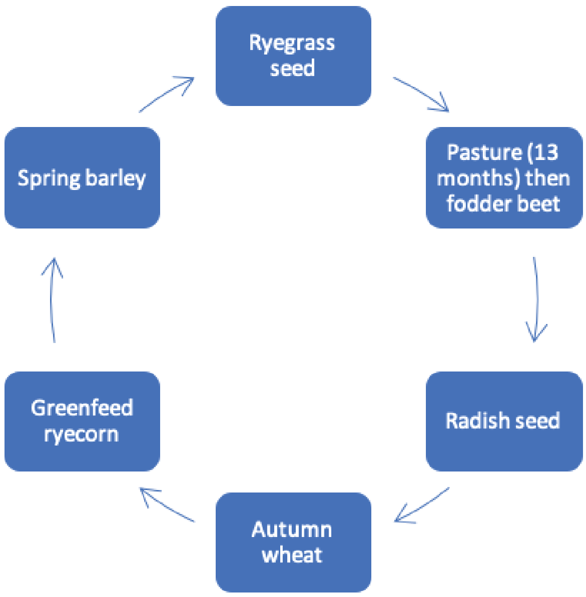

Figure 61: Five harvest year irrigated mixed arable crop rotation
Source: Macfarlane Rural Business

4.5.1.2 Livestock enterprises

The predominance of the cropping enterprise on this farm means most livestock feed is available on-farm through the winter and prior to grass seed crops being closed (from grazing) in the spring. Only the beef animals are carried through the summer and autumn (Figure 62). Winter lambs were either owned by the farm business or as contract grazing. Beef finishing consists of 'bought in' steer calves and rising two-year old (R2) beef steers. Also, included in the farm system are the fattening/wintering of cull dairy cows and dairy cow contract grazing.

The sum-total synthetic fertiliser nitrogen applied to pasture was 96 kg N/ha, which is well within the NES-F Nitrogen Cap of 190 kg N/ha/yr. The highest sum-total for any of the annual forage crops was 122 kg N/ha applied to the irrigated fodder beet. The highest sum-total for a grain and seed crop was 176 kg N/ha for autumn-sown irrigated wheat, but the NES-F Nitrogen Cap does not apply to non-grazed crops.

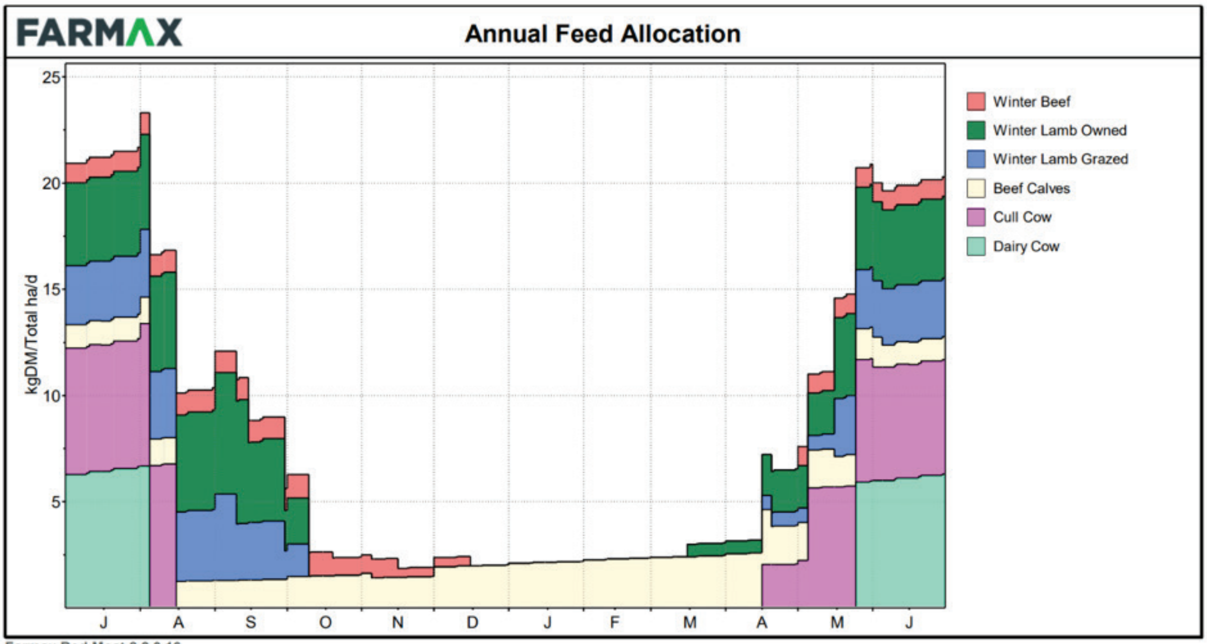

Figure 62: Annual feed allocation by livestock class
Source: Macfarlane Rural Business

4.5.1.3 Farm results – current environmental actions

The Arable 1 'steady state' farm model was adjusted to accommodate environmental actions to meet recent policy changes (as described in Section 4.3.1). Based on recent policy changes, the main environmental issue for this farm was management of CSAs. Analysis of aerial maps and discussions with farm owners determined the nature of CSAs and whether they triggered the livestock exclusion and intensive winter grazing regulations. The nitrogen cap regulation was not triggered for this farm. The CSAs were small on the dryland part of the farm at roughly 0.7 per cent. CSAs were larger on the irrigated part of the farm at 3.3 per cent.

Permanent fencing was used for livestock exclusion from waterways and CSAs not already included: 1.1 kilometres on the dryland areas, 6.9 kilometres on the irrigated areas. Three metres of the farm's effective area was retired with the permanent fencing along the edge of waterways (there was already some distance between current cropping and livestock grazing activities from the waterways). This equated to roughly two hectares on the irrigated part of the farm and 0.3 hectares on the dryland part of the farm (0.3 ha was not a large enough change to model in FARMAX). Capital expenditure for permanent fencing for this farm was $144,000.

The extra temporary fencing hardware needed cost just over $3,100. An extra casual labour component was also costed at just under $3,400 for the winter grazing period. Within the farm financials, the capital expenditure for permanent fencing and extra temporary electric fence was added to the term debt (and reflected in greater interest costs) and increased depreciation was allowed for over a ten and five-year periods respectively.

A small area of terminal buffer planting was removed from the winter grazing area on the irrigated part of the farm. Similarly, a minor CSA was removed from the winter grazing area on the dryland part of the farm. In both cases it meant a minor decrease in winter grazing area (and feed grown) and the cropping rotation on each part of the farm was unchanged. The permanently fenced off areas decreased the irrigated land by less than one per cent, which impacted all crops grown on this part of the farm.

The removal of CSA and terminal buffer planting area from the winter grazing area changed the base FARMAX livestock model slightly. The only notable reduction in land area was the permanently fencing off the waterways on the irrigated block. The relationship between supply and demand remained very similar. The small changes in the area of winter feed grown had minimal impact on livestock numbers and no impact on arrival dates.

4.5.1.4 Farm results – additional environmental action (nitrogen fertiliser regime)

The environmental actions applied to Arable 1 were to make changes to the farm's nitrogen fertiliser regime. Arable 1 'steady state' farm model was adjusted to accommodate environmental actions to meet recent policy changes (as described in the previous section). Once the steady state was brought up to current legislation it was further adjusted to determine;

- the extent to which nitrogen fertiliser reductions could be made before it was no longer financially viable to grow each crop (the profit bottom-line became breakeven); and
- what impact a nitrogen fertiliser withholding period between 1st March to 30th September would have on yields and profitability.

The methods used are described in Section 4.3.2.1 but an important point to make is that the farmer was already applying nitrogen fertiliser efficiently (e.g., using tools such as soil testing to inform fertiliser rates). Nitrogen fertiliser was not applied where soil testing results showed there was adequate soil nitrogen and as a result four crops did not receive any nitrogen fertiliser (these are identified with 'NA' in the 'Resulting reduction in crop yield' column of Table 32). Note that this may differ from year to year depending on soil test results and the nitrogen needs of the subsequent crop. On average across the farm business an eight per cent reduction in nitrogen fertiliser rates decreased yields so that the profit 'bottom-line' became breakeven (Table 32). The analysis demonstrated that mixed cropping farm systems are sensitive to reduced crop yields.

A nitrogen fertiliser withholding period between 1st March to 30th September impacted yields and profitability and had the most substantial impact on the spring sown crops. For spring crops there was no change in nitrogen rate, but yields decreased as a result of not being able to apply fertiliser in September (the withholding period delayed crop establishment and yields). Early spring growth is important on arable farms for agronomic and environmental reasons. Agronomically it is important to optimise yields and environmentally it is important to avoid bare soil by promoting ground cover, which reduces sediment loading in runoff events.

Table 32: Changes in nitrogen fertiliser applied to decrease yields to breakeven point and associated yields

Crop	Fertiliser (N/ha) reductions for profit to reach 'breakeven' point	Resulting reductions in crop yield
Nui ryegrass seed (dryland)	-15%	-6%
Spring barley (dryland)	0%	-9%
Greenfeed ryecrorn (dryland)	-	-
Greenfeed rape (dryland)	-18%	-22%
Greenchop triticale (dryland)	0%	-18%
Flower seed (dryland)	-	-
Autumn wheat (dryland)	-15%	-17%
Greenfeed oats (dryland)	-	-
Spring wheat (dryland)	0%	-8%
Proprietary ryegrass seed (irrigated)	-15%	-5%
Fodder beet (irrigated)	-12%	-5%
OP radish seed (irrigated)	-8%	-13%
Autumn wheat (irrigated)	-9%	-9%
Greenfeed ryecrorn (irrigated)	-	-
Spring barley (irrigated)	0%	-12%

Source: Foundation for Arable Research
Note: A dash indicates where nitrogen fertiliser is not applied because soil testing shows there is adequate soil nitrogen.

A nitrogen fertiliser withholding period may have unintended consequences if it inadvertently encourages farmers to apply additional nitrogen fertiliser prior to 1st March when it is 'allowed'. This 'front loading' of fertiliser before winter may occur in the hope that some will still be available to support strong spring growth needed to optimise yields (but risks increasing nitrogen leaching over winter). Applying nitrogen fertiliser at the right time is important to if fertiliser is to be used efficiently and reduce the risk of nitrogen losses.

The delay in spring application of nitrogen fertiliser on ryegrass seed crops meant that there was reduced pasture growth for livestock grazing in September (and in some cases October), before shutting out livestock for the seed crop. There was also reduced pasture regrowth immediately following the grass seed harvest, resulting in lower pasture covers in March. The changes in both total feed production and the timing of when the feed was grown, not only had an impact on the total numbers of livestock farmed, but also changed the balance of livestock enterprises. For example, the reduction in cull cows and cow grazing was greater than beef calves due to the reduction in winter feed crop yield.

4.5.2 Arable 2 – Predominately arable (dryland)

Arable 2 is a large mixed arable dryland (i.e., non-irrigated) model farm. The farm has average annual rainfall of 850 millimetres. The farm is mostly grain and specialist seed cropping (biased towards grain), selling some feed as cut and carry off-farm as well as contract grazing. The farmer owns no livestock but contract grazes lambs over winter, and a smaller proportion of higher stocking rate dairy cow that winter graze.

Arable 2 was selected to test additional environmental actions associated with overland flow management options. Before this analysis occurred, the farm model was adjusted to be compliant with recent policy changes relating to fresh water that have occurred nationally and specifically for Otago.

4.5.2.1 Crop rotations

The farmer runs two separate rotations; one on the home block based on grain and seed crops (Figure 63), and the other on a separate block of land close by (Figure 64) is based on cut and carry and forage crops.

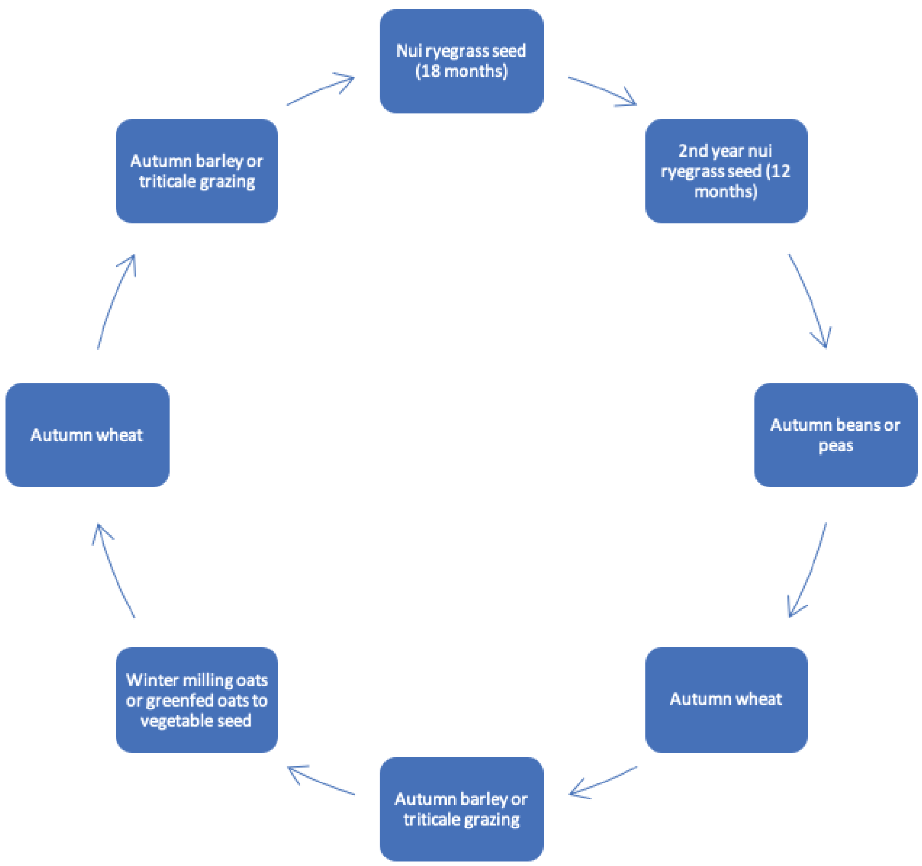

Figure 63: Eight harvest year main crop rotation
Source: Macfarlane Rural Business

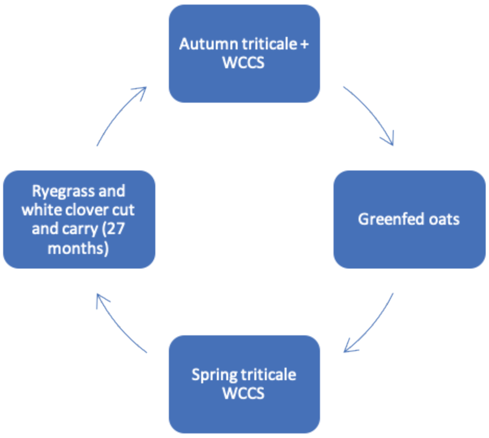

Figure 64: Four-year secondary crop rotation (no grain or seed)
Source: Macfarlane Rural Business

4.5.2.2 *Livestock enterprises*

Given the high predominance of cropping on this farm the majority of feed is available through the winter and prior to grass seed crops being shut up in the spring. There are no livestock on the property from mid-October to the end of February and any surplus pasture is sold off-farm as silage. The lambs and dairy cows that come on farm are contract grazed. The seasonal allocation of feed to the different livestock classes shows that all feed is consumed from March to September (Figure 65).

The sum-total for synthetic nitrogen applied to the pasture areas is 62 kg N/ha, which is well inside the NES-F Nitrogen Cap of 190 kg N/ha/yr. The highest sum-total for an annual forage crop is for autumn sown triticale at 260 kg N/ha, but this nine-month crop is only grazed for a period of two months, then shut for whole crop cereal silage (WCCS) and cut for export off-farm. There is no cap on non-grazed (e.g., grain and seed) crops, so is not discussed here (the highest being 237 kg N/ha for high yielding autumn sown wheat).

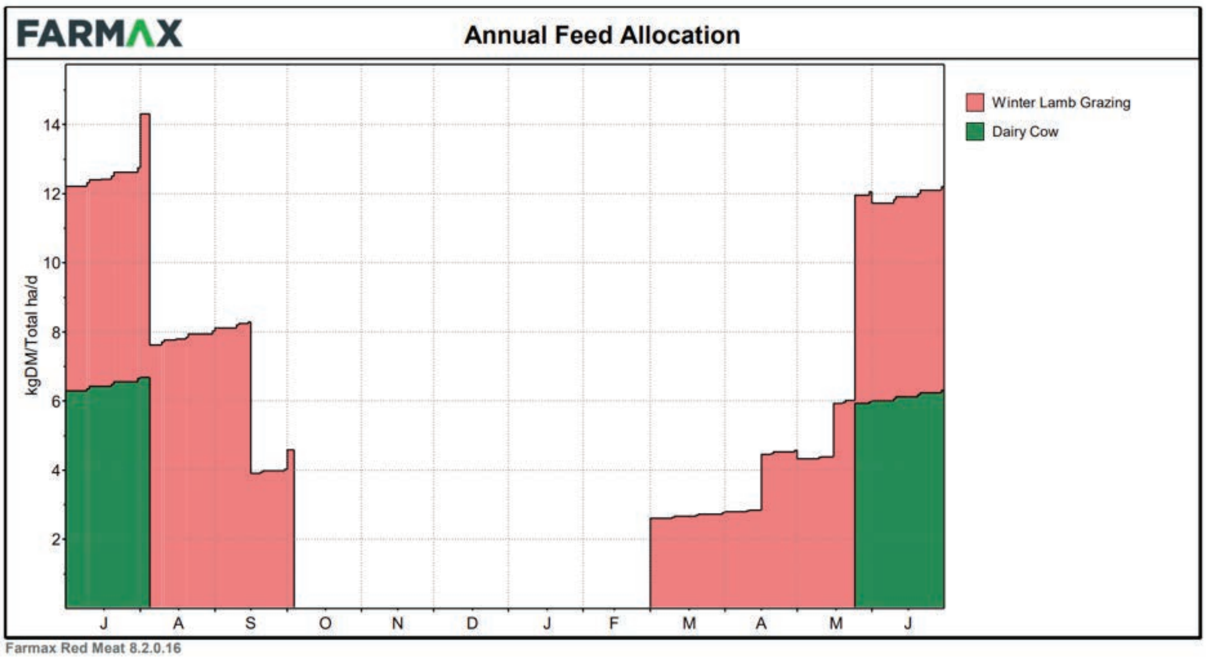

Figure 65: Annual feed allocation by livestock class
Source: Macfarlane Rural Business

4.5.2.3 Farm results – current environmental actions

The Arable 2 'steady state' farm model was adjusted to accommodate environmental actions to meet recent policy changes (as described in Section 4.3.1). Based on recent policy changes, the main environmental issue for this farm was management of CSAs and increasing the area of permanent setbacks from waterways.

All the grazing on Arable 2 occurs from March through to the middle of October, with surplus pasture in the summer and autumn being sold off-farm. Bringing the business up to recent policy changes required altering feed production and utilisation as some designated areas were removed from the planting of winter feed crops for grazing and will only be used for growing grain and seed crops (areas of sloping land near or adjacent to a watercourse). The total extent of CSAs was just under five per cent of the farm – roughly three-quarters on the home block and one-quarter on the separate block.

Given the wide distribution and weaving nature of the CSAs on the main cropping area, it was assumed that many of these on the home block will be able to continue to be farmed with a consent. Adjustments were made to meet assumed conditions of consent such as keeping the bottom/terminal sections of some awkward 'gully' type CSAs in forage crop over winter when intensively grazing, and to complete a 'last bite' of that area at the very end of the grazing period immediately before establishing the next crop. That way an overland flow buffer is maintained.

Considerations around permanent fencing and temporary fencing was discussed with the farmer before being modelled. A three-metre setback was used for the permanent fences from the edge of the waterways. Cropping and livestock grazing activities on Arable 2 were already setback two metres from waterways, so the productive farming area removed was extra 1.3 hectares to achieve the three-metre distance to meet recent policy changes. The distances needed these CSAs and waterways totalled 11,662 metres. Livestock were excluded from other CSAs with temporary electric fences while being utilised for grazed pasture or forage crops, with the fence being removed when these areas were arable cropped.

The cost of permanent fencing for Arable 2 to be compliant with recent policy changes is around $195,000. The cost of the extra temporary fencing hardware needed is likely to be in the vicinity of $6,200. An extra casual labour component was also costed at $5,000 for the winter grazing period. The capital expenditure for all fencing was added to the term debt (and reflected in higher term interest costs) and increased depreciation was allowed for over a ten and five-year period respectively (Table 33 in the next section).

4.5.2.4 Farm results – additional environment action (overland flow management)

The environmental actions applied to Arable 2 compared the steady state model brought up to recent policy changes (where there was a 3-metre setback of permanent fences from the edge of waterways) to a fixed approach and a risk assessment approach (as described in the previous section). The methods used are described in Section 4.3.2.2.

The fixed approach resulted in a need for a total of 21.7 kilometres of additional permanent fencing. The total cost of fencing was budgeted at $346,000 and the annual cost of the permanent fencing (over a 10-year period, undiscounted) was budgeted at $34,600. The total effective farm area reduced by 21 hectares (in addition to the 1.3 hectares lost to bring the steady state up to meet recent policy). Profitability decreased by 4.3 per cent to adjust the farm from 'steady state' to 'meeting recent policy' and a further 8 per cent to get from there to achieve the fixed approach (Table 33).

Numerous studies have shown that setbacks can be effective in reducing sediment delivery to streams by decreasing the velocity of runoff and allowing particles to settle. In some instances, adding to the buffer area can be more efficient but in others it was not as efficient as modifying in-field practices (e.g., implementing appropriate tillage, land-shaping, and in-field buffer practices) (Dosskey et al., 2002; Barling & Moore, 1994). A common theme in the studies is that a flexible approach based on an appropriate risk assessment is likely to result in better outcomes for the farm and the environment than a unilateral approach.

Carrying out a risk assessment to identify where other actions may be appropriate is best carried out on a farm-by-farm basis as one size rarely fits all situations. It is likely that there will be areas where setbacks need to be greater than five metres. Other actions that fit the scale and character of the risk would be identified from a tool kit of mitigation-type of environmental actions (interception drains, culverts, diversion bunds, benched headland, swales, sediment traps, silt fences etc).

For Arable 2 the risk assessment approach increased the setback width from three metres to a 5-metre permanent set back from a waterway. This increase resulted in a total of 12.5 kilometres of additional permanent fencing. The total cost of fencing was budgeted at $225,000 and the annual cost of the permanent fencing (over a 10-year period) was budgeted at $22,500. The farm's effective area was reduced by 2.7 hectares (in addition to the 1.3 ha lost to adjust the farm from 'steady state' to 'meeting recent policy'). Profitability decreased by 4.3 per cent to move from the steady state to being brought up to meet recent policy and a further 1.2 per cent to move on to achieve the risk assessment approach (Table 33).

Table 33: Changes in returns of recent policy changes and additional environmental action (either as a fixed approach or flexible 'risk assessment' approach)

Metric	Recent policy changes (%)	Fixed approach (%)	Risk assessment approach (%)
EBITRD/Cash farm working profit	-0.7	-5.2	-0.7
Cash operating surplus/deficit	-1.4	-6.0	-0.8
EBITR	-2.6	-8.2	-1.1
Profit before tax (after interest, rent and depreciation)	-3.6	-9.3	-1.2
Profit after tax (interest, rent and depreciation)	-4.3	-8.1	-1.2

Source: Foundation for Arable Research

Note: A dash indicates where nitrogen fertiliser is not applied because soil testing shows there is adequate soil nitrogen.

4.5.3 Arable 3 – Even mix of arable and pasture (dryland)

Arable 3 is a medium-sized model farm spread over three dryland (i.e., non-irrigated) blocks. The 'home' block (roughly three-quarters of the farm) is largely 'cropable' land[165] with a small undeveloped tussock hill. A 'subsidiary' block is arable cropped land while a third 'greenfeed' block is used for pasture and greenfeed crops. The farm has breeding ewes (retaining replacement ewe hoggets), and winter beef and lamb finishing. The farmer sells feed and grain into the dairy market but does not winter dairy cattle. Grain is grown for human and livestock end-uses. While some specific seed crops are grown, they are not the specialist seeds found on irrigated farms.

Arable 3 was selected to test additional environmental actions for variable rate fertiliser. Before this analysis occurred, the farm model was adjusted to be compliant with recent policy changes relating to fresh water that have occurred nationally and specifically for Otago.

4.5.3.1 Crop rotations

Two types of rotations are used on this farm. The main rotation is grain and seed based across two blocks (a 'home' block and a 'subsidiary' block) (Figure 66), while the second rotation is pasture and greenfeed based on a third block that has small awkward shaped paddocks because of the nature of the site. The second rotation on this 'greenfeed' block is relatively simple: pasture (just under 6 years), then swedes, followed by oats whole crop cereal silage (WCCS). The three blocks are not necessarily all contiguous, which can influence farm management.

Figure 66: 12 harvest year main crop rotation
Source: Macfarlane Rural Business

165 Not all land on a cropping farm is 'cropable', especially in Otago, and some steep areas may be in permanent pasture and sit outside the rotation.

4.5.3.2 Livestock enterprises

In comparison to the other farms, this property has a considerable area of pasture, and is the only farm to have breeding ewes as well as lamb finishing and winter bull finishing. The ewe breeding and finishing programme is based on a self-replacing system and finishing of all lambs to slaughter. Replacement ewe hoggets are mated. Over 70% of feed is consumed by the sheep breeding and finishing enterprise (Figure 67). The seasonal allocation of feed to the different livestock classes shows over 70 per cent of feed is consumed by the sheep breeding and finishing enterprise.

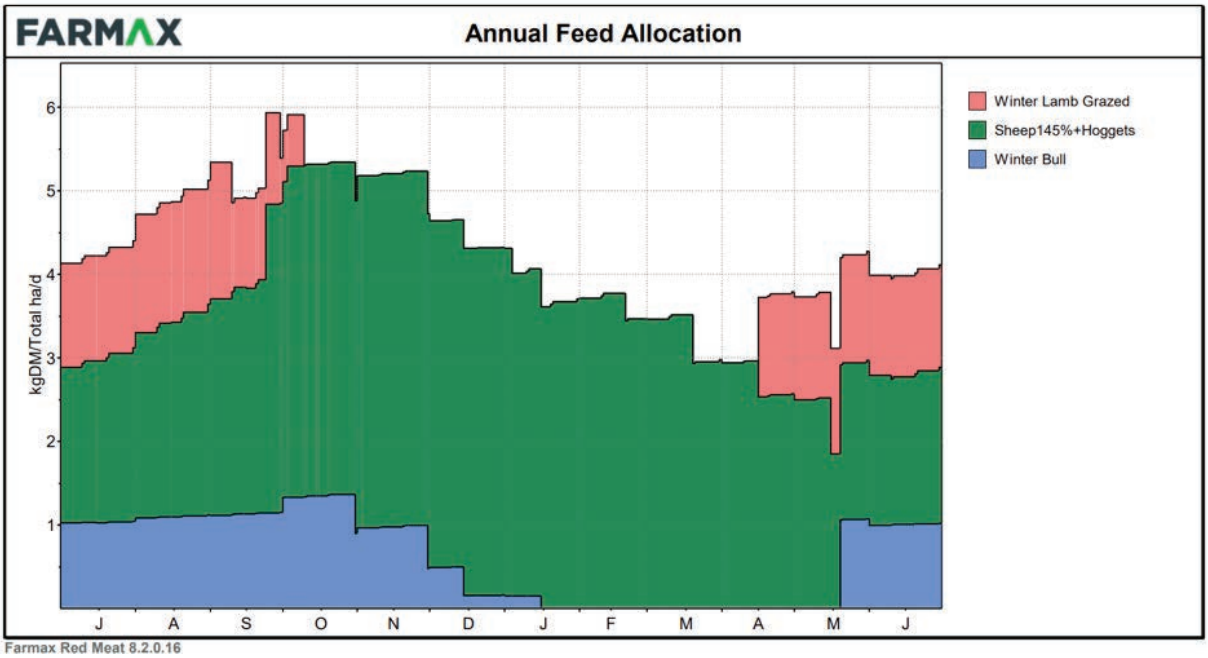

Figure 67: Annual feed allocation by livestock class
Source: Macfarlane Rural Business

4.5.3.3 Farm results – current environmental actions

The Arable 3 'steady state' farm model was adjusted to accommodate current environmental actions to meet recent policy changes (as described in Section 4.3.1). Based on recent policy changes, the main adjustments modelled were in relation to management of intensive winter grazing and CSAs.

The first two blocks (the 'Home' block and a 'subsidiary' block) were modelled together under the same rotation (Section 4.5.3.1). The subsidiary block had 3.60 hectares of CSAs identified, of which 3.44 hectares needs to be excluded from winter grazing. The remaining 0.16 hectares can be grazed under a Freshwater Farm Plan.

The 'Home' block had two paddocks excluded from winter grazing. Instead of planting these paddocks in winter feed crops an Italian ryegrass was planted for the winter. This was modelled as occurring twice as there are two feed crops (swedes and oats) in the 12-year rotation. The two paddocks are part of a large rotation over a 12-year period so the average annual area in Italian ryegrass modelled as 'x' hectares over 12 years divided by two crops. In reality, there will be less winter feed and more Italian ryegrass in some years as these two paddocks pass through the winter feed phase of the rotation, however long-term analysis means the area of Italian ryegrass must be modelled on an average basis. The yield of the Italian ryegrass is modelled at 4.0 tonnes of dry matter per hectare.

There are 18 CSA terminal points that end in the paddock on the Home block. When winter cropping these paddocks a 10 metre X 10 metre terminal planting of long grass or riparian planting is needed as a buffer or nutrient soak. This area equates to 0.18 hectares of land being excluded from the winter grazing area.

In summary the following areas (totalling 12.52 ha) were removed from winter grazing in the first rotation:

- Subsidiary block 3.44 hectares of CSA exclusion;
- Home block 0.18 hectares of terminal plantings;
- Home block 8.9 hectares – two paddocks excluded from intensive winter grassing but planted in Italian ryegrass.

This represents an average annual reduction in winter feed of 2.1 hectares, with 1.5 hectares replaced by Italian ryegrass.

The ‘greenfed block’ has 0.36 hectares of CSAs identified as needing to be excluded from the winter feed area. One CSA also needed terminal planting in long grass of 10 metre x 10 metre, and so the total excluded area was 0.37 hectares.

Permanent (as opposed to temporary) fencing requirements were discussed with the landowner with distances tallied up to just over 8.4 km, for those waterways and CSAs that would more obviously need to have full stock exclusion. Three metres of productive farming area was lost due to permanent fencing from the edge of the waterways (based on 8.4 km this equates to approximately 2.5 hectares). Modelling of other CSAs excluded livestock with temporary electric fences while in grazed pasture/ forage but removed the fence when the area was arable cropped.

Based on the cost of permanent and temporary fencing (Section 4.3.1), the cost of permanent fencing to this farm was $151,470 and the extra temporary fencing hardware needed was $3,528. An extra labour component was also costed at $3,356 per intensive winter grazing period. Within the ‘policy changes’ version of the financials, the capital expenditure for permanent fencing and an assumption for extra temporary electric fence was added to the term debt (and reflected in higher term interest costs) and increased depreciation was allowed for over a ten and five-year period, respectively. This resulted in a decrease in net profit before tax (but after interest, rent and depreciation) of 20 per cent and a reduction in EBITR of 14 per cent.

4.5.3.4 Farm results – additional environmental action (variable rate nitrogen capability)

The environmental actions applied to Arable 3 related to variable rate fertiliser. This action aimed to determine how the suitability of variable rate technologies is affected by economies of scale. The methods used are described in Section 4.3.2.3. It carried this out by looking at the suitability of investing in variable rate nitrogen capability on two farms with different areas in crop (102 ha for Arable 3 and 429 ha for Arable 1).

Where farmers are already using nitrogen efficiently and including soil supply into their fertiliser rate calculations there can be opportunities to further reduce nitrogen use by investing in variable rate technologies. However, the extent to which variable rate technologies will further reduce nitrogen fertiliser without reducing yields depends on topography and variability. Where the soil variability and topography suit variable rate technology, four other factors influence return on investment:

- Area – Economies of scale, to spread the cost and potential savings over a larger area to justify the investment.
- Yield potential – The higher the yield potential and actual yield variability then the bigger the savings.
- The ability of the grower to maximise yield potential on dry years through irrigation.
- Price of fertiliser and grain – the higher the price of the input or output the quicker the return on investment.

In this comparison the business that had less cropping area (Arable 3) had a payback period for return on investment of 12 - 23 years (Table 34) and as a result this would not be a viable technology for this business. The differences in payback years between Arable 1 and Arable 3 is driven by area and economies of scale. Paddock variability is also influential as the greatest gains from variable rate technologies is when the majority of the paddock is in at least two yield zones. These results suggest that investment in variable rate technology may be a viable opportunity for some businesses but not for others. For Arable 1 it is likely to take three to six years to payback, after which, savings from reduced fertiliser use will increase profitability. As a result, such technologies will minimise economic impacts where it fits the farm system.

Table 34: Savings in product per hectare and the time to payback capital investment options for two case study farms (Arable 3 and Arable 1)

Option	Cost ($)	Savings in N fertiliser product ($) Arable 3	Arable 3 Payback (years)	Savings in N fertiliser product ($) Arable 1	Arable 1 Payback (years)
1: N Sensor	50,000	4,143.01	12.1	14,959.39	3.3
2: N Sensor + GPS	60,000	4,143.01	14.5	14,959.39	4.0
3: N Sensor + VRT spreader	85,000	4,143.01	20.5	14,959.39	5.7
4: N Sensor + GPS + VRT spreader	95,000	4,143.01	22.9	14,959.39	6.4
5: VRT spreader + GPS	45,000	3,810.53	11.8	10,685.28	4.2

When calculating the return on investment in technology, if that technology can be used on multiple aspects of the farming system, then it will reduce the time it takes to recover the costs. For example, tractors with GPS control systems are generally used for several applications. Table 34 focuses on the equipment needed for applying fertiliser at different rates, without considering the possible savings of using that unit for other applications. Depreciation is not accounted for in the values[166].

4.5.4 Arable 4 – Some arable (mostly irrigated)

Arable 4 is a medium to large model farm, which is almost all under irrigation by centre pivots, travelling Rotorainer style irrigators, or fixed permanent sprinklers in more awkward areas. While farms of this type initially used irrigation to effectively increase livestock performance (their core skill set), they are increasingly diversifying into more arable cropping. The farmer grows grains, specialist seed crops, and includes dairy cow wintering, bull beef finishing, and winter lamb finishing.

Arable 4 was selected to test additional environmental actions for intensive winter grazing. Before this analysis occurred, the farm model was adjusted to be compliant with recent policy changes relating to fresh water that have occurred nationally and specifically for Otago.

4.5.4.1 Crop rotations

The dryland part of the farm has a four-year rotation that was simplified to similar sized blocks in each step in a 'steady state' rotation for ease of modelling. The dryland rotation is ryegrass and white clover pasture for 33 months duration (two blocks or 50%), then summer rape (one block or 25%), followed by autumn triticale grazing (one block or 25%).

The irrigated part of the farm is split into two rotations, depending on type of irrigation. The grain and seed-based rotation is under the centre pivot irrigators (Figure 68), while the forage-based irrigated rotation (fixed areas where the infrastructure is not practical for tramline based, sprayer and spreader, arable crop operations) used the travelling Rotorainer. The forage-based irrigated rotation is ryegrass and white clover pasture for 57 months duration (4 blocks or 66%), then greenfed winter kale (1 block or just under 17%), followed by spring triticale (1 block or just under 17%).

166 According to the NZ IRD depreciation rates Sept 2020, computerised agricultural machinery on average has an estimated useful life of eight years, with a depreciation diminishing value of 25 per cent or a straight line depreciation on 17.5 per cent. Generally, when the tractor unit is replaced then the GPS control system is also replaced, be it at ,5000 hours of work for example, or after five to eight years depending on the growers replacement policy.

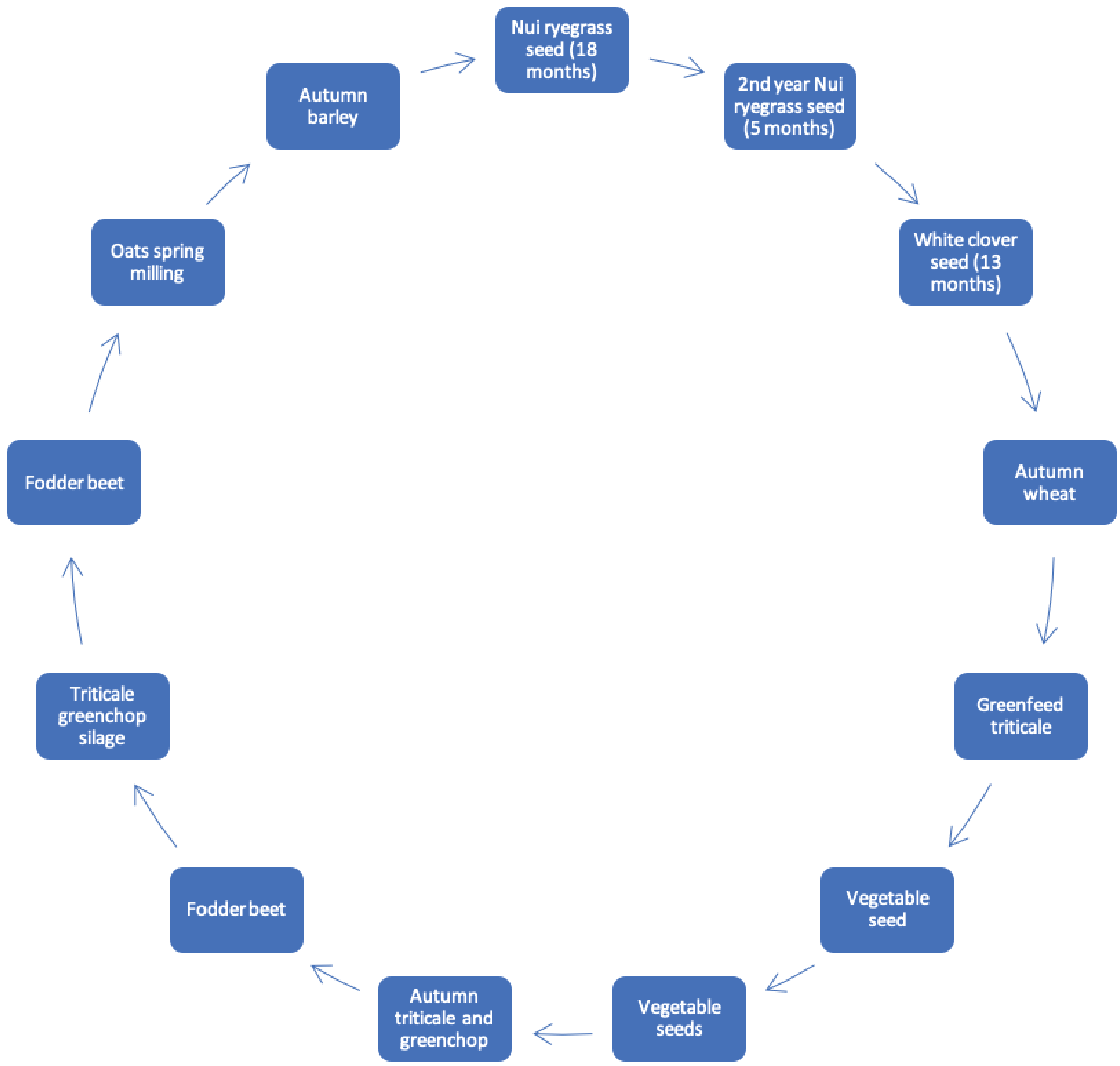

Figure 68: 10-year irrigated grain and seed-based crop rotation
Source: Macfarlane Rural Business

4.5.4.2 Livestock enterprises

Given the high predominance of cropping in this farm model, most feed is available through the winter and prior to grass seed crops being shut up from grazing in the spring. Analysis of the seasonal allocation of feed to the different livestock classes shows that most of the feed consumed in June and July is by contract grazed dairy cows and winter lambs. Bulls are finished throughout the year and are the only animals carried through the summer (Figure 69).

Nitrogen applied to pasture in this farm model ranges from 104 kg N/ha/yr on dryland pasture, to 128 kg N/ha/yr on irrigated pasture. These levels are well inside the NES-F Nitrogen Cap of 190 kg N/ha/yr. The highest sum-total for any annual forage crop is 129 kg N/ha applied to irrigated greenfeed kale. There is no cap on non-grazed (e.g., grain and seed) crops, so it is not discussed here. The highest being 145 kg N/ha for autumn sown irrigated barley.

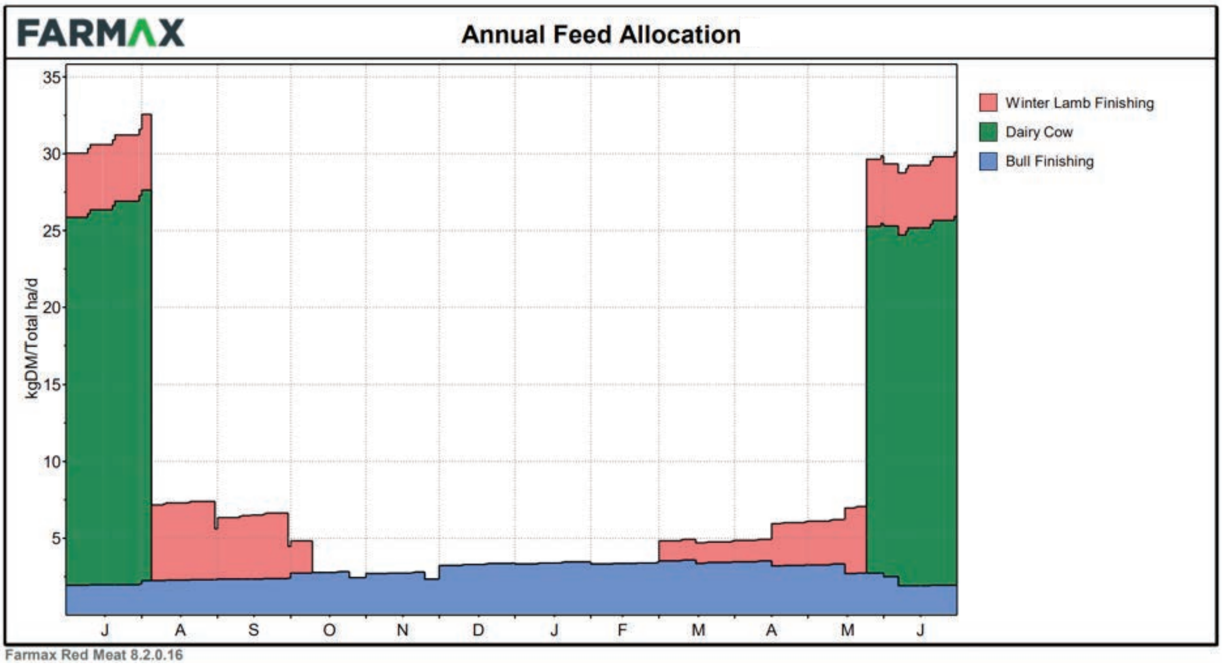

Figure 69: Annual feed allocation by livestock class
Source: Macfarlane Rural Business

4.5.4.3 Farm results – current environmental actions

The Arable 4 'steady state' farm model was adjusted to accommodate environmental actions to meet recent policy changes (Section 4.3.1). Most of forage for grazing on this farm is grown during the winter period and a feature of this farm was some higher slope land. The main impact of the NES-F was the farmer's inability to plant winter feed crops for grazing in designated CSAs, which affected feed production and its utilisation. The extent of CSAs measured was relatively small at around 1.5 per cent of the farm area modelled. As a result, the focus of the modelling was on the two possible approaches for additional actions, which are discussed in Section 4.3.2.4.

4.5.4.4 Farm Results – additional environmental action (intensive winter grazing)

The environmental actions applied to Arable 4 were changes to the farm's winter grazing regime. This environmental action was tested by comparing a permitted activity approach to a risk assessment approach where effects were managed via either a consent process or with an audited Freshwater Farm Plan. The permitted activity and risk assessment approaches are described in Section 4.3.2.4.

4.5.4.4.1 Permitted activity approach

The permitted activity approach resulted in a 40 per cent reduction in net profit after tax (interest, rent and depreciation) compared to the modelled steady state (Table 35). The risk assessment approach is discussed in the next section.

Table 35: Changes in nitrogen fertiliser applied to decrease yields to breakeven point and associated yields

	Permitted activity (%)	Risk assessment (%)
EBITRD/Cash farm working profit	-27.7	-2.6
Cash operating surplus/deficit	-27.1	-2.7
EBITR	-35.7	-3.5
Net profit before tax (after interest, rent and depreciation)	-35.7	-3.5
Net profit after tax (interest, rent and depreciation)	-40.0	-3.5

The reduction in profit from the permitted activity approach was primarily because of decreases in income from stock grazed or sold and/or feed sold (although there was an increase in crop revenue with the addition of maize silage and triticale silages in the permitted activity analysis).

Due to the change in the ratio of feed consumed under permitted activity conditions, grazing management needed to be adjusted to match feed supply and the resulting changes in effective area and feed production had a direct impact on the number of livestock farmed (Table 36). The beef cattle numbers were maintained at the expense of lamb and dairy cow grazing numbers to make sure the pasture was utilised through spring and autumn. The dairy cow numbers had the largest drop. On average across the rotation, the purchase date for winter lambs was brought forward to eat more autumn feed (i.e., March), which resulted in heavier lambs at processing.

Table 36: Changes in livestock between the steady state model and the permitted activity approach for intensive winter grazing

Livestock	Purchase			Sale			
	Number	$/head	Average date	Number		$/head	Average date
Winter lambs	-30%	-1%	Shifts from 10 April to 1 April		-30%	2%	Stays at 23 September
Bull beef	0%	0%	Stays at 1 December	R2	0%	0%	Stays at 10 May
				R3	0%	0%	Stays at 9 November
Cow grazing	Number of cows grazed -56%			Days cows grazed 72 (no change)			

The projected loss from the permitted activity pathway for this business is of a magnitude where in a similar situation, many arable farmers in Otago may shift towards pastoral farming. In some cases, it may occur through land sales and purchases, resulting in a loss of diversity in land uses and skills in the region. There would also be flow on effects to other sectors integrated with cropping and mixed cropping farms.

4.5.4.4.2 Risk assessment approach

The risk assessment approach resulted in a 3.5% reduction in net profit after tax compared to the modelled steady state (Table 35).

The risk assessment approach, where environmental actions are targeted to effects via a consent process or an audited Freshwater Farm Plan, resulted in capital expenditure for extra temporary electric fences. The expenditure was added to the term debt (and reflected in higher term interest costs), with increased depreciation was allowed for over a five-year period. An extra labour component, costed at $1,670 per winter grazing period, was added.

There were only small differences in the ratio of feed consumed under risk assessment approach and only small changes in grazing management were needed (Table 37).

Table 37: Changes in livestock between the steady state model and risk assessment approach for intensive winter grazing

Livestock	**Purchase**			**Sale**		
	Number	$/head	Average date	Number	$/head	Average date
Winter lambs	-1%	-1%	Shifts from 10 April	-1%	0%	Stays at 23 September
Bull beef	-1%	0%	Stays at 1 December	R2 -1%	0%	Stays at 10 May to 12 May
				R3 -2%	0%	Stays at 9 November
Cow grazing	Number of cows grazed -1%			Days cows grazed 72 (no change)		

A risk assessment alternative approach to the full exclusion of stock from CSAs would impose remediation of activities (e.g., larger catch buffer areas) that would vary from farm to farm. At Arable 4, ensuring brassica forages were undersown with species that can regrow to maintain ground cover, was included in the permitted activity bundle. However, in some instances it could be a fitting option in the risk assessment approach.

A risk assessment alternative approach would aim to utilise the rotation as a mitigation tool. The crop rotation is an important tool in arable farming because although the crops grown need to be marketable, the rotation itself is used as a tool to manage a range of agronomic issues within a farm's physiographic constraints. The integration of livestock (modified to match the supply of feed provided) is tailored within a crop rotation to help with:

- breaking soil-borne disease-cycle;
- managing seed contamination risk and weed burden;
- supplying enough feed to carry the appropriate number of livestock through winter as needed for seed crop; and
- improving soil quality (e.g., where pasture species are involved) in some situations.

For example, leaving a CSA uncropped or ungrazed on an arable farm puts it at risk of becoming weedy. Weeds can result in contaminating highly valued seed lines with undesirable species, and the produced seed is unable to be certified as 'pure', and so is unsaleable. There is a greater risk of herbicide resistance where the rotation becomes too limited and the ability to rotate through chemistry is reduced (using the same mode of action repetitively is one way to speed up the process of resistance)[167].

Arable 4 had fewer CSAs than the other three case studies in this research. If its production system was on a property with more CSAs, especially those that weave through the paddocks often connecting with one another as in Arable 2, then it is probable that some paddocks would need to be retired from seed cropping. In such a situation, livestock exclusion is extremely complicated for two main reasons:

1. Farmers are unlikely to risk planting a seed crop where they are unable to maintain a clean seedbed through forage crops, as it may not be possible to guarantee a pure seed line (leaving a CSA uncropped or ungrazed on an arable farm puts it at risk of becoming weedy).
2. Arable farmers tend to use scale to minimise costs. Larger machinery does not navigate boundary changes well and so often smaller areas are excluded from cropping.

4.5.4.4.3 Difference between the permitted activity approach and the risk assessment approach

The main difference between the permitted activity approach and the risk assessment approach was that the permitted activity approach resulted in less winter feed grown and a considerable change to the ratio of pasture to forage feed consumed. Pasture increased from just over 28 per cent of feed consumed to just over 41 per cent (i.e., +13%) from steady state to permitted activity conditions. The increase in pasture led to a higher proportion of grass silage being made (t dry Matter fed +139%, Table 38) and far less cereal silage fed to livestock (t dry matter fed -90%, Table 38). Any cereal silage not fed to livestock was sold.

Under the permitted activity rotation, a maize crop between red beet and milling oats was introduced. The area of kale sown between the steady state and both the permitted activity and risk assessment conditions decreased by 8.3% (Table 38). Although there was no difference between the area there were differences in yields as under permitted activity conditions the kale crop was modelled to be sown later (December) and there was a reduction in kale yields by 2.5 t/ha because plantain was included to ensure constant ground cover. With careful grazing the plantain will regrow after grazing, maintaining ground cover and continuing nutrient uptake in early spring.

167 New Zealand is developing an increasing number of herbicide-resistant weed populations, but still has a much lower incidence of herbicide resistance than Australia (Harrington & Ghanizadeh, 2023). One reason is Australia is much larger than New Zealand so greater areas of weeds are exposed to herbicides annually. Other reasons are higher rainfall in most parts of New Zealand allows much more crop rotation which means different modes of chemistry can be rotated (which reduces the risk of overuse of a particular mode of action). Greater crop yields also give New Zealand farmers more flexibility to use higher application rates and more expensive herbicides in rotation than is feasible in Australia. Dry conditions result in more use of summer fallows in Australia using glyphosate which has caused some of the problems. Selection pressure for resistance still occurs in New Zealand, so herbicide and crop rotation may just be delaying the appearance of resistance in this country.

Table 38: Changes in feed in area (hectares) and tonnes dry matter (t DM) from an additional environmental action (either as a permitted activity or a risk assessment approach).

Feed type	Change to permitted activity conditions	Change to risk assessment conditions
Fodder beet (ha)	-52%	-1.3%
Triticale/Oats (ha)	-36%	-1.6%
Kale (ha)	-8.3%	-8.3%
Straw fed (t DM)	-56%	-3%
Cereal silage fed (t DM)	-90%	0%
Pasture silage made (t DM)	+140%	-7%

4.6 Research Findings

Pasture or grass phases are an important component of any crop rotation as their roots restore or enhance soil structure, and the biomass cycling through animals accelerates the building of soil carbon/organic matter lost through cultivation of other crops. While some other large root mass species (e.g., cereals) also contribute to soil structure enhancement and build organic matter, pasture is the most effective option, provided it is grazed. The proportion of pasture within an arable farm's production system depends on many variables, including stock classes grazed, crop establishment methodologies, types of winter feeds grown, and climate and available resources. Reductions in winter feed crop area will have impacts across the rotation as there will also need to be reductions in grazed pasture or grazed seed crop areas to balance the farm's winter-summer feed balance. Depending on what they are replaced with, this may reduce soil quality if overall the restorative crops grown in the rotation are reduced.

4.6.1 Current environmental actions

The current financial position across the four case study farms was variable. Each farm encountered reduced profit as a result of the recent policy changes, with reductions in profitability (EBITR) varying from two per cent to fourteen per cent. The factors negatively impacting profit were less stock grazed and sold, increased costs of fencing, resource consents (upfront, auditing, and annual administration costs). The two farms with the greater profit reductions had a higher degree of land that moved from being in production to non-production (the steeper the land the greater the reductions in income).

4.6.1.1 Losses in asset values

Losses in asset values associated with the actions modelled on the case study farms can be used as a metric for assessing long-term viability. Land that has shifted from being productive to non-productive decreases in market value. This aspect is usually unfavourable to the landowner, especially when there is debt owed, effectively on those land areas that still need to be repaid (essentially the impact on the farmers' equity is magnified). Likewise, it is anticipated that other actions that mitigate environmental effects may result in a reduction in land value. For example, Muller and Neal (2019) modelled that a 20 per cent reduction in nitrogen leaching on a Southland dairy farm corresponded to a reduction of land value by 17 per cent.

The effective asset value of the four farms was estimated to have decreased by between 1.0 and 3.6 per cent to bring management up to current regulation. An investor considering these businesses would need to weigh up if the cost of borrowing/debt/capital (e.g., 6.0 per cent) would be a viable business decision, relative to the return on that capital for the four case study farms (which ranged from 3.0 to 6.8 per cent). Where the return on capital is lower than the interest rate, there is no profit margin on the money borrowed and as a result increased debt would further erode net profit.

4.6.1.2 Livestock exclusion

All four arable farm models included sheep and beef cattle enterprises. Where rivers were unfenced, a sheep proof fence was installed to protect waterways from winter grazing of both sheep (lambs) and cattle. While there are no registered wetlands or areas of 'natural significance' on the properties, there are areas that may be wetlands. The areas that may be wetlands are not currently cropped or grazed, and there is no impact on the carrying capacity of the blocks once livestock are excluded with a fence.

All four farms have reticulated water installed where both intensive grazing and intensive winter grazing occur, and no additional stock water reticulation was needed. However, many properties do not have stock water reticulated throughout and are likely to need considerable investment in stock water infrastructure upgrades to be compliant with the stock exclusion regulations. The fencing of all waterways not already fenced with a five-metre buffer had a negligible impact on the farm business as many waterways were already fenced or have a five-metre natural buffer between the arable land and the waterway.

4.6.1.3 Critical source areas (CSAs)

In many instances, important CSAs are already excluded from grain and seed cropping, and/or winter feed cropping. The exclusion of CSAs within paddocks used for winter grazing is a loss of productive land. Arable farmers design their crop rotations to integrate appropriate agrichemical management to reduce the need for pesticides, for example, by utilising grazing at various stages of the rotation. This strategy can reduce expenditure and resistance pressures and considers societal expectations to reduce pesticide use. Their decisions to reduce 'weed' burden of the next crop also helps break the cycle of host-specific diseases. Weeds establish when unmanaged areas of pastures or crops are left to go to seed.

An arable farm is likely to become weedy when a CSA is left uncropped or ungrazed through the duration of winter grazing of crop. Undesirable plant species can contaminate seed lines, resulting in the produced seed being unable to be certified as "pure", and therefore unsaleable. As an alternative, a grower can consider planting a short-term harvestable crop (silage cereal or annual ryegrass). However, planting a short-term species is often not feasible on a seed production farm as different types of grasses (Italian, annual, perennial, diploid or tetraploid) will remain in the ground and interrupt future grass seed production. Similarly, there may be a loss of subsequent cereal grain crop yields if cereal planting is not withheld for a period to break the life cycle of the cereal-specific diseases that can occur in forage cereals. It can also be impractical to fence off many CSAs during grazing to use the 'last-bite system'[168] because of the number and vein-like pathways the CSAs take within most paddocks.

168 A fenced off area, e.g., the bottom of a slope, left to be grazed last (immediately before establishing the next crop) so that it can act as an overland flow buffer.

The limitations to crop rotation, disease management and practicalities of break feeding, meant crop rotations were altered in some cases, removing winter grazing from some blocks. The primary focus of the analysis was to continue to graze CSAs while creating a grass buffer in the paddock downstream of the winter grazing paddock or a 10 x 10 metre terminal buffer[169] if the winter grazing paddock is adjacent to a receiving waterway. A 10 x 10 metre terminal buffer remained un-grazed as long grass or planted in sediment-trapping wetland plants as a means of capturing sediment contained in runoff. It is likely that terminal buffers will become a permanent feature of paddocks over time, but for this analysis they were only excluded while the paddocks are planted in forage crops for winter grazing.

4.6.1.4 *Intensive winter grazing areas*

Winter forage crops are grown to carry enough capital livestock through winter to make sure there is the best utilisation of either: a) the peak feed produced by pastures between November and February, or b) the seasonal grazing management demands of seed crops (e.g., grass seed, clover, or plantain). All the case studies exceed the permitted activity threshold for intensive winter grazing area[170]. They range from 55 hectares or 16 per cent of farm area to just over 300 hectares or 38 per cent. As discussed above, alternative crop rotations were considered to reduce the winter feed area, and so reduce the number of CSAs to be managed, but there were limited options.

On an arable farm, forage crops are selected based on the grower's seed and grain preferences and disease and seed contamination risk. Pasture or restorative grass phases are an important component of any crop rotation as their roots restore or enhance soil structure, and the biomass cycling with livestock accelerates the building of soil carbon/organic matter lost in cultivating other crops. While some other large root mass species (such as cereals) also help enhance soil structure and build organic matter, grazed pasture is the most effective. The proportion of pasture in an arable farm rotation depends on many factors including: livestock classes grazed, crop establishment methodologies, types of winter feeds grown, climatic conditions, and available resources. To reduce winter feed crop area, a farm needs to also reduce pasture or grazing of seed crop areas to maintain the winter/summer feed balance.

An alternative to retaining winter feed and maintaining the pasture area may be to sell stock in the autumn on a traditionally low market and buy back animals in the spring on a high market. This system was not included in the analysis for two key reasons. First, selling in the autumn to buy back in the spring is not as financially viable, incurring additional freight costs and an increase in greenhouse gas emissions. The livestock still need to winter somewhere, and by moving them off the arable farm only shifts the winter feed to another farm. The case studies were able to be restructured to operate within the current regulations (Section 4.3.1) with some relatively minor changes to management.

4.6.1.5 *Intensive winter grazing on slope*

Where practical, winter forage crops were removed from paddocks where sloping land is a relatively small proportion of the property, and it does not adversely affect the crop rotation.

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169 An area of land that is left in long grass or left ungrazed for the duration of the paddock planted in winter forage crops.
170 10 per cent of farm area or 50 hectares, whichever is the greater.

4.6.1.6 Catch cropping / fallow periods

Catch cropping, where cereals follow winter forage crops to capture excess nitrogen in the soil, is a well-established feature of arable farms. For some systems, main cereal crops such as triticale, wheat and barley could be planted early and dual-purposefully used as a catch crop as well as a main crop (e.g., whole-crop silage or grain). Arable farms have few fallow periods, because it is a missed opportunity for biomass production, and crop rotation is designed to have crops planted in close succession. The four case studies all have crop rotations that are designed to minimise fallow ground, therefore, there were limited opportunities for the four case studies to alter the crop rotations to reduce fallow periods. However, there may be other farms in Otago where there is an opportunity to introduce more catch crops and/or reduce fallow periods with short term cover crops.

4.6.1.7 Synthetic nitrogen fertiliser

None of the four farms assessed in this analysis exceeded the NES-F Nitrogen Cap of 190 kg N/ha/yr used to manage the use of synthetic nitrogen fertiliser on pastoral land. Therefore, no farm system or crop management changes relating to this were required or made. While this result is thought to be a reasonably typical of cropping in Otago, there will likely be some arable farm systems with similar rotations that trigger this limit.

4.6.2 Additional environmental actions

Otago-wide arable mixed-cropping farms are particularly diverse and are characterised by both complexity (e.g., due to the degree of integration with livestock and the range of crops grown) and flexibility (e.g., across a rotation). As a result, it is likely that new environmental actions will impact different farm systems, in markedly different ways.

The main finding from this research was that a flexible approach (based on a risk assessment that fit actions to risks) had fewer impacts on an arable farm business than fixed approaches because it offered opportunities to customise environmental actions (e.g., based on a farms risk profile as well as its system, rotation and topography). Importantly, a flexible approach was able to utilise the rotation as a mitigation tool. Rotations are an important tool in arable farming because although the crops grown need to be marketable, the rotation itself is used as a tool to manage a range of agronomic and environmental issues within a farm's physiographic constraints (in the same way that there are regional provisions relating to land use), an individual farm may span multiple Land Use Capability classes that inform how the rotation may be used as a tool).

A common concern that came through in the farmer interviews was that fixed approaches may be unfit for purpose.

- "If the system is too tight and there is no room to flex, then it is more difficult for farmers to find solutions".
- "We want to be more sustainable and look after what we have already. Need to incentivise good management practices which work with the actual issues".
- "One size does not fit all – the same action may solve an environmental problem on one farm but create an environmental problem on another farm".
- "Perverse outcomes are inevitable as soon as you try to lock in something you think is a silver bullet".

If cropping farmers are unable to apply nitrogen fertiliser in September, an example of an unintended consequence would be that it may inadvertently encourage them to apply fertiliser prior to 1st March to front load before winter when they are 'allowed' to apply nitrogen. Although environmentally risky due to risk of nitrogen leaching over winter, the hope would be that it would still be available to support strong spring growth necessary to optimise yields.

Other than a farmer's skills, there is no simple explanation for a farm's viability as a business or its environmental footprint. The economic impact of the fixed vs flexible approach will differ depending on the business in question. In the worst-case, arable farmers in Otago may shift towards pastoral farming. In some cases, it may occur through land sales and purchases, resulting in a loss of diversity in land uses and skills in the region.

There will also be flow on impacts to other sectors integrated with arable cropping. Likewise, the impacts of the two approaches on environmental externalities will vary depend on the business. Overall, a flexible approach on externalities (e.g., nitrate leaching and overland flow) has the potential to be more effective than a fixed approach as long as the journey of continuous improvement emphasises the importance of thorough and robust risk assessments.

4.6.2.1 Changes in the nitrogen fertiliser regime

The impacts on reducing nitrogen application rates will depend on the business. For the case study farm where the impact of changing the nitrogen fertiliser regime was investigated (for all crops on that farm in one year), on average an eight per cent reduction in nitrogen application rates resulted in reaching the break-even point for growing that crop (beyond which would be grown at a loss). The impact of not being able to apply nitrogen fertiliser in September to spring sown crops was financial unviability for these crops even without any rate reductions. Early spring growth is important on arable farms agronomically to optimise yields and environmentally by promoting ground cover which reduces sediment loading in runoff events. Inadvertently it may encourage farmers to apply fertiliser prior to 1st March in the hope that it will still be available to support strong spring growth necessary to optimise yields (at the risk of increasing nitrogen leaching over winter).

4.6.2.2 Overland flow management options

For the case study farm where overland flow management options were investigated by comparing a fixed approach to a flexible approach (based on a risk assessment that fit actions to risks), there was a 10.8 per cent and 3.7 per cent reduction in profitability (EBITR) compared to the steady state for the fixed and flexible approach respectively.

A risk assessment identifies where there may be areas on the farm where setbacks need to be wider than other areas of the farm. The exercise is best carried out on a farm-by-farm basis as one size rarely fits all situations. A risk assessment helps identify actions that fit the scale and character of the risk from a tool kit of actions (interception drains, culverts, diversion bunds, benched headland, swales, sediment traps, silt fences etc).

4.6.2.3 Variable rate nitrogen capability

Where farmers are already using nitrogen efficiently and including soil supply into their fertiliser rate calculations there can be opportunities to further reduce nitrogen use by investing in variable rate technologies. However, the extent to which variable rate technologies will further reduce nitrogen fertiliser without reducing yields depends on topography and variability. For the case study farm where variable rate nitrogen capability was investigated, the impact of variable rate fertiliser capability was also shown to vary depending on economies of scale. The results suggest that investment in variable rate technology may be a viable opportunity for some businesses but not for others.

4.6.2.4 Management of winter grazing options

For the case study farm where management of winter grazing options were investigated by comparing a fixed approach to a flexible approach (based on a risk assessment that fit actions to risks), there was a 35.7 per cent and 3.5 per cent reduction in EBITR compared to the steady state for the fixed and flexible approach respectively.

The risk assessment approach focused on managing adverse effects. It aimed to maintain the use of the rotation as an important tool for weed and disease management and made alterations to grazing. A risk assessment alternative approach to the full exclusion of stock from CSAs would impose remediation of activities (e.g., larger catch buffer areas) that would vary from farm to farm.

Removing livestock from mixed rotations may have an unintended consequence of increasing pesticide use and introduce considerable risk to the production of disease free, pure seed lines. Quality seed lines are the ultimate driver of value in an arable business and New Zealand's primary sector as a whole.

Image 32: Otago, and New Zealand more generally, is well suited for small seed production because the cool temperatures and day length associated with its latitude drives reproductive growth.
Source: Emma Moran

5 Dairy Farming

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5.1 Summary

Dairy farming characteristics vary across Otago, with the highest number of dairy cows and largest area of dairy land in the Clutha district. Waitaki and Central Otago districts have larger herd sizes and Waitaki the highest stocking rate when compared across the region. A higher stocking rate in the Waitaki district probably reflects the use of irrigation on farms.

Ten case study farms were selected to represent a spread of different variables; locations, soils, irrigation types, farm production systems and profitability. The modelling of case study farms tested the economic implications of achieving Good Management Practice (GMP) as defined for dairy farms in Otago, and environmental actions beyond GMP, so called GMP+.

The environmental actions were also assessed regarding reductions in: nitrogen (N) leaching, phosphorus (P) loss, and greenhouse gas reductions (GHG). Several actions reduce more than one contaminant and can also improve water use efficiency. The actions' effectiveness for sediment, *E.coli* or water quantity was not quantified, but are mentioned for those environmental actions that are likely to have multiple effects.

Several national regulations and regional plan rules have been introduced over the last couple of years, of which some are yet to be fully implemented on farm. These have been assessed as part of GMP or GMP+, bringing farms up to the current policy baseline.

Some key findings for this research are:

GMP leads to small profit and nitrogen leaching reductions, reflecting the farm's starting point. Farms with relatively lower baseline nutrient losses only experienced a small decrease or improved operating profit, and achieved smaller reductions in nitrogen leaching, compared to farms with relatively higher baseline nitrogen leaching.

Big nitrogen leaching reductions are costly since they are primarily associated with infrastructure changes, such as irrigation equipment upgrade and wintering barns (GMP+). In this modelling it was assumed that changes made on farm should not lead to an increase of losses of another contaminant or GHGs. That meant that the cost increase for changes to infrastructure can not be offset by an increase in production since it could lead to a pollution swap. Intensification of the farm system has previously been a way of financing the investment. However, under current regulatory frameworks, this is no longer feasible or a preferred solution.

However, large investments in wintering barns are not necessarily driven by financial or environmental reasons. Previous studies have shown that the main reason farmers invest in barns is to improve management, for example to improve conditions for staff and cows and reduce reliance on contracts for winter grazing. The main reasons for environmental decision making is not always well understood and would benefit from further research.

Using plantain as part of the pasture mix is cost effective but more research specific to the conditions in Otago is needed, to be sure its use as an environmental action is practically feasible for dairy farms in the region.

In some cases, nitrogen leaching is influenced more by soil type and rainfall than on-farm N- use efficiency.

An overall finding is that both the cost of implementing relevant environmental actions and the reductions in nutrient losses that result are largely specific to each farm. Each farm is unique in terms of the existing state and what may be practically achievable. What may be effective and viable for one farm may not be for another.

5.2 Introduction

Farmers are increasingly facing the need to make economically viable decisions that provide improved outcomes across a range of different environmental factors, including freshwater quality and quantity, greenhouse gas emissions and biodiversity. It is important to understand which levers are available for farmers to pull and their implications for farm business and environmental outcomes.

To contribute to this understanding, a range of environmental actions were tested for ten case study dairy farms across the Otago region. The relative effectiveness of these actions was assessed in terms of effects on nitrogen (N) and phosphorus (P) loss, greenhouse gas reductions (GHG) as well as the economic implications of those actions on operating profit.

Dairy farming in Otago is diverse, representing different farm systems and management preferences depending on location and biophysical factors such as rainfall, soil type and topography. The industry was described in some detail in Chapter 6: Dairy Farming (Ross, 2022) of the[171] "*Farmers and Growers in Otago*" Report and only a subset of characteristics presented here.

Since the 1990s, dairy farming has expanded in Otago – although to a lesser extent than in Canterbury and Southland over the same timeframe. By 2020-21 Otago represented roughly four per cent of New Zealand's dairy herds, 5.6 per cent of the dairy cows, and 5.4 per cent of its dairy land (effective hectares not total hectares). Dairy farming in Otago increased substantially from the early 1990s but since 2013, industry growth has plateaued and is now quite stable in terms of the regional dairy herd (i.e., number of cows in milk), land area and herd size.

The distribution, location, and size of dairy farms varies across the region. Clutha and Waitaki are the main dairy districts with 46 and 33 per cent of the region's dairy herds respectively. Broadly speaking, dairying in Clutha (South Otago) has similarities to Eastern Southland, while dairying in Waitaki (North Otago) tends to have more in common with how it is occurring across the Waitaki River in South Canterbury. Herd sizes in Waitaki and Central Otago Districts are a similar size to those in Waimate and Timaru Districts, and are typically larger than those in Clutha and Dunedin Districts. Herds in Clutha District are a similar size to those across the Southland region.

171 Moran, E. (Ed.) (2022). *Farmers and Growers in Otago*. EM Consulting for Otago Regional Council (LWRP Economic Work Programme), Dunedin.

Image 33: Dairy cows (mixed breeds) on rolling country in South Otago.
Source: Luke Kane

Otago Regional Council has divided Otago into five freshwater management units (FMUs) and the Clutha Mata/Au is further divided into five Rohe (areas). To decide on FMUs is a requirement for all regional councils and will be used to set freshwater objectives and limits in the regional Land and Water plan[172]. Of the approximately 450 dairy farms in Otago, around 180 are in the Lower Clutha Rohe (part of Clutha Mata Au FMU) and approximately 140 in North Otago FMU (Table 39).

North Otago FMU has almost 100% of dairy land under irrigation compared to around 17 per cent in the Clutha Mata-Au FMU. Total irrigated dairy land in Otago is just above 40 per cent of the total effective area used for dairy in the region, based on numbers for 2020/21.

Table 39. Number of dairy farms in Otago in 2020 (total dairy farms = 455) and dairy land use for FMU and Rohe[173].

FMU	Clutha Mata Au					Catlins	Dunedin	North Otago	Taieri
Rohe	Upper Lakes	Lower Clutha	Roxburgh	Dunstan	Manuherekia				
Number of dairy farms	0	183	0	1	13	27	25	140	66
Dairy land use (ha)	42,580					5,257	5,308	27,237	14,040

Source: Number of dairy farmers based on DairyNZ data and official FMU / Rohe boundaries from ORC data portal (August 2022). Dairy land use based on Otago Regional Council land use analysis based on Great South's land use map.

172 Find your area | Otago Regional Council (orc.govt.nz) Retrieved 7/05/2023.
173 Moran, E. (Ed.) (2022). Farmers and Growers in Otago. EM Consulting for Otago Regional Council (*LWRP* Economic Work Programme), Dunedin, p198.

5.3 Methodology

The methodology chosen for this project has been used in previous work by the DairyNZ modelling and economics team and is well established, including the modelling tools chosen. However, even with a well-established methodology, it is important to remember that the scenarios are modelled only and as such, must be seen as estimates of the impact on businesses and of risk to the environment.

5.3.1 A case study approach

The ten case study farms are spread across the Otago region and are diverse in respect of soil types, soil drainage, rainfall, farm systems, farm infrastructure, irrigation systems and farm management. There are important differences in the distribution, location, and size of the dairy farms across the region driven by variability in climate, topography, and soils. These variables dictate the need for irrigation, and on-farm management, for example selection of dairy effluent system and wintering practices.

A case study approach was chosen rather than developing an 'average farm' and testing environmental actions against that 'average farm'. The case study approach, drawing from real life working farms, was preferred because it provides an opportunity to understand how specific farm systems that are influenced by these variables, will respond to environmental actions that reflect the specific farming context (M. Newman, Principal Economist MPI, pers. comm., April 2023). A case study approach is preferred because:

- Each farm is unique in terms of soil types and drainage, rainfall, farm system, and management ability, which are better reflected in the use of case studies compared to modelling an 'average farm'.
- Including a range of farms helps describe the likely distribution of impacts and understand the impacts for different productions systems.
- Case study modelling avoids the need to create aggregate models which need detailed assumptions around variables associated with farming nutrient loss and production, for example soil type/s, fertiliser use, infrastructure, etc.
- Compared to modelling against an 'average farm', modelling case study (actual) farms provides a higher degree of confidence that the modelling is applicable to a 'real life' farming operation, which makes the modelling more relevant when discussing the actions with farmers and decision makers.
- Some environmental actions are not suitable for some farms; a case study approach recognises this reality.
- Individual farms also have differences in terms of crop management, wintering, stock management etc. It is important to capture these factors, particularly where the modelling is focused on setting out environmental actions that are within the farmer's scope of control.

The case study approach may limit the purposes for which the findings may be used. Additional analysis of the regional economic impacts will be needed if considering how findings from case studies impact the regional economy (i.e., how to upscale the results from a local to a regional level). Further work is also needed to consider how the findings of case studies may be used to inform and test policy settings at different spatial scales.

5.3.1.1 *Selecting the Case Study farms*

The ten case study farms are equally divided with five farms in North Otago and five in South Otago. The ten farms were selected to cover a range of soil types and soil drainage, rainfall, farm systems, farm infrastructure, irrigation systems and farm management; different variables that will affect a farms environmental footprint.

Information on these farms was drawn from the MPI Farm Monitoring and Benchmarking Programme, which relies on the DairyNZ National Baseline Project. The National Baseline Project collects farm physical, financial and environmental data, which is then added to the DairyNZ DairyBase database.

Inputs of the environmental data were used to create a farm Overseer file. The 2020-21 season was chosen as the baseline year against which environmental actions and operating profit would be compared, as the 2020-21 season was the most recent year with a complete data set.

5.3.1.2 *Overview of farm characteristics*

The selected farms vary in size, stocking rate (number of cows per hectare), production and inputs (for example fertiliser use). The farms located in South Otago (D1-D5) in general had a lower stocking rate compared to the North Otago farms (D6-D10).

Dairy farms (D6-D10) are all irrigated, reflecting their location in North Otago where the dry summers do not necessarily provide reliable pasture production without irrigation. Two of the three most profitable farms have border dyke irrigation. Border dykes are cheaper to operate than most other irrigation types, but many different factors influence profitability, such as a farmer’s skill levels. The reasons for a farm’s nitrogen losses are similarly complex.

Dairy farm 1 is highly profitable, but also has the most bought in feed as a share of total feed, and lowest nitrogen loss. It is not irrigated hence it does not incur those expenses, but it is likely to only be a part of the explanation.

The irrigated farms also have a slightly higher stocking rate (cows per hectare) compared to the non-irrigated farms. Increasing the number of cows, and hence production, has in the past been a way of financing investment in irrigation infrastructure. Irrigation also means a more reliable access to feed throughout the season, and this can support more cows. Under the Resource Management (National Environmental Standards for Freshwater) Regulations 2020, increasing irrigated dairy land area is no longer a realistic option to finance costly changes to the irrigation system. This has been reflected in the modelling assumptions and further explained in that section.

Another consideration is where wintering of stock (dairy cows and replacement stock) is taking place when assessing the environmental footprint of a farm, and how any changes to the farm system might change its footprint. Wintering of dairy cows can be done on farm or using a grazier.

All the South Otago farms (Dairy 1-5) and one North Otago farm (D9) were self-contained, with all livestock grazed on these properties during winter. This means that for these farms, diffuse discharges are not ‘exported’ since the modelling includes the support block. Nutrient discharges on these farms continue throughout the season, whereas some farms with higher stocking rates may ‘winter off’ stock, reducing the diffuse nutrient losses on the farm.

Dairy 5 has a wintering barn and a covered stand-off pad and all cows are wintered inside. The effluent from the barn and stand-off pad is used as a nutrient source which means only a small amount of additional nitrogen fertiliser is used. Very little supplement feed is imported, which means the farm has one of the lowest nitrogen surpluses of the 10 farms, as seen in Figure 70.

The nitrogen surplus for the ten farms farm was calculated using Overseer, in addition to estimating the nitrogen leaching for the baseline year. Nitrogen surplus is the balance between nitrogen inputs and nitrogen outputs and in this case, includes the nitrogen fixing capacity of clover. It is an indicator of how efficiently the farming system is using nitrogen[174] but is not directly corelated to estimated nitrogen leaching risk. It is shown in Figure 70 for each of the ten farms.

Nitrogen inputs into the farm system, how efficiently they are used and how they are recycled will drive nitrogen losses to the environment. That is why the level of nitrogen fertiliser on its own cannot explain the baseline nitrogen leaching. Other factors will also ultimately influence the level of nitrogen loss from a farm system, such as soil texture, drainage, and rainfall (or the use of irrigation). An overview of options for dairy farmers to reduce nitrogen losses from their farm system can be found on the DairyNZ website[175]. Several of these actions have been tested in this work.

The main pathways for contaminant losses from land to water are explained in Sections 2.3.2 and 2.3.3 of Chapter 2: Sheep and Beef Farming (and illustrated in Figure 9).

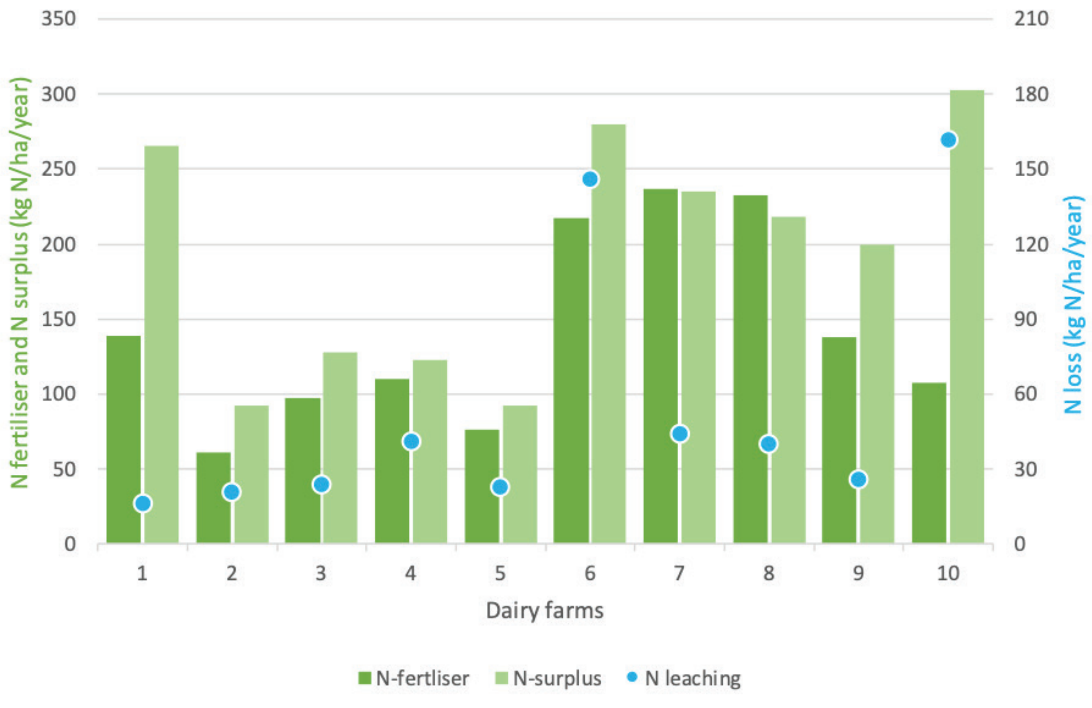

Figure 70: A comparison of nitrogen metrics for 10 dairy farms in Otago for 2021-22
Source: DairyNZ

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174 *What is N surplus and how is it calculated? – Overseer Knowledge base* Retrieved 17/05/2023.
175 *Reducing nitrogen loss - DairyNZ*

The use of synthetic nitrogen fertiliser for the baseline year 2020/2021 ranged from 61 kg/ha/yr to 237 kg/ha/yr, with an average of 142 kgN/ha/yr for the 10 case study farms (Table 40). The Resource Management (National Environmental Standards for Freshwater) Regulations 2020 introduced a synthetic nitrogen fertiliser cap of 190 kg N/ha/yr, which is now in effect. This is something all pastoral farmers need to comply with from 1 June 2021, which means that any use above 190 kg of N/ha/yr would need to decrease unless a non-complying resource consent has been applied for and granted. Meeting the nitrogen cap was modelled as part of GMP.

The median nitrogen leaching for the ten farms for the baseline year (2020/2021) was 33 kg N/ha/yr and the average was 54 kg N/ha/yr. The gap between median and average suggesting the population of dairy farms in Otago has a skewed distribution towards lower nitrogen loss results with a long tail of higher results. The nitrogen leaching varied with a low of 15 kg N/ha/yr per year and a high of 162 kg N/ha/yr, the high leaching reflecting the use of border dyke irrigation.

The use of phosphorus fertiliser for the ten case study farms ranged from 3 kg P/ha/yr to 45 kg P/ha/yr, with an average of 28 kg P/ha/yr for the baseline year. The median phosphorus loss for the ten farms was 2.3 kg P/ha/yr and the average 1.6 kg P/ha/yr. The annual phosphorus loss varied between 0.6 kg P/ha/r and 6.5 kg P/ha/yr, with the higher losses reflecting the use of border dyke irrigation.

Table 40: Use of nitrogen and phosphorus fertilisers, and estimated nitrogen leaching and phosphorus loss (kg/ha/yr) for 2020-21 for the 10 case study farms

	Low	**High**	**Average**	**Median**
Nitrogen fertiliser	61	237	142	124
Phosphorus fertiliser	3	45	28	27
Nitrogen leaching	16	162	54	33
Phosphorus loss	0.5	6.5	2	0.7

A selection of farm characteristics for the ten farms is given in Table 41. Effective hectares are used which excludes hectares that are not grazed (ineffective hectares), such as houses, shed, tracks, bush, water bodies and steep areas, but includes both milking platform and support block, if applicable. The ineffective land areas will have a different nutrient loss than effective areas.

A more detailed overview of the characteristics of each dairy farm is given in Appendix 1 of this chapter.

Table 41: Overview of farm characteristics for ten dairy case study farms for 2020-21

Farm (Dairy 1 to Dairy 10	Total area (ha)*	Support block	Stocking rate (cows/ha)	Milk solids (MS kg/ha)	Irrigation type	Bought in feed (%)	Operating profit (EBITR/effective ha)**
D1	243	No	2.6	1,400	None	28	$4,600
D2	290	Yes	2.3	900	None	3	$2,400
D3	519	Yes	2.2	1,100	None	12	$1,500
D4	427	No	1.7	670	None	4	$1,700
D5	540	Yes	1.9	800	None	1	$770
D6	166	No	3.3	1,300	Border dyke	12	$4,100
D7	118	No	3.4	1,300	Travelling	4	$2,700
D8	190	No	2.8	1,400	Spraylines	7	$3,400
D9	373	Yes	3.0	1,200	Pivot	12	$3,000
D10	130	No	3.7	1,900	Border dyke	17	$5,500

**This includes the area of the milking platform and the support block for those farms that have a support block.*
*** Earnings Before Interest and Taxes and Rent (EBITR) at a milk price of $6.75/kgMS.*

5.3.2 Modelling

Each case study farm was modelled in Overseer FM (version 6.4.3)[176], to determine changes in nutrient losses (as well as GHGs), first establishing a baseline for the 2020-21 season, and then testing different environmental actions in steps, often accumulating. The focus of the Overseer model is mainly on the effects of farm system changes on nitrogen and phosphorus losses as a priority, but greenhouse gas (GHG) emissions have also been assessed. Overseer does not capture the effectiveness of actions for other contaminants that are relevant to freshwater quality: sediment and *E. coli* in particular. However, several of the actions tested through Overseer will influence more than one contaminant as well as water use efficiency, and this is discussed in the results.

FARMAX (version 8.2.0.16) was used to determine the impact of the environmental actions on operating profit and to ensure the environmental actions tested for each farm are biologically feasible.

Overseer[177] and FARMAX[178] are tools that have been used by the primary industry for a long time, chosen because they are well established and well understood. Both have been subject to scrutiny aimed at establishing and recognising model limitations[179]. The actions modelled were a mathematical representation of farmers' maximizing profit (revenue minus costs) subject to environmental and other

176 A decision tree included as part of the Southland Economic Project: Agriculture and Forestry Report provides a flow diagram of mitigation options relevant to Overseer. See page 227 of *Agriculture and Forestry Report.pdf*
177 See *Overseer - Supporting New Zealand's primary industries*
178 See *FARMAX - Home*
179 Overseer, in particular, has been subject to substantial review. See *46360-Overseer-whole-model-review-Assessment-of-the-model-approach (mpi.govt.nz)*

capacity constraints. For the purposes of this work, unless otherwise stated 'cost' or 'economic cost' refers to the costs to the farm business and not wider economic cost, which includes both market and non-market components.

Three main steps were used to test environmental actions.

1. Actions already required under current legislation that may not be fully implemented on all farms.
2. Actions considered Good Management Practice (GMP) for dairy farming in addition to what is required under current legislation.
3. Actions beyond Good Management Practice (GMP+), in addition to both GMP and what is required under current legislation.

For each farm the aim was to apply relevant environmental actions in different steps to assess the impacts on operating profit and changes in nutrient losses and GHG emissions from the 2020-21 baseline. GMP actions were applied to each case study farm, to establish if further reductions were possible, and to establish the marginal cost of those reductions. The full suite of GMP actions were not tested on all farms since some were already in place on some of the farms. However, the aim was for all farms to meet GMP before adding further GMP+ actions.

A second tranche of environmental actions, GMP+, were applied in addition to meeting GMP. These GMP+ actions were staggered from the lowest cost to highest cost and applied until the suitable GMP+ actions were exhausted. Whereas GMP actions are those considered to be applicable to all dairy farming operations, the GMP+ actions modelled include practices that will likely have a considerable impact on the farm's operating profit and are not suitable for all farms.

The GMP+ actions modelled for each farm were determined by the farm nutrient hot spots, cost-effectiveness, practicality and current farm system. As a result, the environmental actions applied to each farm were different, responding to the specifics of that farming system. A summary of the actions modelled for each farm is available in Appendix 1 of this chapter. Similar strategies have been applied and peer reviewed over time in other projects, including The Southland Economic Project[180].

Not all the environmental actions that farmers have at their disposal have been tested, mainly because some actions are not suitable to assess with the chosen models. Other variables may complement the impact analysis: costs reductions, productivity changes, or changes on business strategy.

5.3.2.1 Actions already in place due to current legislation

Several regulations relevant to dairy farmers in Otago are either in place or will be shortly. Some farmers will have already begun to implement these requirements, although it cannot be assumed this applies to all farmers. The following national regulations and regional rules are relevant for this work.

Dairy Farm effluent (both application and storage). New regional rules relevant to the storage and application of dairy farm effluent in Otago were made operative on 4 June 2022[181]. The implementation of the rules is staged over several years which means some farmers are likely to have started adopting the rules while some are still planning for an upgrade, or new effluent pond. The requirements in place for effluent storage and application were partially covered in the GMP actions applied to each farm.

180 *Economy - Environment Southland (es.govt.nz)*
181 *Animal effluent storage and discharge | Otago Regional Council (orc.govt.nz)* Retrieved 18/05/2023.

Cap on synthetic nitrogen fertiliser. On 1 July 2021, a cap on the application of synthetic nitrogen fertiliser for land grazed by livestock took effect nationally. On grazed pasture, farmers can no longer apply more than 190 kg of synthetic nitrogen per hectare per year (190kg N/ha/year) without resource consent. This has been included in the GMP actions applied to each farm.

Stock exclusion. New rules requiring the exclusion of stock from waterways were introduced with the Resource Management (Stock Exclusion) Regulations 2020[182]. These require the exclusion of all dairy cattle from lakes and rivers (wider than 1 metre anywhere on that landholding) by June 2023. Given the proximity of these pending requirements and given stock exclusion from waterways has been a key focus for the dairy industry for over a decade, the modelling assumes stock exclusion is already in place.

Intensive Winter Grazing. New regulations governing this practice came into effect on 1 November 2022. Intensive winter grazing means grazing livestock on an annual forage crop, such as kale or fodder beet over the winter period, defined as anytime between 1 May and 30 September[183]. Wintering practices have been partially covered in the modelling.

Stockholding areas. Minimum standards which apply to feedlots and other stockholding areas such as feed pads, stand-off pads, winter pads and loafing pads were made operative in September 2020[184]. These have been included in the modelling related to GMP+ actions.

5.3.2.2 Good Management Practice (GMP)

Good Management Practices (GMP) are environmental management practices expected for sustainable dairy farming in New Zealand and are developed and supported by all dairy companies[185] They are a set of criteria that the dairy industry expects all farmers to be meeting or working towards meeting over time. They are considered appropriate because they provide clarity for farmers and modelling has shown that they will drive environmental improvements. While GMP set minimum criteria, in many cases national, regional or catchment-based plans or consents may require individual farmers to meet additional practice standards.

GMPs are generally more accessible to farmers than GMP+ and usually less reliant on advancing technology. GMP actions are also generally cheaper to implement, but there are no criteria for GMP to be of low or minor costs. Fencing and planting waterways and critical source areas, and providing stock crossings, for example, are actions that are not cheap. Some GMP's incur opportunity costs such as taking land out of production where it is of higher environmental risk.

Good Management Practice (GMP) was applied to all farms. GMP for dairy farming in Otago has been defined with the following practices and is based on dairy industry agreed GMP[186]. Not all practices defined as good management practices for dairy have been included since some actions are difficult to model with the chosen models or due to lack of information for the case study farms.

182 *Resource Management (Stock Exclusion) Regulations 2020 (LI 2020/175) (as at 05 January 2023) – New Zealand Legislation*
183 *Intensive winter grazing | Ministry for the Environment*
184 *https://www.legislation.govt.nz/regulation/public/2020/0174/latest/whole.html#LMS364219*
185 *sustainable-dairying-annual-report-protecting-our-environment-2022-v141.pdf (dairynz.co.nz)*
186 The dairy industry now more generally refers to this work as Good Farming Practice Principles (GFP), instead of GMP. GMP is used in this report since it is a familiar concept.

Actions used in the GMP scenario:

Water use and irrigation – GMP actions are applied with a view to achieving 85 per cent irrigation efficiency based on agreed technical metrics[187] to manage the amount and timing of irrigation to minimise risk of leaching and run-off. These actions are not applied to border dyke irrigation.

Nitrogen use efficiency – Timing of fertiliser is controlled so that it is not applied during the drainage period from May to August. Application rates of fertiliser are controlled so that they do not exceed 40 kg N/ha per application, with no more than 190 kg N/ha applied to pasture for a season (measured at a block level).

Nutrient recycling (effluent management) – Use of existing off-paddock structures like stand-off pads, wintering pads and feed pads are optimised during wet periods to avoid pugging damage and nutrient losses. The area of effluent application is sufficient for application rates to not exceed 150 kg N/ha/year, with an increase in the area to which effluent is applied if 150 kg N/ha/year is exceeded. If the effluent area is increased, application is only on suitable soils with appropriate (low slope) topography. Spreading solids to a non-effluent block is also considered, where applicable. Effluent is modelled as a nutrient source, with the effluent block receiving less bagged nitrogen fertiliser compared to a non-effluent block[188]. An unquantified benefit of effective nutrient recycling is that it also reduces the loss of sediment and faecal matter (*E.coli*).

Cropping - Direct drilling of crops is used to minimise losses of sediment and nutrients to water. Catch-crops are used to limit exposure of bare soil between crops and pasture. Cropping occurs only in appropriate paddocks, with cropping avoided on slopes and next to waterways. Fertiliser is applied at a rate that does not exceed agronomic optimal fertiliser application rates. Better cropping practices also reduce sediment loss.

Image 34: Winter crop paddock and baleage ready for grazing (with riparian planting). Source: Emma Moran

187 See Ian McIndoe's Statement of Evidence Available at [Ian McIndoe Statement of Evidence to Canterbury Plan Change 5.]
188 For costs capture annual capital depreciation and interest repayments costs. All capital expenditures are captured as depreciation, R&M, and interest.

5.3.2.3 Actions beyond GMP (GMP+)

Further environmental actions were applied, listed as GMP+, to reduce nitrogen and phosphorus losses beyond GMP and to assess changes in operating profit. The GMP+ actions modelled for each farm were determined by technical assessment of the farm nutrient hot spots, cost-effectiveness, and practicality of application for the action, staggered from the lowest cost to highest cost.

The list of environmental actions outlined in this section were selected by DairyNZ's technical experts as those most commonly available and appropriate to test for the modelling purpose. The selection was based on previous discussions within the stakeholder group and with the ORC science team. There are other options beyond those listed that may be applicable. Some actions not modelled are for example environmental actions commonly referred to as edge of field mitigations for example wetlands, riparian planting and variable width grass filter strips along water ways.

The following actions were selected as GMP+:

1. Culling early, with 90 per cent of the known culls gone by March, meaning that feed demand will decrease, which will also reduce autumn urinary nitrogen deposition.
2. Substitution of high protein feed with low protein feed.
3. Growing and use of plantain as feed. Plantain increases urine volume and urination frequency and so reduces urinary nitrogen concentration, partly because the plant contains more water than perennial ryegrass commonly used as a pasture species. These combined effects reduce urinary nitrogen load in the urine patches and increase chances of pasture uptake of urine nitrogen[189].
4. Reduce the cropping area by considering higher yielding crops e.g., shift from kale to fodder beet and no wintering crops, instead using baleage wintering. Reducing crop area reduces soil organic mineralisation and low protein, high quality feed crops, such as fodder beet, reduce urinary nitrogen excretion by animals.
5. Upgrade irrigation equipment if 85 per cent efficiency target cannot be met with current infrastructure. This includes upgrading from border dyke irrigation to more efficient centre pivot irrigation. Improved irrigation efficiency reduces drainage and lowers the chances of nitrogen leaching, as well as decreasing the volume of water used.
6. Building of a covered composting barn with a concrete feeding apron. Standing cows off pasture in winter and autumn reduces urinary nitrogen deposition onto paddocks at the time of year when urinary nitrogen is most at risk of leaching, also when pasture growth rates are low and/or when drainage events are likely to happen.
7. For application of phosphorus (P):
    a. If the farm has Olsen P levels above the agronomic optimum, then these are reduced to the agronomic optimum.
    b. If the farm is suitable for the use of RPR[190], any phosphate fertilisers are swapped to RPR.

189 *Environmental benefits of plantain – DairyNZ* Retrieved 26/04/2023
190 RPR is a reactive rock phosphate which is a slow-release phosphate fertiliser option.

5.3.3 Modelling assumptions

A range of technical assumptions were used in the modelling.

Low nitrogen feed – this could mean replacing imported high protein feed with low protein feed or reducing nitrogen fertiliser then importing low protein feed. This action was only considered where animal protein requirements were being exceeded and only where there was the infrastructure and capacity to accommodate the new feed.

Plantain – it was assumed that one third of the farm was replanted with plantain annually at a cost of $150 per hectare. The target was to achieve 30 per cent plantain in the pasture mix and diet. There was no marked change in pasture production or the growth profile.

Baleage wintering – it was assumed there were no winter crops, but instead cows were wintered in low pasture cover paddocks and were fed 12kg DM/cow/day of imported baleage. No stand-off structure was required if no pasture and soil damage occurred, but, if it did, then a stand-off structure was considered necessary.

Change in irrigation from border dyke to pivot irrigation – the assumptions used were:

- $3,000/ha for equipment and installation[191]
- $3,000/ha for associated costs e.g., fencing, tree lines, levelling borders, re-grassing, shifting water troughs
- Annual costs equalled depreciation, assuming a 20-year life for the equipment
- A seven per cent interest rate was applied to equipment purchase and installation and associated costs
- Increased electricity charges of $200/ha
- Maintenance costs were increased by $50/ha
- Pasture production increased by 5 per cent between October and March
- Increased pasture production was used to reduce imported supplements

Composting barn with a concrete feeding apron (wintering barn) – the assumptions applied were:

- A cost of $3,000 per cow to build the wintering barn, including associated costs
- Annual costs equalled depreciation, assuming a 25-year life
- A seven per cent interest rate was applied to borrowing costs
- A cost of $85 per cow per year was applied to the purchase and removal of bedding
- Cows were in the barn for 24 hours a day in June and July, and for six hours a day in August and from March to May
- Intensification was not provided for or allowed as a method to recoup the costs associated with the wintering barn, as that would have increased greenhouse gas emissions

191 In practice the cost can vary depending on the shape of the farm, as some areas might not be reachable with the pivot and k lines, or fixed grid might need to be used, or might need semi-circle pivots. Also, additional features like variable application rate and effluent lines on the pivot can substantially increase the purchase and installation cost.

Milk price – a milk price of $6.75/Kg MS was applied to all modelled farms. This price is the 10-year average milk price between 2011-12 and 2021-22 and is within $1/Kg MS of this level in seven out of the ten years over this period[192].

Labour – modelling assumed that small changes in cow numbers, when adopted as an action did not reduce labour requirements and farmers would still incur the same labour cost[193].

Management wage – the modelling includes labour, both paid and unpaid such as management and family labour commitments. However, to calculate the cost of producing milk, an economic value must be assigned for a reasonable economic analysis, and this remained a fixed cost through the actions.

Administration, insurance, weed and pest control and rates - the assumption was that these costs remained fixed throughout the actions.

Depreciation - reducing stocking rate or adjustments to the enterprise did not affect depreciation, however the addition of new equipment or infrastructure in environmental actions incurred additional depreciation costs, as outlined above.

5.3.3.1 Assumptions regarding contaminants

At time of writing there is no specific detail around the environmental objectives farmers will face in relation to freshwater quality and quantity. The target attribute states will be set in the new regional Land and Water plan once it is finalised, as well as limits on resource use to meet the objectives. Nor is the mechanism for how reductions in relation to Greenhouse Gas (GHG) emissions will be dealt with finalised.

Image 35: K Line irrigation with spray irrigators further back in paddock on a dairy farm in Waitaki District, Otago. Source: Emma Moran

192 A sensitivity analysis to look at the impact of a changing milk price was undertaken for a similar modelling work in Southland. It showed how a different milk price influences the ability of a farm to pay for environmental actions (*Agriculture and Forestry Report.pdf* Retrieved 13/05/2023).

193 Labour is a 'sticky' cost and only varies when cow numbers are reduced significantly. For example, a decrease of 100 cows will reduce labour by one Full Time Equivalent (FTE). When a labour unit is reduced, ACC costs will also need to be adjusted. Labour costs were adjusted when irrigation frequency was changed to meet GMP as shifting equipment would require more labour.

To recognise this, two key assumptions pertaining to the reduction of nitrogen loss were applied to the selection of environmental actions for each farm. The first was that any action targeting reductions in nitrogen could not markedly increase the level of phosphorus losses from the farm. The second was that any actions targeting reductions in nitrogen could not markedly increase the level of GHG emissions from the farm. This was to recognise the potential need for farmers to reduce several contaminants as well as GHG emissions from their farming operation.

In terms of phosphorus, an 'Olsen P' test was used to estimate how much phosphorus fertiliser is needed to 'maintain' the optimal soil phosphorus status. Where the farm in question had Olsen P levels above the agronomic optimum, then these are reduced to that level[194]. These are discussed further in relation to the results of the modelling.

5.4 Case Study Results

The key findings from the case studies are:

1. Implementing GMP lead to small profit reductions and nitrogen leaching reductions, reflecting the starting point for the farm.
2. Big nitrogen leaching reductions are costly since they can mainly be achieved with infrastructure changes e.g., irrigation equipment upgrade or introducing wintering barns (GMP+). It was assumed that the cost increase can not be offset by an intensification of production since this could lead to an increase in GHG emissions and hence, a pollution swap.
3. Using Plantain as part of the pasture sward is cost effective but Otago specific research needs to progress further to ensure plantain as an environmental action option is practically feasible for dairy farms in the region.
4. In some cases, nitrogen leaching is driven more by soil type and rainfall rather than on-farm N- use efficiency.

5.4.1 Baseline year

Changes in operating profit (Earnings Before Interest and Taxes and Rent), has been used as an indicator of economic implications on the business from adopting different levels of environmental actions. The operating profit needs to cover interest, rent, tax and debt repayments, as well as family spendings.

While care has been taken to ensure the major factors affecting nutrient loss in the region were represented including soil type, rainfall and farm system types, stocking rates and existing infrastructure, the modelling results do not include important factors that are specific to the impacts of changes in operating profit on the financial viability of that farm. These factors include the financial position and debt loading of that farm, and important variables such as the management ability of farm owners, sharemilkers and staff, stage of farming career and attitudes to environmental, technologies and farm system changes. This means that operating profit can be misleading, since it is hard to get an exact understanding of a farmer's debt level when dealing with case study farms.

For some of the actions modelled, these factors may hamper their adoption, for example where reductions in operating profit result in an inability to service debt, or where farms have trouble finding, retaining, or training staff. In other instances, a farmer's innovation and ability to invest may result in improvements in contaminant leaching that may exceed modelled results with a lower impact on operating profit. Neither situation ought to be discounted.

194 For further information see *What is a soil phosphorus 'Olsen P' test? (fertiliser.org.nz)*

Several different factors make a farm profitable and low leaching such as biophysical factors (soil drainage, slope and rainfall) (soil drainage, slope and rainfall) and farm management skills. The case study farms showed in general a poor relationship between operating profit and baseline nitrogen or phosphorus losses (refer to Figure 71 for nitrogen).

Pastoral farming in New Zealand is primarily about balancing feed supply and demand. DairyNZ has described five production systems based primarily on the use, amount and timing, of imported feed. The production system classification makes it possible to compare different farms across the country with the same type of farm system. The production system definitions do not include grazing or feed for young stock[195]. The 10 farms selected for the case study are classified as farm system two to five, but 8 of the 10 farms are defined as system 3 and 4. Figure 71 shows the percentage of bought in feed for each farm. It shows that system type, represented by imported feed, can not explain the nitrogen leaching occurring at the baseline year.

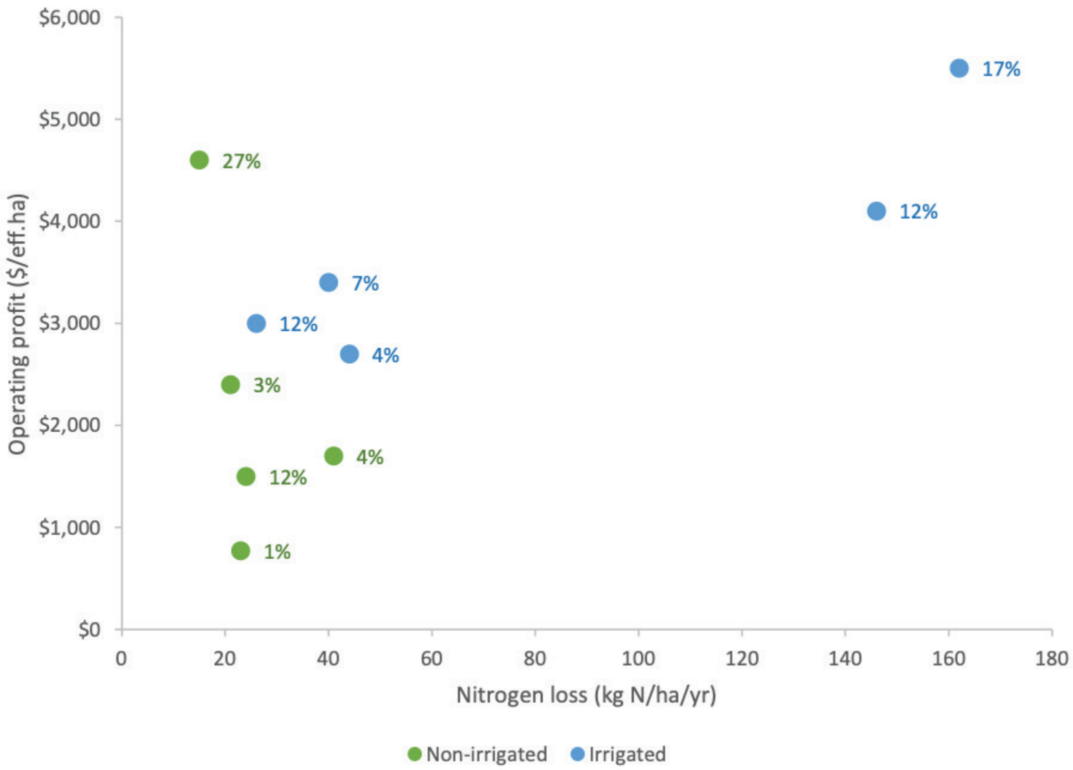


Figure 71: Overview of operating profit and nitrogen loss for the 10 case study farms 2020/21
Source: DairyNZ
Note: The graph also shows whether a farm is irrigated or non-irrigated and the data labels give the proportion of feed that is bought in. The two farms with the highest nitrogen leaching reflects the use of border dyke irrigation for which changes are explored in the modelling.

An important factor in considering the estimated reductions in nitrogen loss as a result of the environmental actions is where each farm sits at the 2020-21 baseline year. The distribution of nitrogen leaching across the case study farms indicates a wide distribution and underlines the differences between the farming types, as shown in the figure above. As a point of comparison, Figure 72 provides a distribution of nitrogen loss for all dairy farms across Otago with an estimated nitrogen loss in Overseer, extracted from Overseer FM, for the baseline year 2020-21.

195 The 5 Production Systems - DairyNZ Retrieved 7/05/2023. A further overview of the farm production systems in Otago can be found in Chapter 6: Dairy Farming (Ross, 2022) in the *Farmers and Growers* in Otago Report.

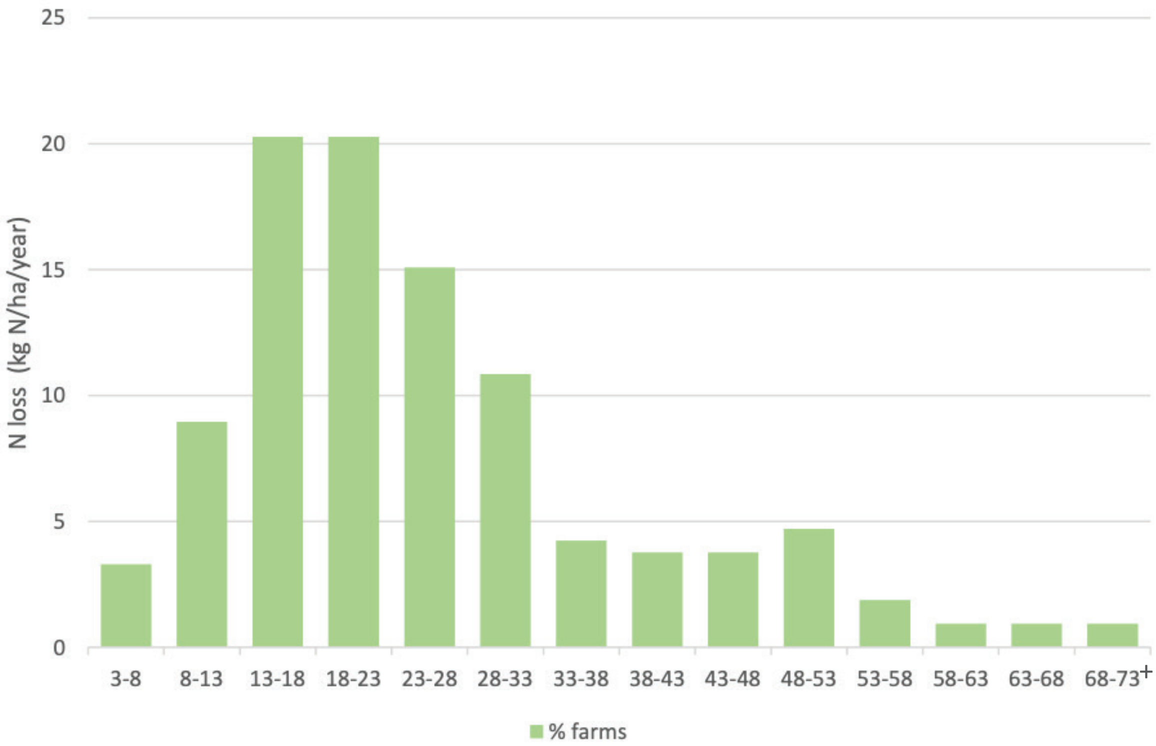


Figure 72: Distribution of nitrogen loss (kg per ha) for 212 dairy farms for 2020-21
Source: Overseer, as reported for Otago

5.4.2 Good management practices (GMP)

Relevant GMP actions were applied to all farms but varied depending on the level of GMP already adopted on each farm. This means that not all environmental actions were necessary on all farms, however, the end result was for all farms to adopt GMP. This approach was possible because of the case study approach using real farms with known practices.

A short overview of the results of each environmental action is outlined below, with additional farm specific information in Appendix 1 of this chapter. These actions were modelled in the sequence listed.

Nitrogen use efficiency

Nitrogen use efficiency was modelled for all farms, excluding Dairy 3 because of the level of GMP already used on the farm. Where nitrogen use efficiency mainly involved shifting the timing of fertiliser application to avoid the period from May to August, there was no or marginal impact on operating profit. However, it only led to a minor reduction in estimated nitrogen loss of one to two per cent. For those with already relatively low rates of nitrogen loss, this translates into only a marginal reduction in an absolute sense. For example, modelling of nitrogen loss efficiency for Dairy 1 provided a reduction of two per cent, but off a low base of 16 kg N/ha. This equates to an improvement of only 0.3 kg N/ha (see also figures with results showing absolute numbers (see also figures with results showing absolute numbers for Dairy 1 to Dairy 10).

An exception when looking at the impact on operating profit, is for farms where nitrogen use efficiency also involved decreasing fertiliser use to the legislated 190 kg N/ha. Dairy 6, for example, resulted in a modelled decrease of nitrogen loss per hectares of six per cent. This relatively greater reduction in nitrogen loss is a result of the use of border dyke irrigation on Dairy 6, with surplus nitrogen resulting in drainage through the border dyke system. Given the baseline nitrogen loss for Dairy 6 is 146 kg/N/ha, this is important in absolute terms. However, it comes with a reduction in operating profit of three per cent, rendering the action relatively expensive financially for the farmer, compared to the costs of better nitrogen use efficiency on other case study farms which mainly involved shifting applications to later in the spring or earlier in the autumn. A similar result can be seen for Dairy 7, with a six per cent reduction in operating profit, due to decreasing the nitrogen fertiliser level to the legislated 190 kg N/ha. It was assumed that this would lead to a reduction in pasture eaten which would have to be replaced with imported feed which comes with an added cost to the business.

Nutrient recycling (effluent management)

For those farms where nutrient recycling was modelled, this generally resulted in minimal reductions in nitrogen loss, but also either no loss of operating profit or some minor increases (e.g., 1%) in operating profit. This is presumably because better effluent management reduced the need for fertiliser. A notable exception is Dairy 5, where better nutrient recycling resulted in a two per cent reduction in nitrogen loss (albeit off a low base) but a five per cent improvement in operating profit, again likely due to the positive impact of effluent application on pasture growth and the reduced need for nitrogen fertiliser.

The new rules introduced in the Regional Plan Water, under Plan Change 8, affect all dairy farms in Otago, and all dairy farmers will eventually have to apply for a discharge consent for effluent applications. In addition to this, not all existing effluent ponds are likely to meet the requirements for them to be a permitted activity. For those who cannot meet the permitted activity standards, an upgrade or a new pond might be needed, with a range in cost depending on what is required. For some farmers, this cost will most likely be substantial and will need to be well planned for in advance.

Tillage practices

Improved, farm specific tillage practices were modelled on Dairy 2, Dairy 5 and Dairy 9 where direct drilling was considered. Modelling showed relatively small reductions in nitrogen loss across all three farms, with no change in operating profit. A change in tillage practices can however, result in a decreased risk of sediment loss from the cultivated area.

Irrigation efficiency

Irrigation efficiency was modelled as an action for two farms: Dairy 7 and Dairy 8. In both modelled outcomes, greater irrigation efficiency resulted in marked reductions in both nitrogen loss (an 18% reduction for Dairy 7 and a 31% reduction for Dairy 8) and Phosphorous loss (an 8% reduction for Dairy 7 and a 17% reduction for Dairy 8), both at no impact on operating profit. This modelling indicates improved irrigation efficiency offers a high value, low-cost option for reducing nitrogen and Phosphorous loss on these farms.

Using irrigation can mean a higher security in production of pasture (feed) for the cows, and milk production per cow will generally be higher. As an example, the average production of milksolids per cow in Clutha is, in general, lower than in the Waitaki district and reflects the differences in use of irrigation, even though this might not be the only explanation.

The increased security in pasture production using irrigation is entirely dependent on the security of the water source and consistent access to water during the milking season. If less pasture is available, farmers will have to bring in supplement feed to make up the reduced pasture growth or reduce feed demand through earlier culling or drying cows off.

Some of the GMP actions that were modelled also result in reductions in sediment loss and *E. coli* levels, although these are not modelled or reported through Overseer. These include:

- Nutrient recycling or effluent management also reduces the loss of E coli. This is because well managed effluent with appropriate application rates, ensuring appropriate paddocks are used and applying effluent when soil and weather conditions are appropriate will minimise or eliminate effluent reaching waterways.
- Tillage practices and catch crops reduce sediment loss. Direct drilling results in less soil disturbance and therefore a reduced risk of sediment loss from the paddock, while catch crops reduce run-off and reduce the direct impact of raindrops on soil, thereby reducing the risk of sediment losses.

5.4.3 Good management practices plus

All GMP+ actions resulted in profit reduction due to the added cost or reduction in milk production.

Plantain

Plaintain was modelled as stock feed on Dairy 4 and Dairy 7, the reduction in nitrogen leaching was 13 per cent and 21 per cent respectively while operating profit was reduced by two per cent and five per cent respectively. Whilst plantain looks promising based on this modelling, with only a small reduction in operating profit, this technology has not yet been widely adopted on Otago dairy farms. As a result, plantain as an environmental action represents what is theoretically achievable in the future. Currently, DairyNZ is working on a plantain adoption project, to ensure an action relating to plantain is practically feasible. Plantain might require a third of the farm to be over or undersown annually to maintain the targeted 30 per cent plantain content in the sward.

Cull early

Identifying less productive animals early, then culling them, can reduce feed demand and the need for more resources with only low impact on profit. This was modelled for Dairy 9 only, where the predicted gains in nitrogen leaching reductions of three per cent are quite low, only corresponding to a decrease of 1 kg N/ha in absolute terms compared to the baseline. It resulted in a two per cent reduction in operating profit.

Baleage wintering

Modelling for Dairy 4 removed winter crops, then wintered cows on pasture and baleage (while assuming there was no need for a stand-off structure). The model predicted a considerable reduction in nitrogen leaching (28%) but also a reduction in operating profit (22 per cent). However, this level of nitrogen leaching reduction might be difficult to achieve without a stand-off structure, especially on soils that are susceptible to pugging. To account for this, another option was modelled for Dairy 4, changing to baleage being fed in a composting barn. The model predicted a 49 per cent reduction in nitrogen leaching and a 63 per cent reduction in operating profit when a wintering barn was used, compared to the baseline year.

Border dyke to pivot

A change in irrigation practice was explored to increase the water use efficiency on the farms. The model predicted a marked reduction in nitrogen (83%) and phosphorus loss (85%) for Dairy 6, and a marked reduction in nitrogen (83%) and phosphorus loss (88%) for Dairy 10 as a result of changes from border dyke irrigation to pivot irrigation. More effective irrigation can also reduce sediment loss even though this was not quantified in this work. However, due to the high capital cost, this also resulted in a marked reduction in profit with a reduction of 20% for Dairy 6 and a reduction of 11% for Dairy 10. To fund transition, it may be necessary to allow farmers more time to gradually move from border dyke to spray irrigation, depending on their credit rating with their bank. In that regard for some farms this action might not be financially feasible, particularly in the short term.

Historically, an increased investment in infrastructure has been financed by increasing milk production on the farm (increasing the area irrigated and hence the number of cows). Since the assumptions made for the modelling did not allow other contaminants to increase, such as GHG emissions, increasing the number of cows was not seen as an option. Current policy settings also make it harder to increase the dairy land area used for irrigation since a consent will be needed[196].

Barn

Modelling predicted a considerable reduction in nitrogen leaching (50%) in the one example where a wintering barn was considered (Dairy 4b). The cost of building a barn however, made Dairy 4b substantially less profitable, with a reduction in operating profit of 63 per cent. As mentioned earlier, modelling assumed that further intensification, by increasing the number of cows on the farm to recoup some of these costs, could not occur as this would increase greenhouse gas emissions.

While the barn model did achieve large nitrogen loss reductions, ongoing annual costs, like depreciation, interest rate repayment, adding and removing bedding makes it a financially expensive nitrogen leaching action for the farmer. In that regard, for some farms, the wintering barn action might not be financially feasible due to the farms' financial position and profitability. Modelling has shown that some farms can achieve similar results with less profit reduction, as shown by the Dairy 4 and Dairy 4b comparison in the appendix in Section 5.6.

Previous studies by DairyNZ have shown that investments in off-paddock infrastructures such as a barn, is not necessarily driven by financial or environmental reasons. Interviews with farmers with the aim of better understanding the drivers for farmers to invest in barns, showed that management purposes were the main driver. This could be for reasons such as reducing pugging and overgrazing, improving conditions for staff and cows and reducing the reliance on winter grazing contracts. Importantly, all the 33 farms included in the study, intensified their systems as a way of financing the investment in a barn[197].

196 Resource Management (National Environmental Standards for Freshwater) Regulations 2020.

197 To barn or not to barn, that is the question. M. Newman and K. Mashlan, DairyNZ. SIDE conference paper.

5.4.4 Impact of actions for nitrogen on profit

Modelling of GMP actions showed these resulted in only small reductions in nitrogen leaching (i.e., the shift from base to GMP in Figure 73). However, results also indicates that these reductions could be achieved at no or marginal impact on operating profit, with modelling indicating some farms may see increased operating profit, including Dairy 1 (2%), Dairy 3 (1%) and Dairy 5 (5%).

This finding is relevant to both those with a relatively high nitrogen loss at the baseline year, and those with a relatively low nitrogen loss at the baseline year.

- For those with a relatively low nitrogen loss at the baseline year, there are, generally, few low-cost actions that could be implemented to further reduce nitrogen loss.
- For those with relatively high nitrogen loss at the baseline year, the low-cost actions modelled do not result in any notable reductions.

The latter is important as it indicates there are few actions available for those with relatively higher nitrogen loss that do not come at a high cost. This indicates that for the relatively higher emitting farms, reducing nitrogen loss requires large investment in GMP+, for example changes to infrastructure. This will depend on the level of contaminant reductions required by the upcoming policy changes, and what is considered a high, or an acceptable loss, meaning that the target will decide the impact on operating profit.

Some of the farm specific GMP+ actions that were modelled resulted in marked reductions in nitrogen losses, but also came at considerably greater cost. For example, for Dairy 7, the cumulative costs of applying applicable GMP actions and the planting of plantain (a GMP+ action) came at a cumulative 11 per cent reduction in operating profit.

The option of culling early was only considered applicable to Dairy 9 since other farms already cull early and there was no opportunity to implement it on those. Culling early resulted in modelled reductions in nitrogen loss of three per cent, however, came at a cost of a two per cent reduction in operating profit. Given Dairy 9 has a lower baseline nitrogen loss compared to some of the other case study farms, the benefits of a three per cent reduction in nitrogen loss at the cost of a two per cent reduction in operating profit may be marginal, depending on what level of reductions in contaminant losses the farm will be required to meet.

GMP+ options beyond plantain and culling early adversely impact operating profit, particularly where capital expenditure is required. Baleage wintering is expensive for the farmer where a stand-off pad might be required due to soil type and climate. As noted in the assumptions, the modelling assumed that no stand-off structure is needed if pasture and soil damage is not occurring, however, when wintering may result in pasture and soil damage then a stand-off structure is an option.

Composting barns and shifting irrigation from border dyke to pivot irrigation were the two capital intensive actions modelled. For Dairy 4b, construction of a composting barn reduced nitrogen loss by 50 per cent, however at the cost of a 63 per cent drop in operating profit.

For Dairy 6, changing from border dyke irrigation to pivot irrigation led to a 20 per cent reduction in operating profit but was effective at reducing both nitrogen loss (83% reduction from baseline) and phosphorus loss (85% reduction from baseline). Similarly, a switch from border dyke irrigation to pivot irrigation for Dairy 10 meant an 11 per cent reduction in operating profit and reduced both nitrogen loss (83% reduction from baseline) and phosphorus loss (88% reduction from baseline). Depending on the individual circumstances of each farm, the investment required to shift from border dyke irrigation to pivot irrigation may be achievable over time. However, it is unlikely either farm will be able to assimilate these losses in the short term, if indeed they were able to secure lending.

The assumptions used for the modelling, meant that the milk production on Dairy 6 and Dairy 10 could not increase as a way of financing the changes in irrigation infrastructure. Increasing the amount of feed eaten could lead to an increase in GHG emissions and the assumptions made was for existing GMG emissions to not increase. Having water use efficiency in mind, the changes are positive, even though this has not been quantified.

Taken together, the modelling of environmental actions aimed at reducing nitrogen loss underpin the point that the solutions differ for each farm. For some farms, application of both GMP and GMP+ may result in limited reductions in nitrogen loss per ha. This finding is particularly relevant for those who are already at relatively low loss rates, often because they have already invested heavily in capital heavy actions. For these farms, additional investment in further actions may result in little further reduction in nitrogen loss at relatively high cost. Actions that need capital expenditure come at a large cost in terms of reduced operating profit.

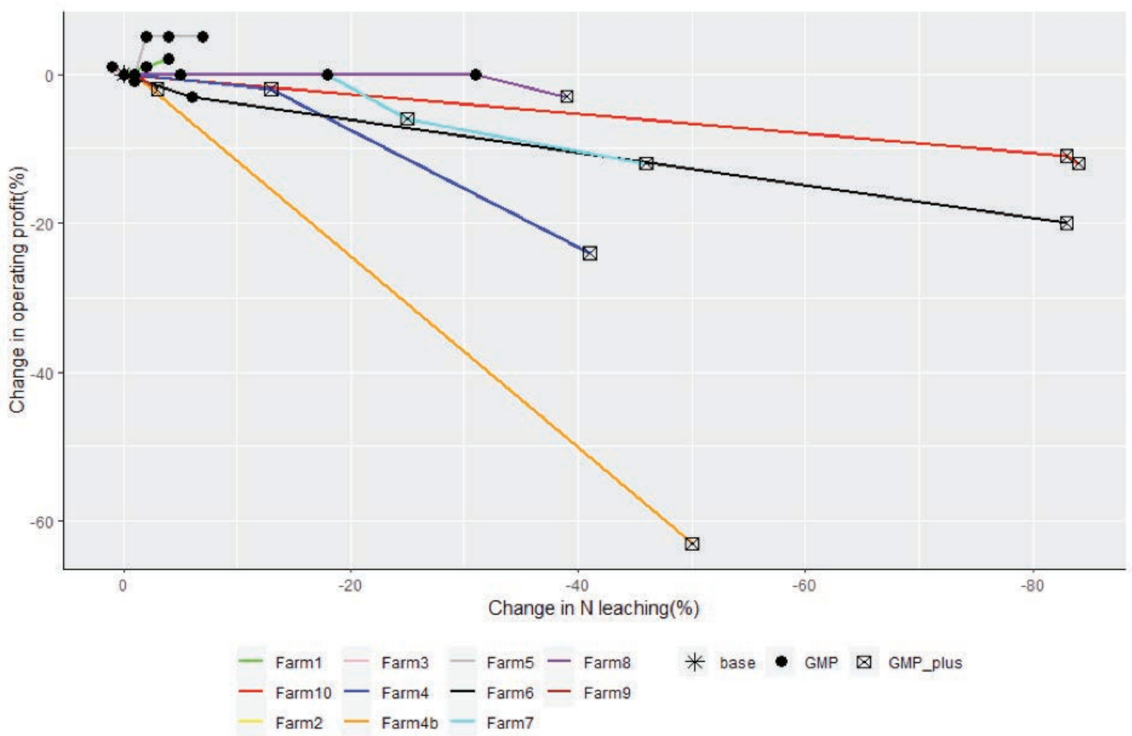


Figure 73: Change in profitability and nitrogen losses (as a percentage) for 10 case study farms across all environmental actions tested
Source: DairyNZ

5.4.4.1 Absolute numbers of change

Farms with higher baseline nutrient losses do not necessarily have a wider range of options to reduce environmental impacts than farms with lower losses. Also, the options that are practically available will not necessarily be either more effective or able to be achieved at relatively low cost.

Some dairy farms, namely Dairy 4 and 4b, Dairy 6, Dairy 7, and Dairy 10, had higher baseline nutrient losses relative to other case study farms and few, if any, low-cost mitigation options. For these farms, to achieve lower nutrient losses will require substantial reductions in operating profit, particularly where capital expenditure is required, to the point where land use change may be required.

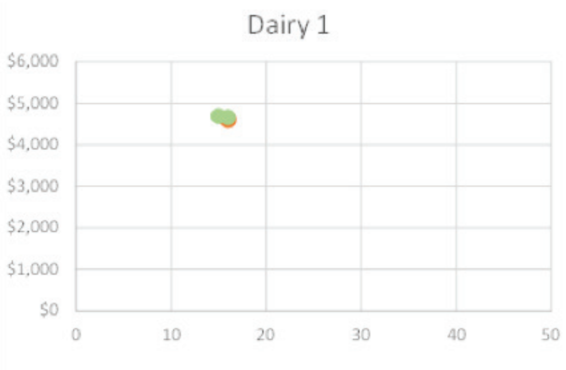
To illustrate this, individual graphs showing the changes in operating profit and nitrogen leaching in absolute numbers for Dairy 1 to Dairy 10 are presented in Figure 74.

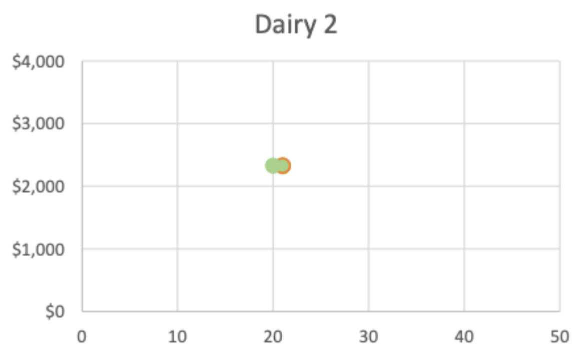
For some farms, reduced nitrogen losses were possible with modelled improvements to operating profit; Dairy 1, Dairy 3, and particularly Dairy 5. Notably these were already relatively low nutrient loss operations. Based on modelling, some farms, Dairy 2, Dairy 8, and Dairy 9, appear to be able to achieve reductions with no or relatively small reductions in operating profit. However, a recurring question for relatively low nutrient loss dairy farms is whether these reductions can be achieved in practice.

The modelling outlined per centage reductions from the current state (or baseline), but absolute numbers are important:

- A five per cent reduction from a farm currently leaching 25kg/N/ha will result in a reduction of 1.25kg/N/ha.
- A five per cent reduction from a farm currently leaching 100kg/N/ha will result in a reduction of 5kg/N/ha

Some farms working off a low baseline of nitrogen leaching may achieve further reductions through application of GMP practices with limited operating cost or improvements to operating cost. Requiring further reductions from these farms may result in few if any reductions in nutrient losses and may only be achievable with large reductions in operating profit.





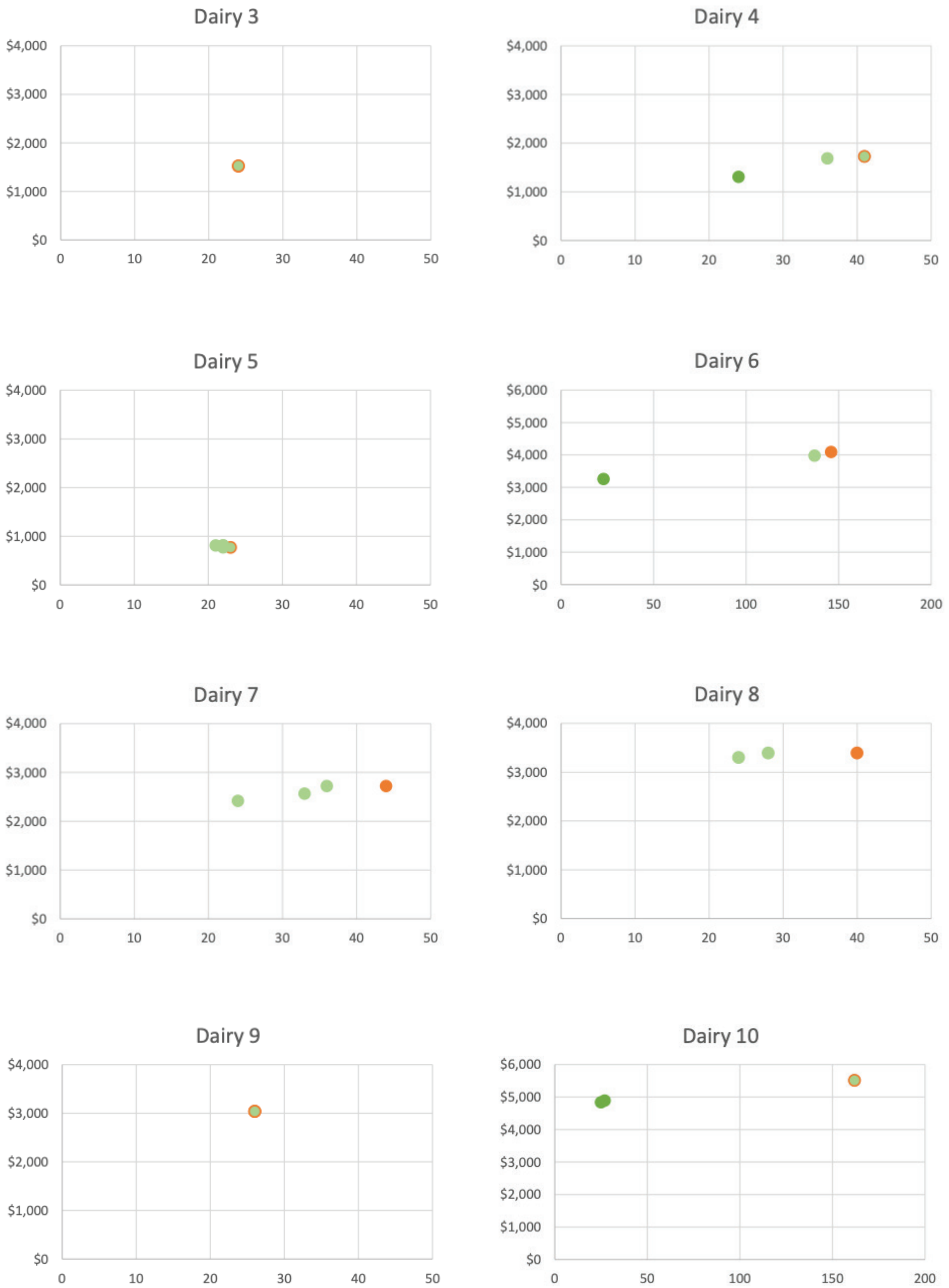


Figure 74: Operating profit ($/ha) and nitrogen leaching (kg N/ha and year) for the different environmental actions applied to each farm (Dairy 1 to Dairy 10). Orange markers = baseline, light green = GMP, and bright green = GMP+ (in some graphs the orange marker may not be obvious because it is sitting behind a green marker)
Note: in contrast to the other graphs, the scale on the y axis is different for Dairy 1, Dairy 6 and Dairy 10 and on the x axis for Dairy 6 and Dairy 10.

5.4.5 Impact of actions for phosphorus on profit

Modelling of case studies considers the effectiveness of environmental actions for the risk of phosphorus loss but does not consider in-paddock environmental actions that would further reduce this loss. As already noted, the intention was to ensure that reducing nitrogen would not inadvertently increase phosphorus and identify where potential reductions in both nitrogen and phosphorus loss occur.

Phosphorus loss reduction was only marked when irrigation practice was changed (Figure 75). This includes large changes resulting from a move from border dyke to pivot irrigation (85% reduction for Dairy 6 and an 88% reduction for Dairy 1). Greater irrigation efficiency through better soil moisture monitoring resulted in a decrease in modelled phosphorus loss of eight per cent for Dairy 7 and 17 per cent for Dairy 8. Other actions were not effective for phosphorus loss, partly because some actions were applied to farms with an already low level of phosphorus loss. An overview of further options for dairy farmers to reduce the risk of phosphorus loss can be found on the DairyNZ website[198].

Most of the farms did not have a recent soil test result, therefore it was hard to implement reactive phosphate rock fertilisers or adjust maintenance phosphorus fertiliser application rates. Overseer does not model phosphorus losses particularly well, and caution is needed when interpreting the results.

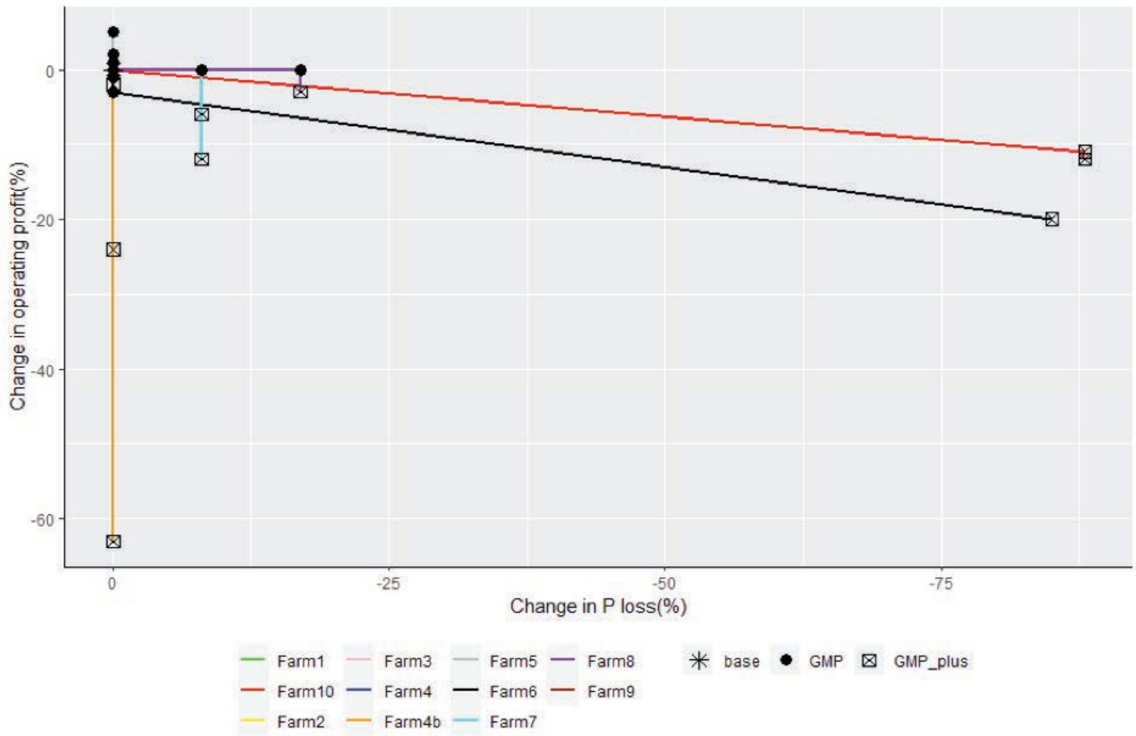


Figure 75: Change in profitability and phosphorus losses (as a percentage) for 10 case study farms across all environmental actions tested
Source: DairyNZ

198 Reducing phosphorus (P) loss - DairyNZ Retrieved 21/05/2023.

5.4.6 Effectiveness of actions on GHG

There was no more than a five per cent reduction in GHG from the selected actions (Figure 76). This was because most of the actions did not result in less feed eaten where feed eaten is the primary driver of methane emissions. Most of the GHG emission reductions were driven by reduction in nitrous oxide emissions. No changes to stocking rate (either reductions or increases) were modelled, as part of the assumptions used.

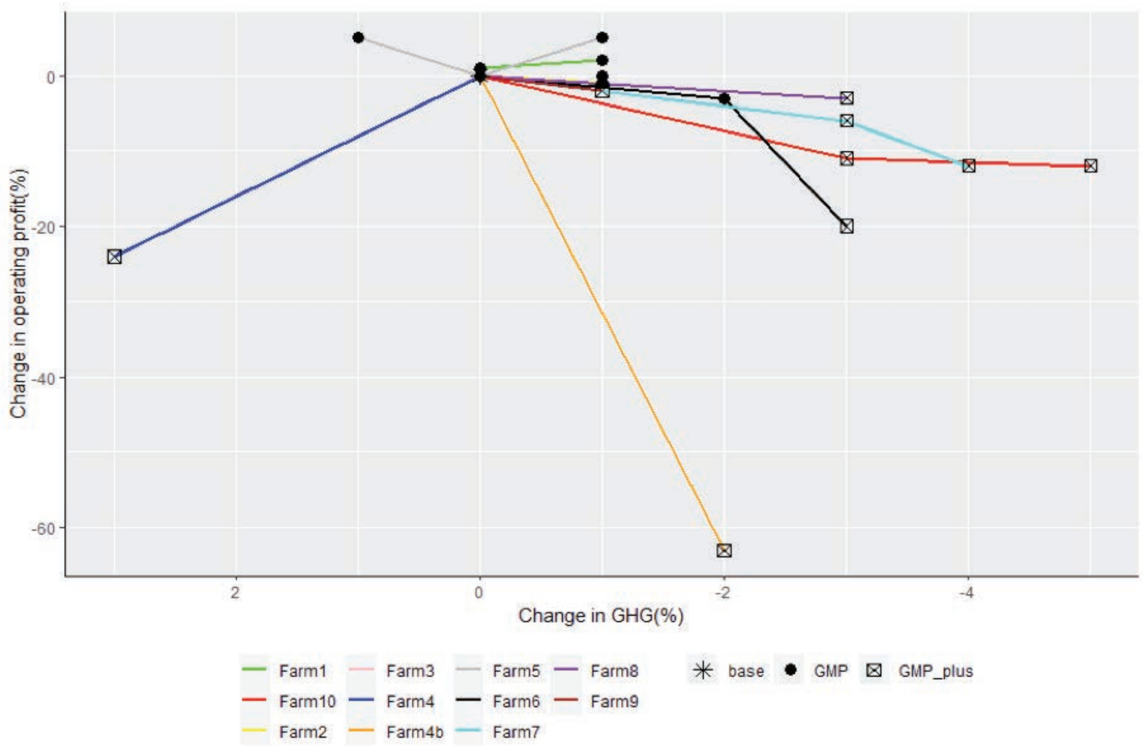


Figure 76: Change in profitability and GHG emissions (as a percentage) for 10 case study farms across all environmental actions tested
Source: DairyNZ

5.4.7 Limitations and constraints

Modelling undertaken through this study is designed to estimate the impacts of environmental actions on case study farms. They do not assess the broader impacts of reductions in operating profit on the economic viability of the farming operation, or the broader economic impacts to local and regional economies.

As with any approach, the case study approach used as a basis for this report comes with limitations. Given the diversity of climate, topography and soil types, and the farming operations themselves, it is difficult to know to what extent the case study dairy farms are 'typical' of other farms across the region even though they were selected to be representative of the area. In 2021, there were 455 dairy farms in Otago. The ten case study farms modelled in this report represent just over two per cent of this number. In total, the case study farms cover just under 3,000 effective hectares, or 1.3 per cent of the total effective hectares in Otago. In addition, as farmers opt to sign up for the 'Baseline Project' informing these case studies, there may be some form of selection bias.

The environmental actions tested in the modelling of each farm are deemed the most cost-effective options available to the farmer, based on accepted, applicable GMP and GMP+ options available at the time. There may be other options available for the reductions of nutrient losses on these farms and given sufficient time and investment these may result in actions that are more cost effective, although this eventuality should not be assumed.

The modelled actions do not quantify the effectiveness on two important freshwater attributes: sediment and *E. coli*. These contaminants cannot be measured through Overseer, and are best addressed through farm specific actions, for example, management of critical source areas, fencing, effluent management setbacks and planting.[199] As outlined earlier in the report, some actions will also result in a decrease in the loss of sediment and *E. coli*, as well as nitrogen or phosphorus.

The Overseer model is an appropriate tool for helping to understand farm system changes for dairy of environmental actions. However, the results do have limitations, particularly relating to the use of Overseer in a regulatory sense[200]. Overseer modelling can exclude some actions that are available, and which may also be appropriate, effective and relatively low cost for that specific farm. Modelling through Overseer will also underestimate some short term but important leaching events, for example rain events resulting in overland flow, and loss of phosphorus, sediment, and *E. coli*.

The actions modelled are not designed to meet specific reduction targets, which are pending at time of writing. The actual reductions in contaminant losses required by each farming operation, and the timeframes over which these are to be achieved, will by necessity drive on-farm decision making.

Nor does this study consider the downstream economic impacts of reduced operating profit. In general, those options that result in considerable reductions in operating profit will result in lower spending by the farmer, lower supply for dairy processing and lower revenue for the farm system or farm servicing industries.

Increased spending on environmental actions will provide some positive economic impacts to individuals or organisations, albeit often short term. For example, where a farmer needs to invest in an action through the purchase of off-farm feed or leasing of land, or through capital investment. Such investment will also reduce the broader costs associated with adverse environmental impacts, although it is assumed these factors will be considered in the development of environmental limits.

Modelling is focused on explaining the current (or steady) state as it exists now. It assumes the actions that have been modelled can be applied instantaneously, and that the benefits of the actions also occur instantaneously. This means the modelling does not show the transitional changes that can occur.

It is important to recognise these limitations to qualify the results of the study, to underpin the need for additional economic research that builds upon the findings of this study, and to emphasise that further work is needed to understand how modelling results may be best reflected through resource management policies.

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199 For further information around the effectiveness of the environmental actions on the loss of sediment and *E.coli*, refer to *Identifying contaminants - DairyNZ* or *farmers-guide-to-managing-fde.pdf (dairynz.co.nz)*. For actions specific to Otago, see *land_management_on_otago_dairy_farms_3.pdf (dairynz.co.nz)*

200 *46357-The-Government-response-to-the-findings-of-the-Overseer-peer-review-report (mpi.govt.nz)*

5.5 Discussion

Dairy industry production in New Zealand has increased substantially since 2003, driven in large part by the conversion of land to dairy farming, increases in herd size and productivity improvements[201]. Use of debt has funded important capital investment and growth in the industry. Conversion to dairy farming has been funded largely by bank debt. Between 2003 and 2016 dairy farm debt increased at approximately ten per cent per year, outpacing the five per cent growth in dairy farm output value over the same period. Total dairy farm debt now sits at $36.4 billion at February 2023, down from $38.6 billion in February 2021[202].

Debt levels by themselves are not an indicator of farm performance or the long-term viability of a farm. Many heavily indebted farmers will be among the top performers through farm performance and cash flow, including in years where volatile milk payouts are low. Other farms may have relatively low debt levels but may be struggling to cover the cost of this debt due to the high cost of production.

The ability to invest in some of the environmental actions modelled for this report will be constrained by debt loading which is specific to each farm; increasingly banks will consider how well a farmer is able to meet, or is meeting, environmental expectations when considering risk. Farmers with high levels of debt will be less able to invest capital in response to increased environmental limits, both because of the ability to service debt, and because of limited bank willingness to lend to farmers with high debt loads where large amounts of capital investment is needed but no increase in profitability will result.

5.5.1 Increasing productivity and production may no longer be an option

Many investment decisions within the dairy industry have previously been aimed at increasing production, productivity, and profitability. Increased regulations and expectations across a range of environmental factors, means investment decisions will now need to give even greater weighting to how best to reduce the impacts of dairy farming on the environment. This includes increased investment in environmental actions of the nature outlined in this chapter, and through increased efficiencies within an existing or shrinking environmental footprint.

Increased environmental targets for freshwater quality and climate change emissions will also generally limit some of the options farmers have used in the past to increase production, including increasing stocking rates, at least in some regions. While not an argument to avoid environmental outcomes, this underlines the need to consider the impacts and farmers' ability to respond, particularly in the short term.

Within this context it is important that farmers are given sufficient information and clarity to inform their priorities for investment. A prerequisite for good farm decision making is a combination of certainty around what needs to be achieved and the scope, tools, and options to provide farm specific responses to environmental challenges.

201 *Situation and Outlook for Primary Industries December 2019 (mpi.govt.nz)*

202 *https://www.rbnz.govt.nz/statistics/series/registered-banks/banks-assets-loans-by-purpose*

5.5.2 Operating costs and economic viability

The level of each farms' operating profits will be important for a specific farms' ability to take on additional operating costs. Where a farm is experiencing marginal profitability any profit reduction in response to meeting environmental targets or limits may result in that farming operation becoming financially non-viable.

Farms, as with any commercial enterprise, cannot assimilate endless marginal costs; at some point additional costs simply render the enterprise unfeasible. For example, some farmers will be able to manage a three per cent reduction in operating profit. For others this may result in the farming operation becoming uneconomic. While the broader economic impacts will be mitigated by alternative use of capital and land through adoption of alternative uses, it may result in lower profitability and/or lower downstream economic activity. This is particularly relevant given existing debt loading in the dairy industry.

Finally, a fundamental question in relation to any economic enterprise relates to the human side of the equation; why someone is undertaking an activity in the first place. This may be driven by a range of factors including profit or job satisfaction. Fundamental changes to a farming system may result in changes to these factors. At some point, some farmers faced with multiple environmental and financial challenges and stressors may simply decide to stop farming. These farm specific factors and constraints have not been recognised in the modelling but are relevant considerations for any decisions.

A greater focus on shrinking the environmental footprint of a farm means avenues for increased profitability will be more limited than has been the case. Achieving greater productivity, where more output is achieved with a lower impact on the environment, will become increasingly important. Two key avenues for increased productivity are greater 'value add', where dairy products are improved to make them worth more, or economies of scale, where increases in farm size reduces the average cost of production. Achieving these productivity gains necessitates investment whether at the industry, processor, or farm level and, importantly, in time. Some farms may be able to achieve these productivity gains, but others may not.

5.5.3 Operating profit is variable

Average operating profit in the dairy industry varies[203]. This means that farmers need to farm for the bad years, as well as the average and good years.

Figure 77 shows the cash operating surplus for farm businesses between 2008/09 and 2019/20, representing the difference between net dairy cash income and farm working expenses. While operating surplus can be high in 'good' years, in 'down' years costs stay relatively fixed, irrespective of revenue. Additional costs in the form of investment in environmental action can add to these fixed costs, dampening the good years and, more importantly, ensuring the down years are more pronounced.

203 *12 Time Series Tables: Owner Operator | Economic Survey 2020-21 (dairynz.co.nz)*

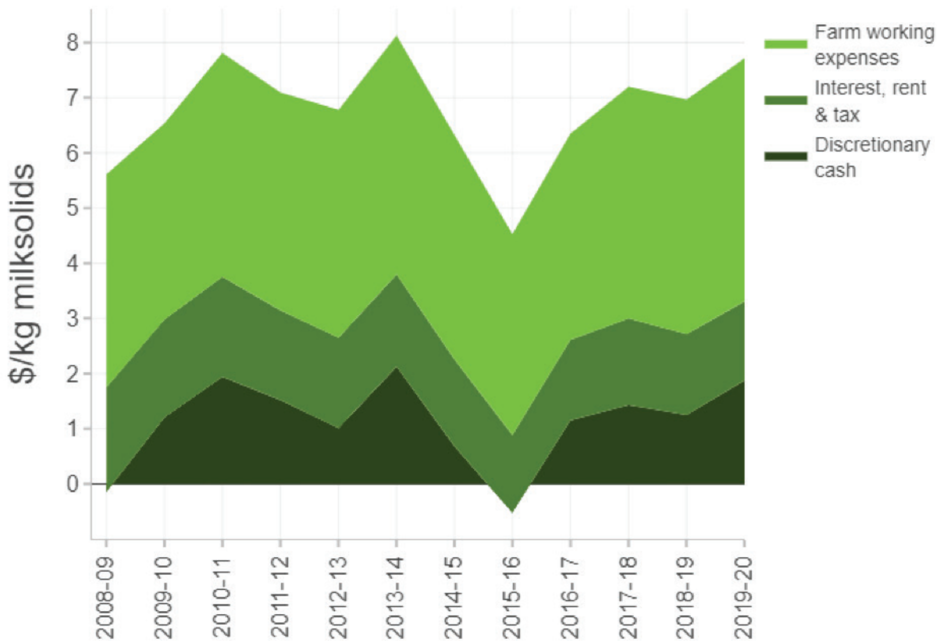

Figure 77: Annual change in revenue and expenditure 2008-2019
Source: 5 Owner Operator: Operational Financial Analysis | Economic Survey 2020-21 (dairynz.co.nz)

5.5.4 Implications for farmers

This analysis highlights the complex nature of balancing economic viability and environmental performance for dairy farmers in New Zealand. Regulatory settings, community, market and farmer expectations are driving a greater level of investment into reducing the environmental effects of the industry on the environment.

GMP actions are, in general, low cost to implement, with some resulting in slight increases in operating profit for some case study farms. However, implementation of GMP generally does not reduce nitrogen leaching to any notable extent.

GMP+ actions can have a marked impact on farm profitability. Some actions, such as plantain and baleage wintering, result in lower profit reductions compared to others, such as pivot irrigation and reducing nitrogen fertiliser. However, the latter two actions resulted in greater nitrogen leaching reductions.

For some farms, reductions in operating profit, either through reduced production or the need to assimilate capital costs into the farming system, may not, or will not, depending on the individual circumstances of that farm, be sustainable in the long term. Further work may be needed to identify the viability of farms facing operating cost reductions of the nature modelled in this chapter. This will depend on the environmental outcomes farmers will be required to (or seeking to) achieve, and the amount of time farmers will have to achieve these outcomes.

5.5.4.1 No 'one size fits all'

Two important findings from the modelling are that there is no 'one size fits all' bundle of solutions for Otago dairy farmers. What constitutes an optimal 'bundle' of actions will be farm specific and will likely change over time. Farmers need a wide range of decision alternatives and options to remain profitable while meeting environmental goals. Key to addressing this finding is carefully selecting the tools used to implement legislation.

Non-regulatory Farm Environment Plans are already prevalent in the Dairy sector, driven by industry initiatives[204] and dairy processor requirements[205], and have become an increasingly important tool for farm and catchment decision making. Farm Environment Plans help farmers identify farm specific issues and plan farm specific practices to reduce impacts on the environment in an efficient manner.

At the time of writing, 'Freshwater Farm Plan' regulations are in development as a means of providing for farm specific actions to help mitigate the effects of farming on the environment and will be targeted to the environmental context and community and tangata whenua expectations[206].

Once developed and if implemented as intended, Freshwater Farm Plans can build upon non-regulatory Farm Environment Plans. From a regional planning perspective, this will provide an opportunity to develop a regulatory framework which allows farmers to understand what is required on each farm and manage environmental impacts by identifying and targeting actions that are specific to that farm, enabling effective farm decision making.

5.5.4.2 Timeframes are important – particularly for action focused capital costs

Transitioning time is a way of accommodating the investments needed for these environmental actions. This is particularly important as farmers make decisions that will impact their operations for many years to come. Implementing these actions may require large upfront costs and may take time to see a return on investment. Farmers that can plan for these costs, including through improved linkages between farm budgets and environmental planning, will be in a better position to adjust their operations accordingly.

The results outlined in this chapter highlight a need for the identification of further actions for dairy farmers to consider as they seek to reduce environmental impact. For example, there may be alternative ways to reduce nitrogen leaching that are less costly or less disruptive to farmers' operations, including those that cannot be easily modelled in the current versions of Overseer or through use of other tools. This is particularly important given a regulatory context where farmers are no longer seeking a balance between environmental management and farm profitability, with the key question being how farmers can best achieve the environmental outcomes they need to or want to achieve in the most efficient manner.

204 Primarily the Sustainable Dairying: Water Accord
205 For example, Fonterra's Tiaki campaign https://www.fonterra.com/nz/en/campaign/tiaki.html
206 Freshwater farm plans | Ministry for the Environment

5.6 Chapter Appendix 1: Individual Case Studies

The summaries below provide an overview of the characteristics of each dairy farm. It also describes the farm specific environmental actions deemed appropriate for that farm by DairyNZ's farm systems experts and applied to each farm through the modelling (separating out GMP actions from GMP+). The impacts of those actions on operating profit and the effectiveness in reducing the contaminants (N, P, GHG) on a percentage basis from the initial baseline is outlined for each farm. The environmental actions are modelled as stacked mitigations (i.e., cumulatively moving across the columns starting with GMP and adding on GMP+ actions).

When referring to low, medium or high in this appendix, it is in comparison with the other case study farms. It is not implying a low, medium or high impact on the environment, or on operating profit. Some of the information used in the modelling relating to the case study farms is not reported to protect the anonymity of that farm.

5.6.1 Dairy 1

Characteristics – current farm system

- Total effective area of 243 ha, no support block.
- 650 peak cows milked (Friesian) producing 370,000 kg MS.
- Stand-off pad on-farm.
- Wintering: All self-contained grazing, Kale crops grown on the farm.
- Soil type: Gley poorly drained.
- No Irrigation.

Environmental Actions Tested – Dairy 1

Environmental actions	Overview of actions
GMP 1). N use efficiency	1. Shift August (24 kg N/ha) N fertiliser application to September. 2. Split April application (49 kg N/ha) into two applications 25 kg N/ha in March and 24 kg N/ha in April.
GMP 2). Nutrient recycling	1. Reduce effluent block N fertiliser from 144 to 80 kg N/ha to acknowledge nutrients from effluent. - Both effluent and non-effluent blocks receive the same amount of N fertiliser. N from effluent going on the effluent block 146 kg N/ha, assume about 50% might be readily available for plant use.

Results – Dairy 1

	Baseline	GMP 1. Nitrogen use efficiency	GMP 2. Nutrient recycling
N loss kg/ha	16	16	15
Farm gate N surplus kg N/ha	266	264	259
P loss (P kg/ha)	0.7	0.7	0.7
Total GHG kg/ha	17,035	17,034	16,909
N loss reduction	0%	-2%	-4%
P loss reduction	0%	0%	0%
Total GHG reduction	0%	0%	-1%
Change operating profit	0%	1%	2%

Dairy 1 is a medium-sized operation with a moderate stocking rate and sizable amount of bought feed (29%), based in South Otago, with a low baseline N loss. Dairy 1 has an operating profit of $4,600 per effective hectare.

The two GMP actions applied to Dairy 1 (N use efficiency and better nutrient recycling) resulted in reasonable percentage reductions in N. Off a low baseline loss of 16 kg N/ha, this does not translate into large reductions in an absolute sense in terms of nitrogen loss. However, implementation of both GMP measures provided positive results in terms of a one per cent reduction in GHG at a two per cent improvement to operating profit, in addition to reductions in nitrogen loss. The improvements to modelled operating profit are due to the effectiveness of effluent management on pasture growth and the reduced need for nitrogen fertiliser.

5.6.2 Dairy 2

Characteristics – current farm system

- Total effective area of 290 ha, including both milking area and support block.
- 400 peak cows milked (Jersey) producing 170,000 kg MS.
- Farm has got a support block, all self-contained grazing.
- Kale, summer turnip and oat crops grown on the farm.
- Soil type: 70 per cent Pallic imperfect, 30 per cent brown well drained.
- No irrigation.

Environmental Actions Tested – Dairy 2

Environmental actions	Overview of actions
GMP 1). N use efficiency	1. Split and shift the August (25 kg N/ha) N application to November and December. 2. Increased silage harvested, put in storage, and then fed in August, increased harvesting costs.
GMP 2). Nutrient recycling	1. Reduce effluent block N fertiliser from 88 to 65 kg N/ha to acknowledge nutrients from effluent. - Both effluent and non-effluent blocks receive the same amount of fertiliser. N from effluent going on the effluent block 46 kg N/ha, assume about 50% might be readily available for plant use.
GMP 3). Tillage practices	1. Change tillage practice from conventional to direct drilling on the kale, bulb turnips & oats crops.

Results – Dairy 2

	Baseline	GMP 1. Nitrogen use efficiency	GMP 2. Nutrient recycling	GMP 3. Tillage practices
N loss kg/ha	21	21	21	20
Total N loss	7,989	7,881	7,873	7,584
Farm gate N surplus kg N/ha	92	92	90	90
P loss (P kg/ha)	0.6	0.6	0.6	0.6
Total GHG kg/ha	6,169	6,138	6,118	6,115
N loss reduction	0%	-1%	-1%	-5%
P loss reduction	0%	0%	0%	0%
Total GHG reduction	0%	-1%	-1%	-1%
Change operating profit	0%	-1%	0%	0%

Dairy 2 is a medium-sized operation with a moderate stocking rate and a small amount of bought feed (three per cent), based in South Otago, with a low baseline nitrogen loss. Dairy 2 has an operating profit of $2,400 per effective hectare.

Modelling of three GMP actions, better nitrogen use efficiency, better nutrient recycling, and better tillage practices, was applied to Dairy 2. While off a low baseline loss of 21 kg N/ha, implementation of all three actions cumulatively resulted in a five per cent reduction in nitrogen loss, a one per cent reduction in GHG and no reductions in operating profit. Improved tillage practices were the primary driver for reduced nitrogen loss.

5.6.3 Dairy 3

Characteristics – current farm system

- Total effective area of 519 ha, including both milking area and support block.
- 800 peak cows milked (Friesian) producing 350,000 kg MS.
- Kale, summer turnip and fodder beet crops grown on the farm.
- Soil type: 66 per cent Melanic poor, 34 per cent brown well drained.
- No irrigation.

Environmental Actions Tested – Dairy 3

Environmental actions	Overview of actions
GMP 1). N use efficiency	1. Reduce effluent block N fertiliser from 156 to 120 kg N/ha to acknowledge nutrients from effluent. - Both Effluent and Non-effluent blocks receive the same amount of fertiliser. N from effluent going on the effluent block 71 kg N/ha, assume about 50% might be readily available for plant use.

Results – Dairy 3

	Baseline	GMP 1. Nitrogen use efficiency
N loss kg/ha	24	24
Farm gate N surplus kg N/ha	128	126
P loss (P kg/ha)	0.5	0.5
Total GHG kg/ha	8,478	8,444
N loss reduction	0%	-1%
P loss reduction	0%	0%
Total GHG reduction	0%	0%
Change operating profit	0%	1%

Dairy 3 is a larger scale operation with a moderate stocking rate and a moderate amount of bought feed (12 per cent), based in South Otago, with a low baseline nitrogen loss. Dairy 3 has an operating profit of $1,500 per effective hectare.

The only GMP action applied to Dairy 3, better nutrient recycling, resulted in a one per cent reduction in nitrogen loss, no change to GHG or P, and to the benefit of a one per cent increase in operating profit due to the positive effects of nutrient recycling on pasture growth and the reduced need for nitrogen fertiliser.

5.6.4 Dairy 4

Characteristics – current farm system

- Total effective area of 427 ha, no support block.
- 800 peak cows milked (FXJ) producing 290,000 kg MS.
- Swedes and fodder beet crops grown on the farm, modelled with a crop block.
- 100 per cent brown well drained.
- No irrigation.

Environmental Actions Tested – Dairy 4

Environmental actions	Overview of actions
GMP 1). N use efficiency	1. Shift August application to November on both effluent & non-effluent blocks. 2. Reduce the April 63 kg N/ha applied on the non-effluent block to a split application in April & March (31 kg N/ha)
2. Plantain	1. Consider plantain as 30% of the sward. 2. 1/3 of the farm stitched with plantain annually at $150/ha 3. Assumed similar annual pasture production.
3. Baleage wintering	1. Remove all cropping and consider baleage wintering as the farm sits on sedimentary well-drained brown soils, assumed no need for a stand-off pad, this will work using low-cover paddocks. 2. Cows fed 10 kg baleage + 3 kg DM pasture. 3. Ex-crop area now used for grazing and baleage harvests. 4. Shortfall feed imported to fill the deficit.

Results – Dairy 4

	Baseline	GMP 1. Nitrogen use efficiency	2. Plantain	3. Baleage wintering
N loss kg/ha	41	41	36	24
Farm gate N surplus kg N/ha	123	119	117	148
P loss (P kg/ha)	1	1	1	1
Total GHG kg/ha	8,152	8,164	8,079	8,417
N loss reduction	0%	-1%	-13%	-41%
P loss reduction	0%	0%	0%	0%
Total GHG reduction	0%	0%	-1%	3%
Change operating profit	0%	0%	-2%	-24%

Environmental Actions Tested – Dairy 4b (alternative using a composting barn instead of plantain and baleage wintering)

Environmental actions	Overview of actions
GMP 1). N use efficiency	1. Shift August application to November on both effluent & non-effluent blocks. 2. Reduce the April 63 kg N/ha applied on the non-effluent block to a split application in April & March (31 kg N/ha)
2b. Composting barn	1. Covered composting barn with a concrete feeding apron. 2. Cost $3000/cow to build including associated costs, annualised costs, depreciation assuming 25-year life= $89,400, interest @ 7%= $156,000. 3. $85/cow to purchase and remove bedding, annual cost $63,325 4. Winter crop is now fodder beet only, crop lifted in April and put in the stack. Assumed 20% yield reduction as leaves are lost during lifting and in the stack. 5. Oats catch-crop is planted, harvested the following year, stacked, and fed in the barn. 6. Cost of lifting fodder beet, stacking, and feeding out = 4c/kg DM, this increases the crop cost from $2,700 to $3,420/ha 7. Import 161 tDM silage to compensate for yield loss during lifting. 8. Decided not to intensify, so not as to increase GHG. 9. Cows are in the barn 24 hours in June and July, 6 hours in August, March, April, and May.

Results – Dairy 4b

	Baseline	GMP 1. Nitrogen use efficiency	2. Barn
N loss kg/ha	41	41	21
Farm gate N surplus kg N/ha	123	119	106
P loss (P kg/ha)	1	1	1
Total GHG kg/ha	8,152	8,164	7,955
N loss reduction	0%	-1%	-50%
P loss reduction	0%	0%	0%
Total GHG reduction	0%	0%	-2%
Change operating profit	0%	0%	-63%

Dairy 4 is a medium scale operation with a low stocking rate and a low amount of bought feed (four per cent), based in South Otago, with a moderate baseline nitrogen loss. Dairy 4 has an operating profit of $1,700 per effective hectare.

Baleage wintering was applied as a GMP+ action for Dairy 4 in addition to better nitrogen use efficiency (GMP) and the use of plantain (GMP+) as a feed source. Cumulatively these actions resulted in a reduction in nitrogen loss of 41 per cent below baseline (28% of which was due to baleage wintering alone). Cumulatively these impacts reduced operating profit by 24 per cent (with 22% of the reduction due to baleage wintering).

However, the environmental actions modelled for Dairy 4 also resulted in an increase to GHG loss of three per cent[207]. Baleage wintering would also be difficult to achieve without a stand-off structure. As a result, another action was modelled for Dairy 4 (Dairy 4b) this time with the baleage being fed in a

207 As noted earlier, modelling included the assumption that environmental actions could not increase GHG emissions to be considered applicable.

composting barn. Modelling indicated this more practical action could achieve a 49 per cent reduction in nitrogen leaching and a two per cent reduction in GHG loss. However, it comes at the cost of a 63 per cent reduction in operating profit. Based on the operating profit per hectare it is unlikely that either of these bundles could be implemented, particularly in the short term.

5.6.5 Dairy 5

Characteristics – current farm system

- Total effective area of 540 ha, including both milking area and support block.
- 700 peak cows milked (FXJ) producing 270,000 kg MS.
- The farm has got a barn and a covered stand-off pad; cows are wintered inside.
- Mixed pasture species grown on the farm for wintering.
- Pallic soil poorly drained.
- No irrigation.

Environmental Actions Tested – Dairy 5

Environmental actions	Overview of actions
GMP 1). N use efficiency	1. Shift August applications to September, and May applications to April.
GMP 2). Nutrient recycling	1. Reduce effluent block N fertiliser from 79 to 56 kg N/ha to acknowledge nutrients from effluent. - Both effluent and non-effluent blocks receive the same amount of fertiliser. N from effluent going on the effluent block 46 kg N/ha, assume about 50% might be readily available for plant use.
GMP 3). Tillage practices	1. Direct drilling kale, triticale, and turnips crops.
GMP 4). Optimise use of stand-off structures	1. Extend the use of existing stand-off pad to autumn- 4 hrs/day from March to May and increase stand-off to 24hrs for 78% of the cows in the barn in June.

Results – Dairy 5

	Baseline	GMP 1. Nitrogen use efficiency	2. Barn	GMP 3. Tillage practices	GMP 4. Optimise use of stand-off structures
N loss kg/ha	23	22	22	22	21
Farm gate N surplus kg N/ha	92	93	89	89	93
P loss (P kg/ha)	0.6	0.6	0.6	0.6	0.6
Total GHG kg/ha	7,511	7,515	7,415	7,413	7,578
N loss reduction	0%	-1%	-2%	-4%	-7%
P loss reduction	0%	0%	0%	0%	0%
Total GHG reduction	0%	0%	-1%	-1%	1%
Change operating profit	0%	0%	5%	5%	5%

Dairy 5 is a large-sized operation with a low stocking rate and low amount of bought feed (one per cent), based in South Otago, with a low baseline nitrogen loss. Dairy 5 has an operating profit of $770 per effective hectare.

Four GMP actions were applied to Dairy 5; nitrogen use efficiency, nutrient recycling, better tillage practices and the optimisation of stand-off structures. Cumulatively they resulted in a seven per cent reduction in nitrogen loss, although the latter, optimisation of stand-off structures, resulted in an increase in GHG emissions of two per cent. Improvements to operating profit (five per cent) resulted from better nutrient recycling alone, due to the reduced need for nitrogen fertiliser.

The modelling results indicate that if Dairy 5 were to apply the first three of the GMP actions, this would result in a four per cent reduction in nitrogen loss, a one per cent reduction in GHG and a five per cent improvement in operating profit. This finding underline that some actions are farm specific.

5.6.6 Dairy 6

Characteristics – current farm system

- Total effective area of 166 ha, no support block.
- 550 peak cows milked (FXJ) producing 220,000 kg MS.
- Farm has no support block, cows grazed off in winter and young stock grazed off from weaning.
- Fodder beet crops grown on the farm.
- Pallic soil poorly drained.
- Border dyke irrigation.

Environmental Actions Tested – Dairy 6

Environmental actions	Overview of actions
GMP 1). N use efficiency	1. Non-effluent block getting 284 kg N/ha, reduce to legislated 190 kg N/ha.
2. Change from border dyke to pivot irrigation.	1. Changing from border dyke to centre pivot irrigation assuming a cost of $3,000/ha for equipment purchase and installation. 2. $3,000/ha for associated costs, e.g., refencing, removing tree lines, shifting water troughs, levelling borders and re-grassing. 3. Annual costs included interest at 7% per year, depreciation assuming 20-year life, increased repairs and maintenance assumed at $50/ha/yr and increased electricity at $200/ha/yr. Added annual cost. $34,860 interest for Pivot, and $34 860 interest for associated costs. $8,300, increase in maintenance cost. $33,200 increase in electricity cost. $24,900 increase in depreciation cost. Pasture production increased by 5% October to March. Used increased pasture production to reduce imported supplements.

Results – Dairy 6

	Baseline	GMP 1. Nitrogen use efficiency	2. Pivot
N loss kg/ha	146	137	23
Farm gate N surplus kg N/ha	280	254	107
P loss (P kg/ha)	4	4	0.6
Total GHG kg/ha	14,203	13,886	13,471
N loss reduction	0%	-6%	-83%
P loss reduction	0%	0%	-85%
Total GHG reduction	0%	-2%	-3%
Change operating profit	0%	-3%	-20%

Dairy 6 is a small-scale operation with a high stocking rate and a moderate amount of bought feed (12 per cent), based in North Otago. Dairy 6 has an operating profit of $4,100 per effective hectare.

Dairy 6 has a high baseline nitrogen loss, due to the use of border dyke irrigation. Application of GMP through better nitrogen use efficiency resulted in a reduction in both nitrogen loss (by six per cent) and GHG (by three per cent) at a cost of a reduction of three per cent to operating profit. However, because of the high nitrogen baseline, application of better nitrogen use efficiency only meant a reduction with 9 kg N/ha in absolute numbers.

As a result, a GMP+ action was applied, through a change from border dyke irrigation to pivot irrigation. This reduced the amount of nitrogen loss to 23 kg N/ha (a further 77 per cent reduction in addition to GMP), reduced P loss by 85 per cent, and reduced GHG loss by three per cent. However, a change in irrigation also reduced operating profit by 20 per cent. This brings into question the ability of the farm to assimilate the costs required for a shift from border dyke irrigation to pivot irrigation, particularly over a short timeframe.

5.6.7 Dairy 7

Characteristics – current farm system

- Total effective area of 166 ha, no support block.
- 400 peak cows milked (FXJ) producing 155,000 kg MS.
- Fodder beet grown for transition feeding in autumn, cows wintered off in winter and all young stock grazed-off.
- 98 per cent Pallic well drained and two per cent Pallic imperfectly drained.
- Travelling and spraylines irrigation

Environmental Actions Tested – Dairy 7

Environmental actions	Overview of actions
GMP 1). N use efficiency	1. Use soil moisture meter or sensors.
GMP 2). Reduce N fertiliser	1. N fertiliser reduced from 237 to 190 kg N/ha to align with fertiliser inputs regulations, assume a reduction in pasture eaten. 2. 81 tDM baleage imported to fix the deficit. 3. Reduce fodder beet crop N fertiliser from 153 to 100 kg N/ha
3. Plantain	1. Plantain as 30% of the sward. 2. 1/3 of the farm stitched with plantain annually at $150/ha 3. Assumed similar annual pasture production.

Results – Dairy 7

	Baseline	GMP 1. Nitrogen use efficiency	2. Pivot	3. Plantain
N loss kg/ha	44	36	33	24
Farm gate N surplus kg N/ha	235	232	213	211
P loss (P kg/ha)	1.2	1.1	1.1	1.1
Total GHG kg/ha	11,672	11,629	11,363	11,204
N loss reduction	0%	-18%	-25%	-46%
P loss reduction	0%	-8%	-8%	-8%
Total GHG reduction	0%	0%	-3%	-4%
Change operating profit	0%	0%	-6%	-11%

Dairy 7 is a small-scale operation with a high stocking rate and a small amount of bought feed (four per cent), based in North Otago, with a moderate baseline nitrogen loss. Dairy 7 has an operating profit of $2,700 per effective hectare.

Two GMP actions were modelled for Dairy 7, irrigation efficiency and reduced use of nitrogen fertiliser. Cumulatively these resulted in a reduction in nitrogen loss of 25 per cent, a reduction in P loss of eight per cent, and a reduction of GHG loss by three per cent. These actions came at a cumulative cost of a six per cent reduction in operating profit, due to reduced pasture production because of lower use of nitrogen fertiliser.

A GMP+ action of growing and using plantain as feed was applied to further reduce N-loss beyond GMP. This reduced nitrogen leaching by a further 21 per cent and reduced GHG leaching by an additional one per cent but came at a cost of an additional five per cent reduction in operating profit, with the result that all the actions applied reduced operating profit by 11 per cent.

Modelling results for Dairy 7 underline the marginal costs associated with the reduction in nitrogen limits required. Requiring a reduction from 36 kg N/ha to 33 kg N/ha by requiring reductions in nitrogen fertiliser comes at a six per cent reduction in operating profit. Requiring an additional reduction from 33 kg N/ha through the introduction of plantain comes at an additional cost of a further reduction to operating profit of five per cent. Cumulatively, modelling indicates requiring a reduction from 36 kg N/ha to 24 kg N/ha which comes with an 11 per cent reduction in operating profit, alongside a four per cent reduction in GHG loss.

5.6.8 Dairy 8

Characteristics – current farm system

- Total effective area of 190 ha, no support block.
- 550 peak cows milked (Friesian) producing 240,000 kg MS.
- Fodder beet grown for transition feeding in autumn, cows wintered off in winter and all young stock grazed-off.
- 84 per cent Pallic well drained and 16 per cent Pallic imperfectly drained.
- Spraylines irrigation

Environmental Actions Tested – Dairy 8

Environmental actions	Overview of actions
GMP 1). N use efficiency	1. Move from visual assessment or dig a hole irrigation-based decision to soil moisture probes.
GMP 2). Reduce N fertiliser	1. Reduce N fertiliser from 233 kg N/ha to 190 kg N/ha to align with N fertiliser regulations. 2. Move May (36 kg N/ha) application to April. 3. More barley grain and PKE imported to fill the feed deficit from reducing N fertiliser.

Results – Dairy 8

	Baseline	GMP 1. Irrigation efficiency	GMP 2. Reduce N fertiliser
N loss kg/ha	40	28	24
Farm gate N surplus kg N/ha	218	214	196
P loss (P kg/ha)	0.6	0.5	0.5
Total GHG kg/ha	12,267	12,211	11,932
N loss reduction	0%	-31%	-39%
P loss reduction	0%	-17%	-17%
Total GHG reduction	0%	0%	-3%
Change operating profit	0%	0%	-3%

Dairy 8 is a small-scale operation with a moderate stocking rate and a low amount of bought feed (7%), based in North Otago, with a moderate baseline nitrogen loss. Dairy 8 has an operating profit of $3,400 per effective hectare.

Application of two GMP actions, better irrigation efficiency and reduced use of nitrogen fertiliser, resulted in a reduction of 39 per cent in nitrogen loss, 17 per cent in P loss and a three per cent reduction in GHG loss. Application of better irrigation efficiency by itself resulted in 31 per cent of the reduction in nitrogen loss and the entire 17 per cent reduction in P loss, with no reduction in operating profit. Applying the second action, reduced nitrogen fertiliser, resulted in a further reduction in nitrogen loss of eight per cent and a reduction in GHG loss of three per cent, at the cost of a three per cent reduction in operating profit due to reduced pasture growth.

5.6.9 Dairy 9

Characteristics – current farm system

- Total effective area of 373 ha, including both milking area and support block.
- 900 peak cows milked (Friesian) producing 350,000 kg MS.
- Fodder beet grown for transition feeding in autumn, cows wintered on support block fodder beet crop and only R1 are grazed-off.
- 80 per cent Pallic imperfectly drained and 20 per cent Pallic well drained.
- Spraylines and pivot irrigation

Environmental Actions Tested – Dairy 9

Environmental actions	Overview of actions
GMP 1). N use efficiency	1. Change February (65 kg N/ha) and March (73 kg N/ha) applications to split applications in September (36), December (32), February (36) and March (32) on the run-off block.
GMP 2). Tillage practices	1. Direct drill 10 ha Kale crop, on the support block.
3. Only keep productive animals	Only keep productive animals, consider culling early, all known empty cows sold by March, and this will reduce autumn feed demand.

Results – Dairy 9

	Baseline	GMP 1. N use efficiency	GMP 2. Direct drilling	3.Keep productive animals
N loss kg/ha	26	26	26	25
Farm gate N surplus kg N/ha	200	201	201	199
P loss (P kg/ha)	0.7	0.7	0.7	0.7
Total GHG kg/ha	11,842	11,845	11,845	11,708
N loss reduction	0%	-1%	-1%	-3%
P loss reduction	0%	0%	0%	0%
Total GHG reduction	0%	0%	0%	-1%
Change operating profit	0%	0%	0%	-2%

Dairy 9 is a medium to large-sized operation with a high stocking rate and a moderate amount of bought feed (13 per cent), based in North Otago, with a moderate baseline nitrogen loss. Dairy 9 has an operating profit of $3,000 per effective hectare.

Three GMP actions were applied to Dairy 9; better nitrogen use efficiency, improved tillage practices and only keeping productive animals. Cumulatively these actions resulted in a reduction in nitrogen loss of three per cent and a reduction in GHG emissions of one per cent, at the cost of a two per cent reduction in operating profit. The addition of the third GMP action, keeping productive animals, delivered two per cent of the reductions in nitrogen loss, the one per cent reduction in GHG loss and the two per cent reduction in operating profit by itself.

5.6.10 Dairy 10

Characteristics – current farm system

- Total effective area of 130 ha, no support block.
- 500 peak cows milked (Friesian) producing 250,000 kg MS.
- Cows wintered off and young stock grazed off.
- 62 per cent Pallic moderately well drained and 38 per cent brown well drained.
- Border dyke irrigation

Environmental Actions Tested – Dairy 10

Environmental actions	Overview of actions
GMP 1). Nitrogen use efficiency	1. Shift May (4kg N/ha), N fertiliser application to March.
2. Change to Pivot irrigation	1. Changing from border dyke to centre pivot irrigation assumed a cost of $3,000/ha for equipment purchase and installation. 2. $3,000/ha for associated costs, e.g., refencing, removing tree lines, shifting water troughs, levelling borders and regressing. 3. Annual costs included interest at 7% per year, depreciation assuming 20-year life, increased repairs and maintenance assumed at $50/ha/year and increased electricity at $200/ha/year. Added annual cost. $27,300 interest for Pivot, and $27 300 interest for associated costs. $6,500, increase in maintenance cost. $26,000 increase in electricity cost. $19,500 increase in depreciation cost. Pasture production increased by 5% October to March, driven by efficient water use.
3. Reduce N fertiliser	1. Reduce September N fertiliser application from 52 kg N/ha to 21 kg N/ha and remove March application 4 kg N/ha. 2. 41 tDM of barley grain imported to replace N boosted pasture from fertiliser.

Results – Dairy 10

	Baseline	GMP 1. N use efficiency	2. Pivot	3. Reduce N fertiliser
N loss kg/ha	162	162	27	25
Farm gate N surplus kg N/ha	297	297	252	236
P loss (P kg/ha)	6.5	6.5	0.8	0.8
Total GHG kg/ha	16,727	16,735	16,213	15,915
N loss reduction	0%	0%	-83%	-84%
P loss reduction	0%	0%	-88%	-88%
Total GHG reduction	0%	0%	-3%	-5%
Change operating profit	0%	0%	-11%	-12%

Dairy 10 is a small-scale operation with a high stocking rate and a high amount of bought feed (17 per cent), based in North Otago. Dairy 6 has an operating profit of $5,500 per effective hectare.

Dairy 10 has a high baseline nitrogen loss, due to the use of border dyke irrigation. Application of GMP through better nitrogen use efficiency resulted in no reduction in nitrogen loss, GHG loss or P loss.

Application of two GMP+ actions, moving from border dyke irrigation to pivot irrigation, and reducing the use of nitrogen fertiliser, resulted in a reduction in nitrogen loss as well as an 88 per cent reduction in P loss and a five per cent reduction in GHG.

Of these improvements, 83 per cent of the reduction in nitrogen loss, 88 per cent of the reduction in P loss and three per cent of the reduction in GHG loss was attributed to the switch to pivot irrigation alone, at a cost of an 11 per cent reduction to operating profit.

Because Dairy 10 is a smaller scale farming with a relatively high operating profit per effective hectare, it is unclear what the impacts of an 11 per cent or 13 per cent reduction in operating profit would be in terms of farm viability.

6 Horticulture

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6.1 Summary

Otago's diverse climate provides ideal conditions for orcharding (pipfruit and summerfuit) and vegetable production. Each horticultural subsector has different pressures and needs that span biophysical factors, growing systems, support services, scale and opportunities, and environmental effects.

The fruit and vegetable industries make an important contribution to the Otago economy, accounting for approximately four per cent of regional GDP.

Representative financial models were constructed for outdoor vegetables, pipfruit, and summerfruit that covered production, revenue and financial performance. These models were used to test a range of environmental actions, including good management practices, reductions in fertiliser use and irrigation water availability, short duration consents, rootstock survival water, and innovations.

Environmental practices

Seven summerfruit and two vegetable growers in Otago completed a Farm Environment Plan using the Environment Management System (EMS) add-on to GAP. Growers answered questions about irrigation and nutrient risk and management practices. Most surveyed growers are achieving Good Management Practice at a minimum, which is consistent with what is being observed across the country.

The risk profile for orcharding is very different to vegetable growing and so risks are assessed and managed differently. Using the EMS, growers can remain agile if risks change. This flexibility is crucial to tailor assessments and practices to risks on farm and in the receiving environment.

Innovations

Most orcharding innovations are designed to maximise production and minimise economic impacts and environmental effects. Two innovations were tested – the upright fruiting offsets (UFOs) and retractable roof systems.

In the UFO system, cherry plants are grown on a trellis and shoots are trained to grow straight up. The advantages are it produces more fruit, and reduces the costs of spraying, irrigation and harvesting. Overall profits can be higher even with additional capital investment required.

Retractable roofing is designed to manage environmental conditions. Advantages include higher yields, better fruit quality, extended season, and reduced agrichemical and irrigation use. Such systems may become a viable alternative for growers where water use efficiency is a key driver.

Irrigation use

Growers need secure and reliable access to water to produce marketable crops, fight frosts, and wash fresh produce for human consumption. Growers need water at specific times in the crop growth cycle to achieve a marketable yield, particularly when soil moisture limits growth.

Analysis on the economic implications of water restrictions showed a decrease in yield for vegetables. Vegetable growers using Good Management Practices use water sparingly. It is more likely that less irrigation water will result in a non-marketable yield or crop failure. At 40 per cent decrease in yield, the vegetable model was at breakeven (no profits).

Orchardists use a high degree of irrigation efficiency, delivered to trees by dripline or micro sprinklers. The exact amount of water is delivered reasonably directly. To keep trees alive and thriving, trees need continued supply of water at the right rate and time throughout the growth and production cycles.

The modelling shows pipfruit is very sensitive to the impact of a reduced yield with the breakeven point reached when yields reduce by 20 per cent. Summerfruit is also sensitive with the breakeven point reached at about 30 per cent reduction in yield. Traditional cherries are more resilient largely because of the high profits; however, the income loss is still sizeable.

On a per hectare basis, the loss in financial performance from a reduction in yield is substantial for all the representative models, which reflects the likely cost of restrictions in access to irrigation water.

Fertiliser use

The losses of nutrients from vegetable production vary greatly depending on the range of crops grown, the timing of growing, the intensity of the operation, and climate and soils. Contemporary grower practices include budgeting, regular soil testing and visual assessments of crop growth. Growers apply fertiliser at intervals to match each crop’s growth cycle. A national project on nitrogen losses from vegetable rotations is currently underway and will develop a nitrogen budgeting tool to accurately inform fertiliser applications.

Nutrient use on orchard is relatively low and typically delivered via fertigation dripline or micro-sprinklers. Available data from apple orcharding in Hawkes Bay showed low nitrogen and phosphorous losses from orchards compared to general primary production losses.

Root stock survival water

Orchard rootstock survival water requires a planning regime that allows sufficient water to be abstracted when the take conditions are below the minimum flow, to keep the plant’s rootstock alive and able to produce a marketable crop the subsequent season.

In the absence of the provision of rootstock survival water, a grower is faced with the removal and replacement of dead plants, and building up production again until the new trees reach full potential. This process can take five years or more. Modelling showed that without rootstock survival water, impacts ranged from 52 to 63 per cent reduction in net present value depending on fruit variety.

Short versus long term consents

Large investments are needed for either developing or purchasing orchards and vegetable production operations, and relatively large annual requirements to maintain that investment.

Reliable access to water and security of water supply are key considerations when planning out an operation and can underpin investment decisions. For example, a new orchard could cost between

$120,000 and $160,000 per hectare. Longer-term consents give producers increased certainty to invest in their land and infrastructure because costs can be spread out over a longer period. Orchards with longer consents usually invest in more technically efficient means of irrigation.

Short-term consents create risk aversion. When producers are faced with unknowns this may make them question the viability of producing. For example, if a six-year consent for water is granted, and tree crops take five years to establish before returning a marketable yield, it leaves a single harvest (one year) to factor in return on investment. Longer term consents will increase producer confidence to manage investment risk.

Enabling vegetable production

Commercial vegetable production in Otago has declined over the last twenty years, with less than 500 hectares remaining in 2021. Otago relies on trucking fresh produce in from other regions, making it vulnerable to supply chain and production disruptions.

Outdoor vegetable production relies on rotating crops in a sequence to manage pest and disease pressures, balance soil health, and access the most fertile blocks. Most vegetable businesses across New Zealand rely on leased land arrangements to achieve effective rotations. Crop rotation presents a unique challenge for growers and policy makers, as often consents are tied to a parcel of land. Consents for commercial vegetable production need to be flexible to allow crops and water use to rotate across non-contiguous, owned and leased, blocks of land in an FMU.

6.2 Introduction

The purpose of this chapter is to test environmental actions for Otago horticulture growing operations in relation to nutrient losses and water supply to understand the impacts on businesses. It uses production, environmental and financial performance data collected from five pipfruit, seven summerfruit, and two vegetable operations as part of the phase one horticulture data collection project. The operations selected in phase one represent a cross-section of horticulture crops grown in Otago and represent a range of property and business sizes in Otago for each growing system.

The production and financial data collected was anonymised and aggregated before being used to populate a standard financial model in Excel. Farm Environment Plans using the NZGAP Environment Management System add-on were also produced for each business. The environmental actions modelled in this report are those currently in use by the horticultural sector and relevant to potential policy options anticipated in the Otago Land and Water Regional Plan.

Environmental actions were tested for the following topics:

- Good Management Practice+[208];
- Reduction in fertiliser use and irrigation water availability;
- Short vs long-term consents;
- Provision of root stock survival water; and
- Innovations

These actions are described in more detail in the sections to follow.

208 GMP – Good Management Practice is a minimum industry standard that growers work to. GMP+ refers to any practices that are considered to exceed GMP, or best practice. See Section 6.4 of this report.

6.2.1 Horticulture in Otago

Orcharding (summerfruit and pipfruit) and vegetable production are different subsectors within horticulture. Both have very different pressures and needs, and key differences that need to be considered, including:

- Climatic and environmental needs;
- Location (static versus dynamic);
- Scale, growth and opportunities; and
- Environmental effects

Image 36: Apricot trees in blossom.
Source: Leanne Roberts

6.2.1.1 Climate

Otago has a diverse climate. The central areas are characterised by high diurnal temperature variations, low rainfall, and frosts[209] in the Dunstan, Manuherekia and Roxburgh Rohe[210]. There are comparatively higher sunshine hours in these areas, and lower rainfall. It is noted that the climate of these inland basins has supported a long-robust history of summerfruit and pipfruit orchards in Otago[211]. The, North Otago, Taieri, Dunedin and Coast and Coast Freshwater Management Unit's and the Lower Clutha Rohe generally have flatter topography and more consistent rainfall over a year than in the Dunstan, Manuherekia and Roxburgh Rohe[212]. These have been the areas where traditionally there has been more commercial vegetable production in Otago. These climatic variations across the region help provide understanding about why the subsectors within horticulture have occurred and thrived in these areas.

209 Otago Climate book WEB 2021.pdf (niwa.co.nz)
210 Find your area | Otago Regional Council (orc.govt.nz)
211 Otago Climate book WEB 2021.pdf (niwa.co.nz)
212 Otago Climate book WEB 2021.pdf (niwa.co.nz)

6.2.1.2 Orcharding

Orcharding in Otago refers to the production of pipfruit[213] and summerfruit[214] and is predominantly located in the Clutha Mata-au Freshwater Management Unit. Orcharding is predominantly in the Dunstan, Manuherekia and Roxburgh Rohe[215] around the towns Roxburgh, Ettrick, Alexandra, Cromwell and Wanaka. Table 42 below shows the planted area of apples and summerfruit in Otago in 2021.

Table 42: Area planted (ha) of Summerfruit and pipfruit in Otago and New Zealand[216].

Crop	Area planted (ha) Otago in 2021	Area planted (ha) NZ 2021
Apples	427	8,615
Summerfruit	1,144	2,140
Nitrogen leaching	16	162

Summerfruit production in Otago is in a growth phase. This is largely in the growth and expansion of cherry production in the Central Otago area. The expansion in summerfruit is largely driven by the demand from export markets such as Taiwan, China, Vietnam and Thailand[217].

Table 43 below contains export sale volumes for summerfruit in New Zealand. The table highlights the significance of the Otago summerfruit industry nationally, with just over half of all production in Otago[218].

Table 43: Export sale volumes 2018/19 and 2021/22[219]

Crop	Export sales 2018-19 (kgs)	Export sales 2021/22 (kgs)
Cherries	2,682,370	3,219,229
Apricots	317,135	168,057
Nectarines	3,840	1,364
Peaches	43,058	31,778
Plums	21,156	10,580

The expansion of summerfruit has led to the development of new orchards in Central Otago to meet the demand. New developments can challenge the traditional view of what an orchard can look like. For example, training trees to grow on 2-D structures enable production efficiencies through mechanisation and automation. 2-D structures, such as those found on Upright Fruiting Orchards (UFO), also allow a higher plant density, and greater pruning and tree maintenance to allow for light and airflow to reduce pest and disease pressure[220].

213 Pipfruit refers to Apples and Pears
214 Summerfruit refers to stonefruits such as: cherries, apricots, plums, peaches, nectarines
215 *Find your area | Otago Regional Council (orc.govt.nz)*
216 *freshfacts-2021.pdf*
217 *2018-19 Season - Summerfruit NZ; 2021-22 Season - Summerfruit NZ*
218 *freshfacts-2021.pdf*
219 *2018-19 Season - Summerfruit NZ; 2021-22 Season - Summerfruit NZ*
220 *Witheford-Simon_Establishing-and-operating-a-Sweet-Cherry-orchard_Kellogg-report.pdf (ruralleaders.co.nz)*

Image 37: Pipfruit orchard in spring Central Otago.
Source: Simon Moran

Image 38: Looking down on orchard at Ettrick.
Source: Simon Moran

Other innovations may incorporate the use of semi-protected cropping structures such as retractable roofing systems. These systems can create other operational efficiencies such as eliminating the need to use water for frost protection. Greater environmental controls can result in higher quality fruit and even sizes consistently produced[221]. More in depth analysis of the different growing approaches, methodologies and consent length impacts is explored further in this report.

There is a direct correlation between consent length and economic decisions made on orchard. Many factors will be considered and planned for before an orchard is planted out[222]. Witherford discusses some of the considerations when selecting a site for orchard development, including: climatic requirements of crop, soil type, water availability, topography, growing risks and management options, cultivar and root stock[223]. Once an orchard of trees is planted, it can take five years before a tree crop will produce a marketable yield.

A short duration consent will influence decisions about the level of investment into infrastructure of both existing and new orchards. Orchard trees are permanently in place for the duration of their life and so a key consideration when developing a new orchard is having access to a secure and reliable water supply when the trees need it, and growing methodology. Productivity of stone fruit trees can diminish after 15 years; however, this is dependent on variety, style and tree care[224]. The lifetime of orchard trees are linked to their productive capacity, and blocks of trees are replanted on this basis. Commercial orchards comprise several blocks of trees of varying ages, and so its lifetime, and long-term infrastructure investment decisions, can be multi-generational.

If short duration consents are issued, of ten or less years, a business has a limited window for a return on investment. This is assuming other factors such as adverse weather events and market disruptions do not impact on the ability of growers to produce and sell a marketable yield once the tree is at production age. These factors, combined with others identified by Witherford and listed above, need to be considered by growers in their long-term business planning.

6.2.1.3 Commercial vegetable production

Most commercial vegetable production in Otago is located around Oamaru, and Kakanui in the Waitaki District.

Commercial vegetable production in Otago has declined over the past twenty years. Table 44 below shows the total area of vegetable production in Otago over three decades at decadal intervals - 2001, 2011 and 2021.

Table 44: Total vegetable production (ha) in Otago 2001 – 2021

	2021 area (ha)[225]	**2011 area (ha)[226]**	**2001 area (ha)[227]**
Total vegetable production area in Otago	428+	439+	836

221 *Kris-Robb_What-Goes-in-Must-Come-Out_-Protecting-Our-Social-License-to-Grow-Cherries_Kellogg-Report.pdf (ruralleaders.co.nz)*
222 *Witheford-Simon_Establishing-and-operating-a-Sweet-Cherry-orchard_Kellogg-report.pdf (ruralleaders.co.nz)*
223 *Witheford-Simon_Establishing-and-operating-a-Sweet-Cherry-orchard_Kellogg-report.pdf (ruralleaders.co.nz)*
224 *The summerfruit industry – Te Ara Encyclopedia of New Zealand*
225 *freshfacts-2021.pdf*
226 *Fresh Facts 2011*
227 *Fresh Facts 2001*

This decline correlates with feedback from remaining Otago vegetable growers. The development of the Horticulture Chapter in the *Farmers and Growers in Otago Report* in 2022 prompted an informal survey by HortNZ. Growers indicated that the once thriving vegetable industry on the outskirts of Dunedin has had a marked decline, particularly in the last twenty years. When asked, growers indicated the key factors of the decline were the rate of regulatory change, the pressure of urban expansion, and the challenges of succession planning[228].

Ninety per cent of fresh vegetables grown in New Zealand are destined for the domestic New Zealand market. Otago is vulnerable to supply chain and production disruptions as it relies on road freight to transport fresh produce from other regions to meet local food needs. If the decline in Otago's vegetable production continues, then access to healthy food at a reasonable price is likely to be further compromised. In other parts of the country where vegetable production has declined or disappeared in the past, the industry has struggled to return.

Outdoor vegetable production systems are highly dynamic because the crops are grown in a variety of rotations, each with a unique sequence and time period. Crops are rotated both on a single parcel of land in succession, as well as across the landscape on non-contiguous blocks in the most fertile soils and micro-climates.

Crop rotation involves planting a specific sequence of different types of crops in a single location over several seasons. The crop rotation is a vital management practice used by all vegetable growers to balance soil health, reduce the risk of soil-borne pests and diseases, and maintain or increase a farms productivity through the recycling of carbon and nutrients of previous crops[229]. Crop rotations are planned out in advance, up to a year, so that inputs such as seeds, fertiliser, agrichemicals and leased land arrangements can be secured by the time that crop is due to be planted.

Outdoor vegetable growers across New Zealand rely on leased land arrangements to achieve an effective rotation. The locations of commercial vegetable activities will vary, and some leases can be in place for a single season. Further to this, growers need to be responsive to climate and significant weather events when these impact on the availability of land or the planting programme. One of the challenges for commercial vegetable growers in Otago is balancing needs of crop rotation, weather events and being able to run an economically viable operation.

Crop rotation presents a unique challenge for growers and policy makers, as resource consents are often tied to a parcel of land. Consents to operate a commercial vegetable growing operation have fewer impacts when they are flexible enough to allow for the movement of crops in rotations across non-contiguous parcels of land in a Freshwater Management Unit. Growers also need the ability to change water requirements and irrigation systems depending on the location of the land parcel to allow for an effective rotation.

The way in which policy is designed is a major factor in both the impacts of the operating environment for businesses and the environmental outcomes achieved. Where expectations are achievable, integrated, and straightforward then growers are in a better position to understand what is needed to meet them.

228 HortNZ internal survey of Otago Growers
229 *Importance of Crop Rotation (bayer.com)*

6.2.2 Economic Overview

Growers rely on a range of support services, infrastructure and access to packhouse and processing facilities to deliver produce to market. Growers also rely on seasonal workers and specialist skilled staff to enable a successful operation. Depending on the seasonality of crops grown, and number of harvests per year (vegetables having multiple), the support services, labour infrastructure needs differ across the different growing systems. Table 45 shows the area, and estimate of investment, made in production and post-harvest facilities for crops grown in Otago.

Table 45: Export sale volumes 2018/19 and 2021/22

Crop	Area (ha)	Investment ($ millions)
Summerfruit	1,144	152.37
Apples	427	81.06
Berryfruit	36	3.16
Nuts	144	9.11
Olives	19	1.66
Other subtropical fruits	21	1.93
Other fruits	36	3.30
Potatoes	196	16.67
Cabbage and cauliflower	164	10.75
Other vegetables	67	4.37
Total fruit and vegetables	2,254+	284.38+

Source: The data presented is sourced from the Fresh Facts document.
Note: The data used for 'area' was compiled by Statistics New Zealand as at 30 June 2017. The data used for 'investment' is an estimate of the investment made in both the production of the crops but also the post-harvest facilities which have been compiled by the authors of Fresh Facts, Plant and Food Research and Horticulture New Zealand.

Producing a marketable yield for a crop is strongly linked to economic viability of commercial growing businesses. Market specifications include size, colour, texture, and sometimes taste. Therefore, a grower must produce what is called 'marketable yield', one that meets those specifications, to make a return on investment. This differs from meat production, for example, where livestock can be sold earlier or later in a season, and the farmer has some certainty of return on investment. If a grower's produce does not meet the primary market specifications, there are few secondary markets available in New Zealand.

For a grower, the relationship between inputs (e.g., nutrients and water) and producing a marketable yield, is often binary, particularly in vegetable production. Without the necessary inputs to grow the crop to meet market specifications, growers cannot afford the cost of harvest if the market will not accept it. There may be greater environmental effects from sowing a crop back into the soil, in terms of input losses.

Image 39: Summerfruit orchard in winter having used water for frost protection.
Source: Sam Hobbs

Growers are heavily dependent on secure and reliable access to water to justify the ongoing investment. Otago growers need water to grow, frost fight[230], harvest, and wash fresh fruit and vegetables. Growers need to be able to irrigate their crops at specific times in the crop growth cycle, particularly when soil moisture is limiting growth potential, to achieve a marketable yield. Growers often need water for crop growth and survival in the summer months when rivers are nearing, at, and sometimes below minimum flows.

The economics of growing these crops is variable depending on local or international prices. Additionally, the demand for irrigation depends on the variability rainfall of the region. Growers need reliable irrigation to be maintained to enable and encourage growers to continue to grow marketable crops.

Most horticulture produce grown in Otago is destined for the domestic New Zealand market. The processing industry in Otago receives, processes, and packs the horticultural produce, and then exports it around New Zealand and international markets. The processing industry is instrumental to the success of growing businesses and employment opportunities in the region.

Investment in infrastructure is needed to support on orchard activities. For example, worker accommodation, packing and processing, cool storage, and access for transport. Accommodation is needed to house the large number of temporary workers required to pick and pack the fruit. Other infrastructure includes sorting and packing lines, cool store facilities, and the provision of a very efficient transport chain. This transport chain allows the fruit to be taken to both the New Zealand market and to export. This is one of, if not the, most efficient production chains for large scale highly perishable fruit in the world.

230 More frost fighting methods are discussed in the phase one report.

An estimate of the area of fruit from Summerfruit New Zealand is used to represent the order of growth in the industry since the 2017 Statistics New Zealand data was produced. This data is shown in Table 46, along with Summerfruit New Zealand's estimate of the short-term growth, either already underway or planned.

Table 46: Estimates of the current and future area of summerfruit.

Crop	Estimated current area in 2020	Expected short-term growth	Total Area
Cherries	1,093	430	1,523
Apricots	267	25	292
Peaches	74	0	74
Nectarines	113	0	113
Plums	38	0	38
Total	**1,585**	**455**	**2,040**

This data shows that the area in summerfruit, and particularly cherries, has grown considerably from the 2017 Statistics New Zealand data and that the rate of growth is expected to at least continue, if not to increase. The expected short-term growth will mean that in a few years the area in summerfruit is anticipated to have increased by around 30 per cent.

The situation with apples is very similar to summerfruit, with considerable growth in the crop area. The area of apples grown in Otago reached 470 hectares at the end of the 2020 season, which is a ten per cent increase on the area recorded in 2017. There is an expectation that this area will increase by an additional 100 hectares in the short to medium term.

The fruit and vegetable industries in Otago make an important contribution to the Otago economy through both supporting industries and employment. The ability to grow, and continue to expand, is dependent on the availability of a reliable irrigation water, and the process for managing and allocating water for irrigation.

By estimating average production and prices for cherries, the cherry crop will contribute approximately $329 million to regional GDP and account for approximately 890 full time equivalents (FTEs), based on the known area of in-ground and planned short-term planting. While cherries are the dominant orchard crop, the area is suitable for other summerfruit and pipfruit varieties and could expand with increased market demand.

According to the Central Otago Labour survey, 4,965 workers, of which 65 per cent were backpackers on working holiday visas, were employed for the 2017/18 harvest season. This labour force increased to 5,035 workers in the 2020/21 harvest season[231]. Temporary, or seasonal labour, brings other opportunities to regions such as Otago with the need for accommodation, food, and tourism opportunities for the temporary workers. In total the investment in the combined fruit and vegetable sector and its ancillary post-harvest facilities is more than $500 milion.

In total, the horticultural sector accounts for approximately four per cent of the Otago region's gross domestic product (GDP).

231 *38290 A4 REPORT Central Otago Labour Survey.pdf (codc.govt.nz)*

6.3 National Policy Direction and Horticulture

This section highlights potential challenges and opportunities of national policy on horticultural production in Otago. Specifically, the National Policy Statement for Highly Productive Land, and Freshwater Farm Plans.

6.3.1 National Policy Statement for Highly Productive Land

The National Policy Statement for Highly Productive Land (NPS HPL) provides clear direction on the preservation of versatile soils (Land Use Classes 1, 2 & 3). Regional Councils are required to map HPL in their regions. There are two policy challenges with the potential to impact horticulture in Otago, explained below.

The first is the protection of horticulturally productive land in Otago that is not covered by NPS HPL.

Most orcharding in Otago occurs in LUC 4 and 5, some of the most horticulturally productive soils when considered in combination with climate (refer to Section 3 on climate and environment). Horticulturally productive areas in Otago, through Roxburgh to Cromwell, are considered the orcharding hubs of the region. These areas are not afforded the protection of the NPS HPL because of their LUC status and are at risk. Consequently inappropriate development could constrain or impact on the productive capacity of this land for horticulture.

The second relates to enabling other types of vegetable production systems that are not provided for in the NPS HPL, for example, covered cropping on LUC 1, 2 or 3.

One of the challenges that commercial vegetable growers have in Otago is the climate and the impact on growing outdoors year-round. One option may be to invest in covered cropping systems. Covered cropping structures can protect the crop in the soil or provide an opportunity for hydroponic cropping operations. A key consideration when growing fresh produce is proximity to markets, transport routes and support services. However, hydroponic covered cropping operations are not included as an appropriate activities on LUC 1, 2 & 3 in the NPS HPL. The question of where to appropriately locate these operations is relevant Otago's Proposed Land and Water Regional Plan as it may be a viable option for reinvigorating vegetable production in Otago in the future.

6.3.2 Freshwater Farm Plans and 'GAP' Schemes

Ministry for the Environment (MfE) released national Freshwater Farm Plan (FWFP) regulation in June 2023. These regulations require farmers and growers over certain hectare thresholds to have an audited and certified freshwater farm plan that meets the regulations.

Over 90 per cent of New Zealand fruit and vegetable growers currently meet a range of market and regulatory standards to sell their produce, using Good Agricultural Practice (GAP) schemes. The GAP schemes are horticulture's Industry Assurance Programmes that cover food safety, social practice, and environmental management. Using GAP, consumers and regulators are provided assurance (via audit and certification) that growing businesses are producing fresh and healthy food, in a safe and sustainable manner. The two GAP schemes operating in New Zealand are GLOBALG.A.P., for export markets, and NZGAP for local markets and regulatory requirements.

The markets and regulators set the requirements, and the GAP schemes adapt their standards and systems to meet those requirements. GAP seeks recognition of their standards by markets and regulators through rigorous benchmarking. Growers are then audited against the approved standards to attain GAP certification and retain access to markets and regulatory pathways. This robust standards-based approach holds growers to account using audit and certification process that meets international best practice.

Growers are constantly adapting to changing requirements, and Freshwater Farm Plans are no different. Growers using the core GAP standards will already be part of the way to meeting Freshwater Farm Plan requirements. GAP schemes can create modules, or add-ons, for specific requirements.

In 2017, NZGAP developed the Environment Management System (EMS) add-on for Farm Environment Plans (FEPs). The EMS contains good and best management practices based on codes of practice and research, further explained in Section 6. The EMS add-on has received recognition in Canterbury and Gisborne as meeting their FEP requirements. The EMS has been tested and rolled out to approximately 40,000 hectares of horticulture land in New Zealand.

Similar recognition is sought for the new national Freshwater Farm Plan requirements. MfE has indicated that Freshwater Farm Plan framework will allow for the continued use of industry assurance programmes, provided they meet the regulations[232]. NZGAP will benchmark the EMS add-on to the regulations, and update the system to meet the content standards primarily in relation to catchment context and prioritising actions.

6.4 Good and Best Environmental Practice in Horticulture

6.4.1 Industry research and extension

The horticulture sector has undertaken decades of research to build understanding of environmental risks, and design appropriate practices and tools to manage those risks. The research, knowledge, practices and tools underpin industry's environmental codes of practice and guidance for growers.

Such initiatives include:

- NZGAP and GLOBALG.A.P. accreditation
- GAP Environment Management System add-on for Farm environment plans
- Erosion & Sediment Control Guidelines for Vegetable Production[233]
- Vegetated Buffer Strip Guidelines
- Code of Practice for Nutrient Management[234]
- A Code of Practice [and growers guide] for the Management of Greenhouse Nutrient Discharges[235]
- Vegetable Wash Water Discharge Code of Practice[236]
- A Water Strategy for the Kiwifruit Industry[237]

232 Freshwater farm plans | Ministry for the Environment
233 Soil and Water Management (waikatoregion.govt.nz)
234 Nutrient Management Code of Practice (hortnz.co.nz)
235 CoP-Managing-GH-Nutrient-Discharges-2nd-edition.pdf (hortnz.co.nz)
236 Vegetable-Washwater-Regional-Requirements-Discharge-Code-of-Practice-v1.2.pdf (hortnz.co.nz)
237 J002013_Water_Strategy_Document_Update_R2_Final_WEB_Small.pdf (nzkgi.org.nz)

NZGAP and GLOBALG.A.P. are useful to consider in the context of on-farm decision making as they provide a framework and expectation of standard practices growers must achieve. On farm decisions are limited to those that will improve the operation and meet accreditation requirements.

Using existing GAP standards and the EMS add-on, growers are already on the journey of good and best practice and are prepared for Freshwater Farm Plan regulations. Additional support is available from industry-led research and extension projects.

HortNZ has regional extension staff actively working with growers to develop Freshwater Farm Plans using the GAP EMS, through the Growing Change project. The Growing Change project is co-funded by HortNZ and MfE (through the Essential Freshwater Fund). By the end of 2025, HortNZ will deliver ten catchment projects to roll out Freshwater Farm Plans for growers. The Otago catchment project is currently underway.

The horticulture industry promotes a grower-led approach to farm planning. The project provides opportunities for growers to work one-on-one with experienced advisors, access science and agronomist experts to understand the full suite of tools and practices available to manage freshwater risks from horticulture, and peer-to-peer learning opportunities. Growing Change is also developing an education programme on how to manage freshwater risks from horticulture, for growers, advisors and auditors.

Another important project for the horticulture industry is the Sustainable Vegetable Systems (SVS) project. SVS is looking at nitrogen use and management in commercial vegetable production systems. The project has undertaken field-based agronomy trials to collect empirical data of nitrogen leaching from different crops in rotation under different fertiliser management regimes. SVS is developing a decision support tool for growers based on the concept of a nitrogen budget, considering soil tests and crop guide recommendations, to inform a grower's fertiliser use for each crop.

Through SVS and Growing Change, the industry has seen continued improvement in environmental practices by growers. Growers in these projects have been working with experienced advisors to understand the value of available practices, like nutrient budgets, soil tests, and crop guide recommendations, to manage nutrient loss risks. As a result, growers match fertiliser applications to crop demand, and maintain marketable yields. Growers are given the confidence to adopt practices into their management systems and staff training.

6.4.2 Environmental management practices

The EMS contains good and best management practices[238]. Good management practices are considered industry minimum standards. Best management practices are not always required and can include new practices and technologies that are not available or appropriate to every growing operation. Depending on the focus of an operation, a grower may operate at good practice for some aspects and best practice for others. As research and practices evolve, best practice will become good practice, and new best practice will continue to push the frontier of horticulture industry's research and knowledge of environmental management.

The EMS presents a toolbox of these practices, asks a grower to assess their risks at a property and paddock scale, and consider each practice and its appropriateness to manage those risks over time. In this section, the growers' responses to the questions posed in the Environment Management System[239] are reported. The risk profile for orcharding is very different to vegetable growing and so risks are assessed and approached very differently between the two subsectors. Table 47 below has combined and aggregated the responses so ensure grower anonymity but provide an overview of the level of practice in irrigation in horticultural farms in Otago.

Table 47: Responses from seven summerfruit and two vegetable growers in Otago to questions in the NZGAP Environment Management System add-on as to Good/Best Management Practices for irrigation.

Good/Best Management Practices Irrigation	GMP/BMP	Yes	Partial	No	N/A
Pre Planting					
Plan irrigation requirements	GMP	9	-	-	-
Develop a long-term irrigation plan	GMP	4	2	1	2
Post Planting					
Volumes applied informed by relevant factors (e.g., Plant growth phase / soil type / water holding capacity and climatic conditions)	GMP	9	-	-	-
Water is applied to maintain soil moisture between the wilting point and field capacity where possible	GMP	9	-	-	-
Irrigation applied allows achievement of the yield target for fertiliser applied	GMP	9	-	-	-
Irrigation efficiency is measurable at greater than 80% (>80% of irrigation water is retained in root zone/target area)	BMP	7	-	1	1
Water use is metered	BMP	5	1	2	1
Irrigation scheduling is undertaken using a crop model or tied into a soil moisture monitoring system	BMP	5	-	3	1
On-site soil moisture monitoring is conducted	BMP	4	2	3	-
Irrigation is variably applied within the paddock to maximise efficiency	BMP	6	1	1	1
Highly automated irrigation systems that allow more frequent applications of less water are used to maximise efficiency	BMP	3	1	-	5
Other					
Non-irrigation water is used efficiently (e.g., wash water)	GMP	4	-	1	4

238 Good Management Practice (GMP) and Best Management Practice (BMP) are commonly used industry term to identify the level of practice a grower follows. BMP refers to practices over and above GMP.
239 From nine grower samples – seven summerfruit growers and two vegetable growers.

The results show that most growers surveyed are already achieving Good Management Practices at a minimum. This is consistent with what is being observed across the country during trials and rollout of the EMS nationally, which covers approximately 40,000 hectares of horticulture land.

All nine growers surveyed plan their irrigation requirements, apply volumes informed by soil moisture and plant growth phase, and irrigation is applied to achieve a yield target for fertiliser applied. Growers are attempting if not achieving best management practice for irrigation.

These surveyed growers also responded to questions in the EMS about nutrient risk assessment and management practices. Responses to nutrient loss risk factors are shown in Table 48.

Table 48: Growers' risk assessment in relation to nutrient loss risk.

Contributing factor	High	Medium	Low
Soil moisture	-	3	6
Irrigation	1	7	1
Soil type	3	6	
Paddock history	-	2	7
Previous crop planted and residual N in the soil	2	2	5
Crops being grown	2	2	5
Crop yield and quality	-	4	5
Intensity of cropping	4	-	5
Topography	2	2	5
Plant uptake of nitrogen	1	2	6
Timing of nitrogen application	1	1	7
Fertiliser application methods	-	6	3
Application of organic manure	-	1	8
Pest and disease	3	2	4
Animal in the rotation	-	-	9
Ground preparation and planting methods	2	3	4
Compaction	1	1	7

The results indicate that a very high proportion of growers rate the risk from the contributing factors either medium or low. A comparatively small number of growers indicated some practices as high risk. Of note are soil type, intensity of cropping, and pest and disease factors.

Risk factors will vary from property to property. Risk will be influenced by any environmental actions a grower may have in place. For example, a grower can use soil testing, like the Nitrate Quick Test[240] for an instant understanding of available nitrogen in the soil to inform fertiliser application rate, placement and timing, as well as timing of irrigation and ground preparation or planting methods.

Based on the risk factors in Table 48, growers assess their overall risk of nutrient loss unmanaged, with current practice, and with GMP in place. The responses of the growers to questions on their assessment of the risk of nutrient losses are reported in Table 49 below. For growers already operating at good management practice, the risk assessments across the three categories will remain the same.

Table 49: Growers' responses to the risk of nutrient losses

Nutrient Loss Risk Assessment	High	Medium	Low
Baseline/unmitigated risk level	2	2	5
Risk level with current practices in place	-	4	5
Risk level with GMP in place	-	4	5

The results indicate that most of the growers surveyed are currently at Good Management Practice in terms of the risk of nutrient losses. In summary, a very high proportion of the growers were at or above Good Management Practice in terms of their impact on both irrigation practices and nutrient management and therefore the potential risk of nutrient loss.

6.5 Innovations

Most of the innovations that are available for the orcharding industries are designed to seek more control over the efficiencies of production and to minimise both the economic impacts and the environmental effects. They are basically designed to improve the return on capital.

Many of the innovations are not necessarily new but are likely to need a major restructuring of how the orchard operates and so they are most likely to be adopted by either green fields developments or as replacement regimes for orchards that are changing the mix of fruit that they produce. Below is a discussion of two available innovations, UFOs, and retractable roof production systems.

240 'Quick test' soil nitrate strips to guide N management decisions in crops - VR & I (vri.org.nz)

6.5.1 Upright fruiting offsets (UFO)

The upright fruiting offset system requires that the plants are grown on a trellis and the growing shoots are trained to grow straight up from the root stock plant. This system involves the added cost of the trellising, and a much larger number of plants than a traditional system. The system requires considerably more pruning work to maintain the growing structure but there are other efficiencies. The advantages of the system are that it produces more fruit and the costs of spraying, the consumption of irrigation water, and harvesting costs are all reduced under this system. Overall profits can be higher under UFO systems, even with the account of the additional capital investment in infrastructure.

6.5.2 Retractable roof production system

The Retractable Roof Production System is designed to gain more control over the climatic and environmental factors that impinge on orchard production. By having the ability to engage or retract a roof over the orchard it is possible to manage environmental conditions.

Advantages of this system include:

- Consistent high yields;
- Better quantity and quality of fruit;
- Advance or extend the season;
- Reduced use of fungicides and insecticides; and
- Reduced use of irrigation.

Retractable roof systems, such as CRAVO, use a retractable roof to reduce the effects of the environment on orchard growth and create efficiencies. More initial investment is needed to set up a retractable roofing system, and additional maintenance costs are incurred, but there are greater operational and environmental efficiencies. These efficiencies include increased plant density on a per hectare basis, reduced agrichemical application and more targeted application, and reduced water use. Water is only used for irrigation and no additional water is needed for frost protection. Smaller, more compact pruning of trees creates efficiencies for tree maintenance and harvest[241]. These efficiencies are a result of a semi-protected style of growing involving the use of retractable roof structures. It can challenge the general view of what an orchard traditionally looks like, however in areas where tree crops cannot be moved and efficient use of water to successfully grow is a key driver, systems such as these may become viable alternatives for growers to consider[242].

One way to measure technical efficiency of water use is to use gross financial output of the production systems. The data displayed in Table 50 uses the average water use in the orchard sector of 350 mm/ha and represents the output of the representative models. Also included are metrics for both nitrogen losses and greenhouse gas emissions, with the latter being expressed as CO_2 equivalents.

241 *Kris-Robb_What-Goes-in-Must-Come-Out_-Protecting-Our-Social-License-to-Grow-Cherries_Kellogg-Report.pdf (ruralleaders.co.nz)*

242 *Kris-Robb_What-Goes-in-Must-Come-Out_-Protecting-Our-Social-License-to-Grow-Cherries_Kellogg-Report.pdf (ruralleaders.co.nz)*

Table 50: Efficiency measures of technical water use efficiency (per hectare)

	Gross Revenue ($)	N leached (Kg)	GHG emissions (Kg)
Cherry UFO	686	-	-
Cherry Traditional	365	-	-
Summerfruit	174	0.04	-
Pipfruit	162	0.04	14.3

6.6 Horticulture Models

6.6.1 Vegetable model

Data was collected from two vegetable growers in Otago[243]. Both were selected due to the similar range of crops grown. Winter brassicas and summer vegetables were dominated by a range of lettuce varieties. It is noted that there is no allium or solanaceous crops or other types of crops commonly grown. The model is a representation of the crops grown, and the time period of the rotations. A summary of production and revenue statistics is shown in Tables 51 and 52 and a summary of the financial performance from the model is shown in Table 53. The full financial performance is shown in Appendix 1 of this chapter.

Table 51: Vegetable Model (brassicas) production and revenue data

Variety	Area (ha)	Yield (T/ha	Total Yield (T)	Price ($/T)	Revenue ($)
Cauliflower	5	30	144	1,150	165,600
Broccoli	7	30	216	1,667	360,072
Brussel Sprouts	5	22	106	2,200	232,320
Cabbage	4	60	252	1,150	289,800
Fallow	17	22	383	350	133,980
Total	39	-	-	-	1,181,772

Table 52: Vegetable Model (lettuce) production and revenue data

Variety	Area (ha)	Yield (T/ha	Total Yield (T)	Price ($/T)	Revenue ($)
Lettuce Iceberg	7	45,000	324,000	0.6	194,400
Lettuce Cos	7	45,000	324,000	0.70	226,800
Lettuce Green	7	45,000	324,000	0.65	210,600
Total	21	-	-	-	631,800
Combined area and revenue[244]	60	-	-	-	1,813,572

243 Representative models for vegetables in Otago have been constructed from the crop rotations growers used for income, the expenses are created from Gross Margins based on Canterbury averages, administration costs are based on a representative model created for Canterbury.

244 Combined lettuce and vegetable growing area and income totals.

Table 53: Summary of financial data for the Vegetable Model

Variety	Whole Property	Per ha
Gross Revenue	$1,813,572	$30,226
Total Operating Expenses	$1,075,260	$17,921
Earnings Before Interest and Tax.	$738,312	$12,305

6.6.2 Pipfruit model

The timing of this report clashed with peak harvest and packing season for pipfruit. To represent this group a pipfruit financial model was built using existing data from five Otago pipfruit orchards. The model was based on a range of large, medium, and small operators that represents the region (details on size and level of integration are not reported for individual confidentiality).

The Pipfruit Model area of 40 hectares was based on the average area of growers registered with NZAPI (New Zealand Apple and Pears Incorporated) in Otago. The variety mix chosen as the panel for the model reflected the regional variety mix of growers[245].

The panel for Otago was smaller than the main pipfruit growing regions, and there was a large range of sizes. The income and cost show trends. The true average of the grower data was used (i.e., weighted to each grower equally). Very few outliers needed to be removed to generate the model. Two years' data for the five growers was combined to construct the model.

A summary of the production and revenue statistics is shown in Table 54 and a summary of the financial performance of the model is shown in Table 55. The model is included in Appendix 1 of this chapter. The environmental performance of the Pipfruit Model was based on that of the Summerfruit Model.

Table 54: Pipfruit Model production and revenue data

Variety	Area (ha)	Yield (T/ha	Price ($/T)	Revenue ($)
Braeburn	2.20	66.75	1,098	161,175
Cox Orange	2.20	48.65	932	99,752
Fuji	4.60	35.90	1,346	222,328
Granny Smith	1.60	42.95	1,029	70,740
JAZZ	5.60	33.45	1,207	226,123
Pacific Queen	4.80	32.10	1,607	247,672
Red Delicious	3.20	65.40	1,366	285,898
Royal Gala	10.20	48.25	1,341	659,826
Other Apples	5.60	35.50	1,356	269,523
Total	40.0	-	-	2,243,037

245 Based on NZAPI information

Table 55: Summary of financial data for the Pipfruit Model

	Categories	Total
Gross orchard income	$2,243,037	-
Other orchard income	$77,920	-
Gross Orchard Revenue	-	$2,320,957
Post-harvest costs	$1,023,183	-
Labour	$845,212	-
Total other working expenses.	$255,360	-
Total overhead expenses	$57,180	-
Total Orchard Operating Expenses	-	$2,180,935
Earnings Before Interest and Tax	-	$140,022

6.6.3 Summerfruit model

Information was collected for seven summerfruit orchards, which, as a set, represented a wide range of property sizes and mixes of different varieties of fruit. There was also a wide variation in the mix of varieties that these orchards grew. Two of these properties grew only cherries and, of the remaining five, one did not grow cherries as part of the varietal mix. Of the cherry growers, there was a split between growers that used the traditional growing method (the majority) and those that used the upright fruiting system (UFO). The UFO method is much more intensive than the traditional method and yields up to twice the amount of the traditional method per hectare but is much more consumptive of capital.

The Summerfruit Model represents the average performance of the orchards from which data was collected. A summary of the production and revenue statistics is shown in Table 56 and a summary of the financial performance of the model is shown in Table 57 the full financial performance is shown in Appendix 1 of this chapter.

Table 56: Pipfruit Model production and revenue data

Variety	Proportion of total area	Area (ha)	Yield (T/ha	Price ($/T)	Revenue ($)
Apples	15%	6.2	5.00	21,250	661,167
Apricots	20%	8.3	8.57	3,450	245,313
Peaches	15%	6.2	12.00	4,500	336,029
Nectarines	20%	8.3	12.75	4,250	449,594
Cherries	30%	12.4	4.75	14,000	827,626
Total	-	41.4	-	-	2,519,729

Table 57: Summary of financial data for the Summerfruit Model

	Categories	Total
Gross orchard income	$2,519,728	-
Other orchard income	$27,055	-
Gross Orchard Revenue	-	$2,546,783
Orchard working expenses (Labour)	$939,262	-
Post-harvest costs	$547,041	-
Operating costs	$396,167	-
Administration and property expenses	$130,206	-
Total Orchard Operating Expenses	-	$2,012,676
Earnings Before Interest and Tax	-	$534,107

6.6.4 Traditional cherry model

The yield and revenue information for the traditional cherry orchard[246] model is a representation of the data collected. It was not possible to separate out the expenditure data for cherries from the other varieties grown so this data is taken from exclusively cherry growers. A summary of the production and revenue statistics is shown in Table 58 and a summary of financial performance of the model is shown in Table 59. The full financial performance is shown in Appendix 1 of this chapter.

Table 58: Cherry Traditional Model production and revenue data

Variety	Area (ha)	Yield (T/ha	Price ($/T)	Revenue ($)
Cherries	45.0	8.1	15,750	5,740,875

Table 59: Summary of financial data for the Cherry Traditional Model

	Categories	Total
Gross Orchard income	$5,740,875	-
Other Orchard income	-	-
Gross Orchard Revenue	-	$5,740,875
Orchard working expenses (Labour)	$960,300	-
Post-harvest costs	$1,520,450	-
Operating costs	$336,330	-
Administration and property expenses	$966,915	-
Total Orchard Operating Expenses	-	$3,783,995
Earnings Before Interest and Tax	-	$534,107

246 Traditional orcharding technique involving a 'vase'

Image 40: Mixed orchard between Clyde and Alexandra, Central Otago.
Source: Simon Moran

6.6.5 Cherry UFO model

The yield and revenue information for the cherry UFO model is a representation of the data collected as there were fewer examples of this growing system included in the data set. A summary of the production and revenue statistics is shown in Table 60 and a summary of the financial performance of the model is shown in Table 61. The full financial performance is shown in Appendix 1 of this chapter.

Table 60: Cherry UFO Model production and revenue data

Variety	Area (ha)	Yield (T/ha	Price ($/T)	Revenue ($)
Cherries	10.0	15	16,000	2,400,000

Table 61: Summary of financial data on the Cherry UFO Model

	Categories	Total
Gross Orchard income	$2,400,000	-
Other Orchard income	-	$2,400,000
Gross Orchard Revenue	-	-
Orchard working expenses (Labour)	$772,000	-
Post-harvest costs	$970,500	-
Operating costs	$158,000	-
Administration and property expenses	$75,946	-
Total Orchard Operating Expenses	-	$1,976,446
Earnings Before Interest and Tax	-	$423,554

6.7 Fertiliser Use and Irrigation

Water availability is a key issue for the Otago region, particularly in areas with high concentrations of horticulture such as Central Otago. In some catchments, such as the Manuherikia, irrigation water has been over-allocated. Orcharding has very low fertiliser inputs and this influences the environmental profile. This is one reason why orcharding is seen as a way of contributing to New Zealand's transition to a low-emissions economy.

There is a possibility that further extraction of water from waterways in Otago could result in river flow levels dropping below the minimum low flow levels set by the ORC. In addition, there is also a risk that the current level of nitrogen in the water exceeds the maximum standard set by ORC. A new allocation regime based on resource use efficiency is needed to address water quality and quantity issues in Otago to ensure the long-term sustainability of water resources for future generations. The following analysis is presented as the economic implications of possible restrictions on water quantity on the horticultural sector.

6.7.1 Irrigation

6.7.1.1 Vegetables

Vegetables are mainly irrigated by guns and so apply between 500 and 700 mm of water per year. This water use is dependent on the climatic conditions and on the crop mix grown in that year. No reliable data was available on the impact of irrigation restrictions on the yield of the range of crops that are grown but this report represents this impact as a decrease in yield. Generally, irrigation of commercial vegetable crops is linked to crop demand, with consideration given to rainfall, fertiliser applications, soil type etc.

Table 20 represents the effects of water restrictions on irrigation as a decrease in yield. However, as irrigation is linked to the requirements of a crop at phases of its growth cycle, if there is not enough water available to meet the requirements of a seeding then restricting water is more likely to result in production of a non-marketable yield or possibly crop failure. Growers will have to make a choice to either underwater a crop, which is likely to result in crop failure or choose to water only a portion of seedlings planted out and get a smaller amount of produce to market. The results of modelling are shown in Figure 78 on the following page.

Modelling in Figure 78 shows the loss of yield has a direct impact on the gross revenue and an impact on operating expenses and so the change in profitability (EBIT) is closely aligned with the loss in gross revenue. The Vegetable Model is close to breakeven at a 40 per cent decrease in yield.

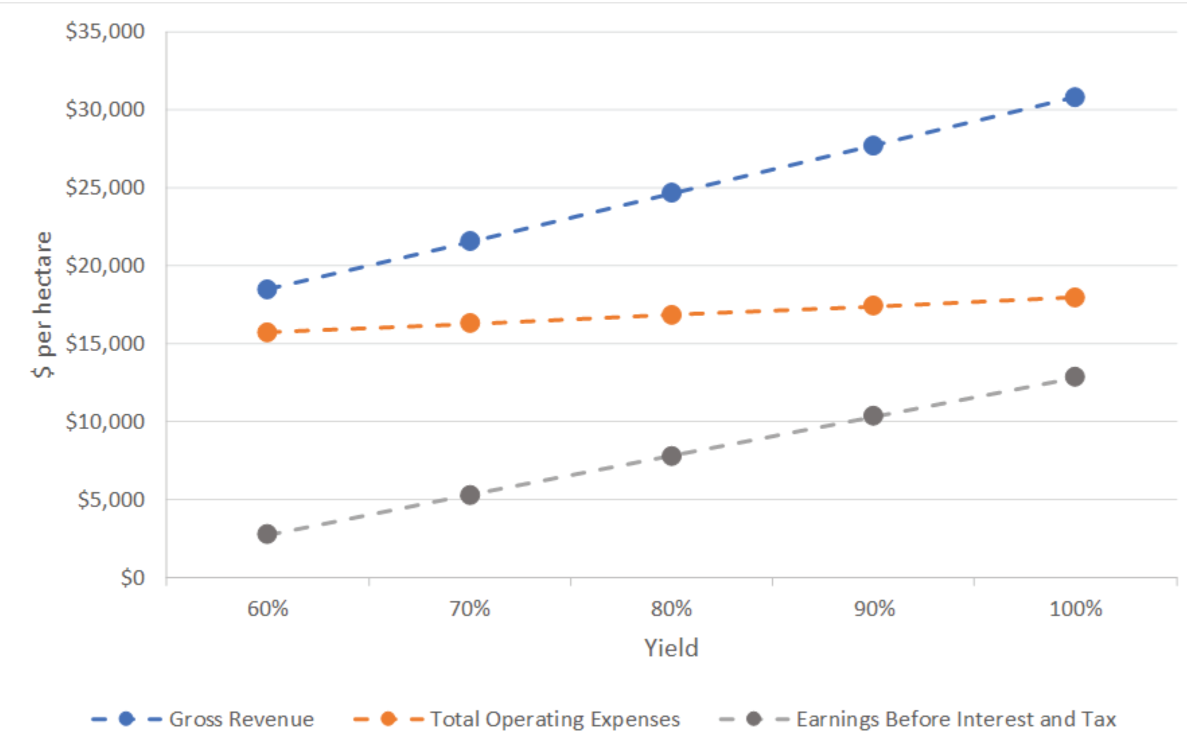

Figure 78: The impact of reduced yield on the economic performance of vegetables

To show the loss of financial performance experienced per hectare across the range of reduced yields modelled, the financial performance at each percentage reduction was deducted from the 100 per cent performance. The results of this modelling are shown in Table 62.

Table 62: Cherry UFO Model production and revenue data

Yield reduction	**-40%**	**-30%**	**-20%**	**-10%**
Gross Revenue	-$12,302	-$9,226	-$6,151	-$3,075
Total Operating Expenses	-$2,204	-$1,653	-$1,102	-$551
Earnings Before Interest and Tax	-$10,098	-$7,573	-$5,049	-$2,524

Approximately 80 per cent of vegetables grown in New Zealand are destined for the domestic market. A grower needs to get a marketable yield from each planting. A marketable product is one that the markets (i.e., consumers) will accept, grown safely and sustainably to accepted standards. The overall goal of a grower is to have every seed started make it successfully to market. There are many factors outside of a grower's control that can impact this being achieved. Some are environmental factors, such as climate and weather events, pest and disease issues, and other factors like water restrictions, which are modelled here.

6.7.1.2 Orchards

A literature search was carried out on the impact of irrigation restrictions on the yield of fruit, but no reliable information was available to establish a relationship between the percentage of availability of irrigation water and the yield of that fruit. However, there is information, such as outlined in Table 63 below, of orchard crop irrigation requirements throughout a season.

Table 63: Irrigation Parameters for Cherries and Apricots[247]

Crop	KC[248] (initial, middle, end)	Rooting depth (metres)
Cherries	0.8, 1.12, 0.85	1.0
Apricots	0.8, 1.15, 0.85	1.0

Table 63 outlines the irrigation demand for crop growth. This does not account for water used for other horticultural purposes such as frost protection or hygiene requirements. Demand for irrigation peaks during October – April. Without access to irrigation, crops would not receive enough water from rainfall to survive. Orchardists use water sparingly, with a high degree of efficiency, as part of their operations. The level of investment needed to establish an orchard of permanent trees means that growers require secure and reliable access to water to keep those trees alive and thriving, to remain financially viable.

In this way access to water and security of water supply are key considerations when planning out an orcharding operation and can underpin investment decisions. For example, if an operation is granted a six-year consent for water, and tree crops take five years to establish before returning a marketable yield. This leaves a single harvest from one-year to factor in return on investment.

Most orchards apply irrigation by dripline or micro sprinklers, which means that the exact amount of water that is required by the plants is delivered to the root system reasonably directly. It also means that orchard trees do not necessarily have the extensive root system of a natural tree because they do not need to forage far for their water. In this way, crops are reliant on the continued supply of water at the right rate and right time, throughout the growing season.

There is an absence of data available on the relationship between water availability in Otago and crop yield. To better understand the sensitivity of profitability to water restrictions, the impact of reduced yield was tested on the economic performance of the range of representative financial models shown in Section 8. The results are displayed in Figures 79 to 82 below – note the scale of the vertical (or 'y') axis changes between the graphs. Tables 64 to 67 (following the graphs) give the impact on financial performance per hectare across the range of yields modelled by deducting the change at each percentage reduction from current situation (i.e., 100%).

The results show pipfruit is very sensitive to the impact of a reduced yield with the breakeven point (no profits) being reached when yields are reduced by 20 per cent. Summerfruit is also sensitive to the impact of a reduced yield with the breakeven point being reached at about a 30 per cent reduction in yield. Traditional cherries are more resilient to reduced yields, largely because of the high profit levels, with the breakeven point at about 50 per cent yield loss. The UFO Cherries are reasonably resilient to the loss in yield with the breakeven point occurring at around a 40 per cent reduction in yield. However, the loss in income from these reductions is still sizeable.

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247 Guidelines For Reasonable Irrigation Water Requirements in Otago (*https://www.orc.govt.nz/media/4499/aqualinc-irrigation-guidelines-2015.pdf*)

248 KC – Crop co-efficients for irrigation – crop water requirements at different stages of growth.

The model reflects a loss of financial performance due to the reduction in marketable yield resulting from irrigation restrictions. Many orchards that have had longer consents, have usually invested in more technically efficient means of irrigation. This can mean that the crops' tolerance for water restrictions is already pushed to the limit as it has been receiving close to the exact amount required for its growth cycle.

On a per hectare basis, the loss in financial performance from a reduction in yield is substantial for all the representative models, which reflects the likely cost of restrictions in access to irrigation water.

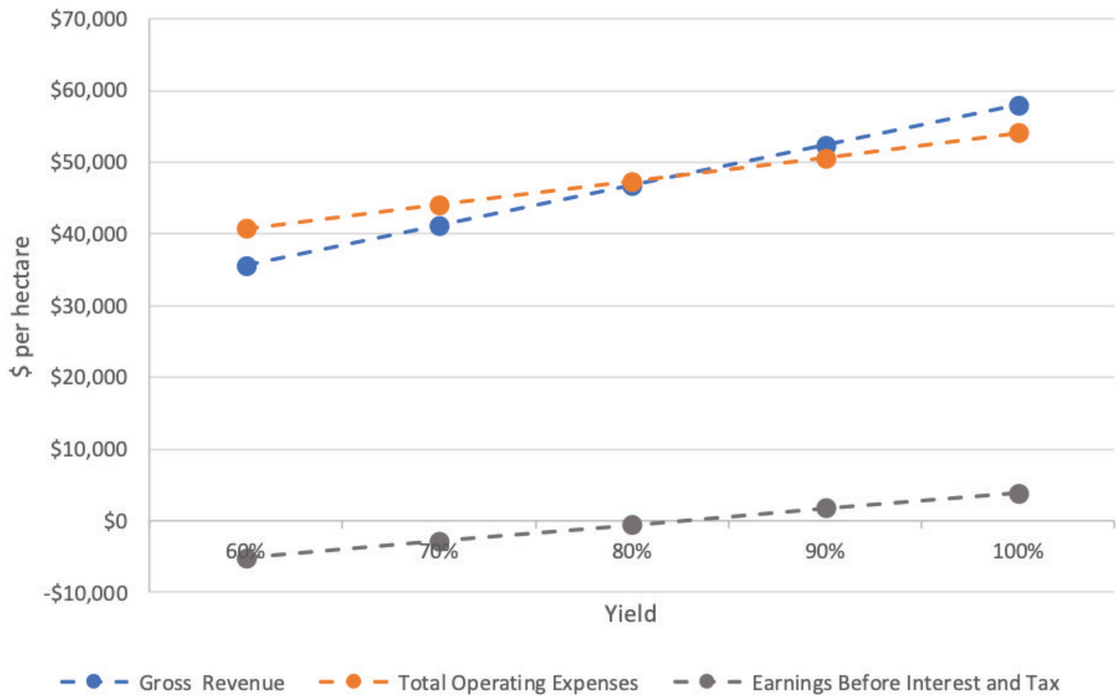

Figure 79: The impact of reduced yield on the economic performance of pipfruit

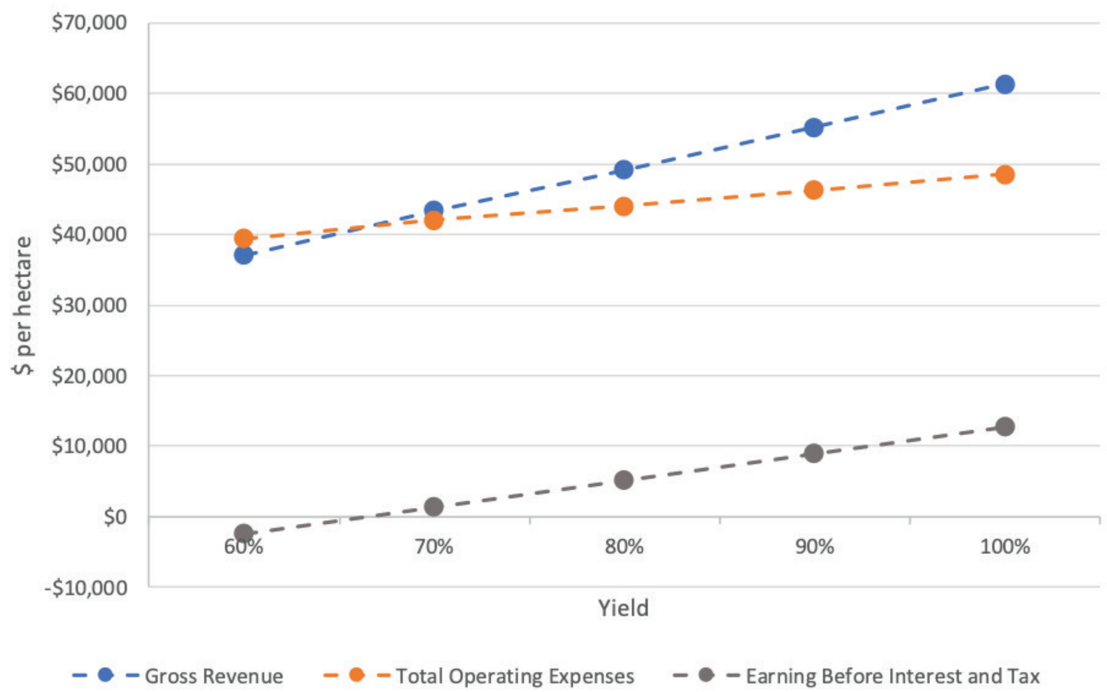

Figure 80: The impact of reduced yield on the economic performance of summerfruit

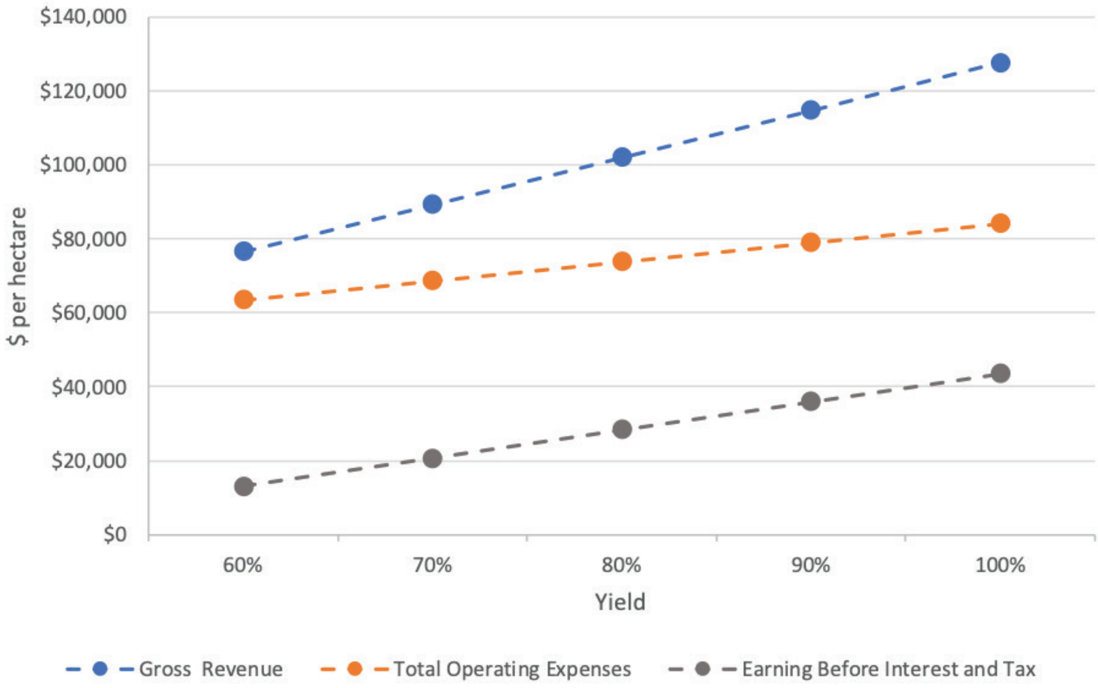

Figure 81: The impact of reduced yield on the economic performance of Traditional Cherries

Figure 82: The impact of reduced yield on the economic performance of UFO Cherries

Tables 64 to 67 below give the impact on financial performance per hectare across the range of yields modelled by deducting the change at each percentage reduction from current situation (i.e., 100%).

Table 64: Change in financial performance across a range of yield reductions for the Pipfruit Model

Yield reduction	-40%	-30%	-20%	-10%
Gross Revenue	$22,430	$16,823	$11,215	$5,608
Total Operating Expenses	$13,389	$10,104	$6,819	$3,535
Earnings Before Interest and Tax	$9,041	$6,719	$4,396	$2,073

Table 65: Change in financial performance across a range of yield reductions for the Summerfruit Model

Yield reduction	-40%	-30%	-20%	-10%
Gross Revenue	-$24,283	-$17,897	-$12,142	-$6,071
Total Operating Expenses	-$9,126	-$6,539	-$4,563	-$2,281
Earnings Before Interest and Tax	-$15,157	-$11,358	-$7,579	-$3,790

Table 66: Change in financial performance across a range of yield reductions for the Cherry Traditional Model

Yield reduction	-40%	-30%	-20%	-10%
Gross Revenue	$51,030	$38,273	$25,515	$12,758
Total Operating Expenses	$20,633	$15,475	$10,317	$5,158
Earnings Before Interest and Tax	$30,397	$22,798	$15,198	$7,600

Table 67: Change in financial performance across a range of yield reductions for the Cherry UFO Model

Yield reduction	-40%	-30%	-20%	-10%
Gross Revenue	-$96,000	-$72,000	-$48,000	-$24,000
Total Operating Expenses	-$62,880	-$47,160	-$31,440	-$15,720
Earnings Before Interest and Tax	-$33,120	-$24,840	-$16,560	-$8,280

6.7.2 Nutrients

6.7.2.1 Vegetables

The losses of nutrients from vegetable production vary greatly depending on the range of crops grown, the timing of the growing of those crops, the intensity of the growing operation, and the climatic conditions and soil types. The scale of the subsector in Otago[249] means anonymity of growers could be compromised. The scale of vegetable growing in Otago is minor compared to the total area (a total of less than 500 hectares) utilised for commercial vegetable production in New Zealand. For this reason, information and data about nutrient management and impacts is taken from industry research undertaken at a national level, or in areas where there is a lot of commercial vegetable production and used to inform the Otago regional profile.

Contemporary grower practice involves understanding nitrogen in the soil through regular soil testing and visual assessments of crop growth. Fertiliser is applied at intervals to match the crop growth cycle, and taking into account timing of rainfall and/or irrigation. HortNZ is a joint funder of the Sustainable Vegetable Systems project[250] analysing the dynamic nitrogen content of the soil, and nutrient leaching under different crops and rotations. The project is designing a nutrient budget tool for growers, to inform their fertiliser application decision-making. The tool is based on leaching data from regional trials and rotations, a grower's soil test results, and crop guide nutrient recommendations. By making informed decisions about fertiliser applications, growers can apply the right product, at the right rate and time, in the right place, and reduce their risk of losses to the environment.

6.7.2.2 Orchards

The vast majority of fertiliser used in orcharding is delivered via the irrigation system, which is either dripline or micro-sprinklers. This is a highly efficient delivery system, which enables a grower to deliver exactly the amount of nutrients to the base of the plant minimising the amount that is likely to be leached and lost to water. The aim of orchard crops is for a tree to produce fruit for harvest. Fertiliser application is sparingly and carefully applied to support the tree's growth cycle without promoting the growth of foliage.

The only data able to be located on the likely losses of nutrients from orchards were estimates for orchards in the Tūtaekurī, Ahuriri, Ngaruroro and Karamū catchments in Hawkes Bay (AgFirst, 2018)[251]. The results of that research are shown in Table 68 below indicate that it is likely that the losses from orchards in Central Otago are relatively low compared with general primary production.

Table 68: Average nutrient losses of orchards in the TANK catchments, Hawkes Bay

Yield reduction	N leaching Kg N/ha	P loss Kg P/ha
Summerfruit	14.1	0.13
Pipfruit	14.6	0.22

249 428+ ha - *freshfacts-2021.pdf*

250 *Sustainable Vegetables Systems Programme - Potatoes New Zealand (potatoesnz.co.nz)*

251 AgFirst (2018): Modelling nutrient restrictions and nutrient losses for Horticulture in the TANK catchment – An economic analysis.

6.7.3 Short-term Consents

Producer confidence is an important aspect of horticulture industries. Large investments are needed for either developing or purchasing orchards and vegetable production operations, as well as the large investment that is also made in the post orchard processing and packaging and marketing and distribution sectors. There is also a relatively large annual requirement in maintaining that investment. When producers are faced with unknowns this may make them question the viability of producing. Limiting these unknowns is key to creating producer confidence.

Offering longer-term consents for water takes gives producers increased certainty for investing in their land and infrastructure. This will also allow them to think further forward into the future about how they can improve their systems with more confidence about their environment. This allows the owners to engage in research into improved environmental performance and more effective farming methods where they might not have otherwise been engaged in these growth activities.

Longer term consents allow for any costs associated with development to be spread out over a longer period. This will have less impact on producers' variable income and will be less detrimental to those who have a poorer productive season. Longer consents also allow for outside parties such as lenders and purchasers to have greater confidence in the producer's performance.

Short-term consents severely reduce producer confidence and create risk aversion. The uncertainty can have negative effects on funds spent on infrastructure and land and can impact every aspect of production down to total yield and quality of produce. This may also cause consent holders to make decisions based purely on working out an economic return based on consent duration. Not only does it affect the confidence of the growers, but it also means that lenders and people further along the value chain fail to have confidence in the producer's long-term abilities as well.

Development costs for a producing orchard range from $50,000 to $90,000 per hectare. When this is added to the purchase price of land at $70,000 per hectare this means that a new orchard development could require investment of between $120,000 and $160,000 per hectare.

The large investment needed means security of supply for fresh water as a critical resource is an issue of concern. Further investment in science may reduce uncertainties around both the supply and demand aspects of water allocation across catchments.

6.7.4 Rootstock Survival Water

The provision of root stock survival water for orcharding requires a planning regime that allows orchardists to abstract sufficient water from their irrigation source when the take conditions are below the minimum flow to keep their capital stock (the root stock or plants) alive. It is not sufficient to maintain the productivity of the orchards, being solely designed to keep the root stock alive so that it is able to recover and produce a marketable crop in the subsequent season.

In the absence of the provision of root stock protection water, the grower is faced with the removal of the dead plants, replacing them, and building up production again until they reach their full potential again. Depending on the availability of replacement plants this process can take five years plus.

To show the costs and benefits of such a policy, 'with' and 'without' root stock water was tested. The 'with' situation sees the orchard not having any production in the year of the low water flows but then being able to resume production at the average season's production the following year. The 'without' situation is where there is the loss of the plants in the year of the low water flows, which then need to be replaced the next season. Production ramps up proportionally until the fifth year when they reach full production again.

The impacts for each of the representative orchards were tested by modelling 'with' and 'without' root stock protection over a fifteen-year period with the low flow year occurring in year two. The results are expressed as a net present value using a seven per cent discount rate (Table 69).

The impacts on the orchards ranged from a 52 per cent to a 63 per cent reduction in the net present value depending on the fruit variety.

Table 69: Financial results for root stock protection

Variety	Root Stock Protection	Net Present Value ($)	Change (%)
Summer fruit	With	$76,930	-
	Without	$40,144	52%
Pipfruit	With	$64,960	-
	Without	$36,981	57%
Cherry Traditional	With	$303,279	-
	Without	$190,868	63%
Cherry UFO	With	$303,279	-
	Without	$158,216	52%

Image 41: New plantings on orchard in Earnscleugh, Central Otago.
Source: Simon Moran

6.8 Key Findings

There is a wide variety of horticulture present in Otago, with vegetable production occurring predominantly in North Otago, and pipfruit[252] and summerfruit[253] production occurring largely in the Central Otago area. Commercial vegetable production and orcharding are quite different in terms of their respective operations and the pressures they face.

There is a long history of horticulture in Otago but also recent development of new orchards in Central Otago. This contributes to a diverse growing community providing employment opportunities, demand for more technical support services and seasonal employment opportunities. Many families in Central Otago are part of multi-generational operation[254] .

From a small geographic footprint, horticulture provides a valuable economic contribution to Otago. When considering the employment opportunities and horticulture support industries, such as post-harvest facilities, advisory and contracting services, horticulture forms an important part of the Otago community and economy.

A reduction in water availability will result in a reduction of yield, or failure to produce a marketable yield in either orcharding or vegetable production systems. There is a higher level of investment into more technically efficient systems of horticulture and therefore, justification for this level of investment will be sought, including consideration of consent length and security of access to water.

The predominant type of horticulture in Otago is pipfruit and summerfruit production, with some commercial vegetable production in North Otago. Pipfruit and summerfruit production are relatively environmentally sustainable in comparison to some other rural land uses, with comparably low water use, nutrient loss and GHG emissions. In the transition to a low-emissions economy there is opportunity for horticultural production to increase and contribute positively towards the country's long-term environmental and economic goals. There is also active growth in the summerfruit industry in key areas such as Central Otago.

Water security and efficiencies are key drivers for horticultural operations. Crop water requirements mean growers, provided they have water security, are likely to invest in more technically efficient forms of irrigation, infrastructure, or alternative growing systems. Tree crops are more permanent in nature compared with other types of primary production and even horticultural systems, factors such as consent length are relevant when making orchard investment decisions.

For commercial vegetable crops, access to lease land and ability to have flexible consent conditions that reflect the need to rotate crops are essential. Purchasing of additional land is problematic as the price of land is high and there is a practice of working in with other growers or farmers to achieve successful rotations. There can be issues with lease land being located in different catchments or with environmental considerations beyond a lessee's control.

252 Pipfruit – refers to apple and pears
253 Summerfruit – refers to stone fruits such as apricot, plum, peach, nectarine, cherry
254 Webb's Fruit, One Family, 100 years (webbsfruit.co.nz); *story | CAJ Apples*

6.9 Appendix 1: Representative Models

Vegetable Model

Financial Data				
		Unit	$ Total	$/ha (eff)
Revenue				
Cereals			-	-
Process/ fresh vege			1,813,572	30,226
Other Crops			-	-
Crop Residues	100	/ha	-	-
Total Crop			1,813,572	30,226
Other Farm Income		/ha	-	-
Gross Revenue			**1,813,572**	**30,226**
Farm Working Expenses	**$/ha**		**$ Total**	
Wages	2200		132,000	
Electricity	325		19,500	
Grading	2009		120,540	
Packing	3500		210,000	
Freight	1750		105,000	
Fertiliser	1850		111,000	
Lime	120		7,200	
Freight	375		22,500	
Seeds/ Plants	1750		105,000	
Weed & Pest	1350		81,000	
Fuel	1250		75,000	
Vehicle Costs	875		52,500	
Repairs & Maintenance	230		13,800	
Communications	26		1,560	
Accountancy	35		2,100	
Legal & Consultancy	15		900	
Admin.	25		1,500	
Water Charges	50		3,000	
Rates	45		2,700	
Insurance	95		5,700	
ACC.	15		900	
Other	31		1,860	
Total Operating Expenses			**1,075,260**	**17,921**
Earnings Before Interest and Tax.			**738,312**	**12,305**

Source: Stuart Ford (The AgriBusiness Group)

Pipfruit Representative Model

Orchard production and revenue	Area (Ha)	Yield (T)	Price ($/ Tonne)	Revenue ($)
Braeburn	2.20	66.75	1,098	161,175
Cox Orange	2.20	48.65	932	99,752
Fuji	4.60	35.90	1,346	222,328
Granny Smith	1.60	42.95	1,029	70,740
JAZZ	5.60	33.45	1,207	226,123
Pacific Queen	4.80	32.10	1,607	247,672
Red Delicious	3.20	65.40	1,366	285,898
Royal Gala	10.20	48.25	1,341	659,826
Other Apples	5.60	35.50	1,356	269,523
Total	**40.0**			**2,243,037**

Revenue			Whole orchard ($)
Gross orchard income			2,243,037
Other orchard income			77,920
Gross Orchard Revenue			**$2,320,957**

Orchard Working Expenses		
Packing	404,924	
Packaging	398,335	
Coolstorage & freight (coolstore to port)	162,691	
Freight (Orchard to P/H)	35,119	
Levies and Subscriptions	22,114	
Post-harvest costs		1,023,183
Orchard Management (WoM)	110,840	
Hand harvesting	299,832	
Pruning	157,740	
Thinning	163,580	
Other wages	103,160	
Employment levies	10,060	
Total Labour		**845,212**
Weed & pest control	123,480	
Pollination	3,160	
Fertiliser & lime	9,860	
Electricity	15,320	
Vehicles	20,580	
Fuel	23,100	
Repairs and maintenance	37,220	
General	17,660	
Contract machine work	4,980	
Total other working expenses.		**255,360**
Rates	8,860	
Compliance Costs (incl. RSE)	19,100	
Insurance	10,220	
Crop insurance	-	
Communication	4,820	
Accountancy	5,180	
Legal & consulting	1,700	
Other admin costs	7,300	
Total overhead expenses		**57,180**
Total Orchard Operating Expenses	**$2,180,935**	
Earnings Before Interest and Tax	**$140,023**	

Source: Stuart Ford (The AgriBusiness Group)

Summerfruit Rerpesentative Model				
Orchard production and revenue				
	Area (Ha)	**Yield (T)**	**Price ($/ Tonne)**	**Revenue ($)**
Apples	6.2	5.000	21,250	661,167
Apricots	8.3	8.570	3,450	245,313
Peaches	6.2	12.000	4,500	336,029
Nectarines	8.3	12.750	4,250	449,594
Cherries	12.4	4.750	14,000	827,626
				-
				-
				-
				-
Total	**41.5**			**2,519,728**
Revenue			**Whole orchard ($)**	
Gross orchard income			2,519,728	
Other orchard income			27,055	
Gross Orchard Revenue			**$2,546,784**	
	MPI model inputs 2006			
Orchard Working Expenses				
Orchard working expenses (Labour)				
Pruning	138,647			
Thinning	160,853			
Harvesting	397,469			
Management	231,871			
ACC	10,422			
	-	**939,262**		
Post-harvest costs	-			
Packing	185,871			
Packaging	227,023			
Coolstorage	73,606			
Freight	60,540			
	-	**547,041**		
Operating costs	-			
Spray and chemicals	131,238			
Pollination	5668.744283			
Fertiliser	34,389			
Electricity	22,302			
Sundry expenses	50,015			
Vehicles	75,251			
Repairs and maintenance	77,304			
	-	**396,167**		
Administration and property expenses	-			
Communication	10,971			
Rates	17,872			
Accountacy, consultancy, legal	16,346			
General insurance	31,622			
Crop insurance	-			
Levies and compliance	27,139			
Other	26,256			
		130,206		
Total Orchard Operating Expenses	**$2,012,676**			
Earnings Before Interest and Tax	**$534,108**			

Source: Stuart Ford (The AgriBusiness Group)

Cherry Traditional Model

Orchard production and revenue	Area (Ha)	Yield (T)	Price ($/ Tonne)	Revenue ($)
Cherries	45.0	8.1	15,750	5,740,875
				-
Total	**45.0**	**8**	**15,750**	**5,740,875**

Revenue			Whole orchard ($)
Gross orchard income			5,740,875
Other orchard income			
Gross Orchard Revenue			**$5,740,875**

	MPI model inputs 2006	
Orchard Working Expenses	**Per hectare ($)**	
Orchard working expenses (Labour)		
Pruning	57,600	
Thinning	-	
Harvesting	800,775	
Management	100,800	
ACC	1,125	
	-	**960,300**
Post-harvest costs	-	
Packing	874,800	
Packaging	340,650	
Coolstorage	-	
Freight	305,000	
	-	**1,520,450**
Operating costs	-	
Spray and chemicals	146,700	
Pollination	39,600	
Fertiliser	76,050	
Electricity	8,370	
Sundry expenses	4,500	
Vehicles	18,450	
Repairs and maintenance	42,660	
	-	**336,330**
Administration and property expenses	-	
Communication	9,450	
Rates	22,545	
Accountancy, consultancy, legal	96,480	
General insurance	34,200	
Crop insurance	128,790	
Levies and compliance	49,950	
Other	625,500	
		966,915
Total Orchard Operating Expenses	**3,783,995**	
Earnings Before Interest and Tax	**1,956,880**	

Source: Stuart Ford (The AgriBusiness Group)

Cherry UFO Model

Orchard production and revenue

	Area (Ha)	Yield (T)	Price ($/ Tonne)	Revenue ($)
Cherries	10.0	15.0	16,000	2,400,000
				-
Total	**10.0**	**15**	**16,000**	**2,400,000**

Revenue			Whole orchard ($)
Gross orchard income			2,400,000
Other orchard income			
Gross Orchard Revenue			**$2,400,000**

	MPI model inputs 2006	
Orchard Working Expenses	**Per hectare ($)**	
Orchard working expenses (Labour)		
Pruning	54,500	
Thinning	-	
Harvesting	601,500	
Management	116,000	
ACC	-	
	-	**772,000**
Post-harvest costs	-	
Packing	627,500	
Packaging	188,000	
Coolstorage	-	
Freight	155,000	
	-	**970,500**
Operating costs	-	
Spray and chemicals	28,500	
Pollination	15,000	
Fertiliser	42,500	
Electricity	14,500	
Sundry expenses	7,500	
Vehicles	22,500	
Repairs and maintenance	27,500	
	-	**158,000**
Administration and property expenses	-	
Communication	7,500	
Rates	9,000	
Accountacy, consultancy, legal	16,500	
General insurance	8,000	
Crop insurance	-	
Levies and compliance	22,000	
Other	12,946	
		75,946
Total Orchard Operating Expenses	**1,976,446**	
Earnings Before Interest and Tax	**423,554**	
Interest		
Tax		
Drawings		
Capital Purchases		
Development		
Principal Repayment		
Net Cash Position	**$423,554**	

Source: Stuart Ford (The AgriBusiness Group)

7 Viticulture

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7.1 Summary

The viticulture sector in Central Otago is made up of many small and medium-sized businesses and a handful of large businesses that collectively make an important contribution to the regional economy. The sector is dependent on the sustainable use of land and water to grow high-quality grapes that are used to produce premium wines.

Viticulture's environmental footprint in Central Otago is minimal, with low to very low nitrogen and phosphorus losses to soil, and low greenhouse gas emissions. Water is essential for irrigation and frost damage prevention. Its use is carefully managed to keep vines in survival mode, used during the growing season, and frost fighting supply is needed usually only two months of year, during spring and autumn. Constraints on access to fresh water and the tenure of that access will impact the ongoing viability of wineries and future development of the industry.

With a predominance of small vineyards and wine companies in Otago, business financial viability is substantially tied to grape yields from the vineyard and the season-to-season success of each vintage. Small and medium-sized vineyards have limited resources to withstand shortfalls in production and changes to access to water has business implications. Viticulture is a major employer in Otago and with almost all vineyards in the region hand tended and hand harvested the loss of jobs due to financial failure would be significant. Labour includes permanent staff working all year in vineyard and wineries, and casual staff working substantially through the summer to autumn.

The research findings show the viticulture sector is particularly vulnerable to restrictions on access to fresh water for irrigation and frost fighting. In Otago, fresh water for irrigation has a direct relationship with grape yields in a lower profit industry. Fresh water for frost fighting prevents substantial crop and vine damage, especially for more severe frosts and snow and locations where frost fans are not an option. Short tenure consents for water presents an additional risk to established vineyards for continuity of production, and a barrier to investment for expansion of existing vineyards or establishment of new vineyards. The impacts from lower yields, crop loss or vine failure is high, even in a single year.

7.2 Introduction

This chapter analyses the impacts of environmental actions relevant to the management of fresh water on Otago winegrowing businesses. It focuses on how such actions may change grape yields (quantity and quality) and the implications for business profitability. It does not consider how such impacts may flow through to the many industries connected to viticulture within Otago's economy. This chapter gives a brief overview of the Central Otago viticulture sector before presenting the research methodology, vineyard models, environmental actions considered, and main findings.

7.2.1 Central Otago viticulture

The Central Otago wine growing region is inland and at altitude (in contrast to other wine-growing regions in New Zealand) and encompasses the Central Otago District and Queenstown Lakes District. Around 81 per cent of the grapes grown are Pinot Noir but the climate is also well suited to a range of cool climate aromatic white wines including Pinot Gris, Riesling, Sauvignon Blanc, Gewürztraminer and Chardonnay. There is a wide range of microclimates and soils, and along the Mata Au (Clutha River) alluvial wash means there are more gravels. Local growing conditions vary considerably, with those around Alexandra and Earnscleugh being particularly distinct. This diversity is reflected in the seven distinct sub-regions: Gibbston, Wānaka, Bannockburn, Bendigo, Lowburn, Pisa, and Alexandra. Bannockburn, Bendigo, Lowburn, and Pisa are all within the Cromwell Basin. There are few (if any) growers in Central Otago producing lower quality grapes for bulk wine products.

Historically, grape vines have been grown in Central Otago since 1860, but the commercial growing of grapes and wine making did not begin until the early 1970s. Since then, the sector has played an important role in the diversification and resilience of the regional economy. Central Otago is the fourth largest wine growing region in New Zealand in terms of wine production (Marlborough, Hawkes Bay, and Gisborne being larger), and is the third largest wine region by vineyard area (Gisborne produces more wine from fewer vines). Importantly, Central Otago is the second largest wine growing region in terms of the number of individual vineyards – largely because there are relatively more small family-owned businesses.

While vineyard returns are generally low the ancillary impact is broad across businesses that support the grape growing, winemaking, packaging, storage, and wine distribution sectors. Roughly half of grape production is used in winemaking and packaged in Otago, with $47 million added to the regional economy

Image 42: Felton Road vineyard, Bannockburn with dry hills in background.
Source: Source: Central Otago Winegrowers Association

from these services annually. The remaining half are transported out of the region for winemaking, packaging and storage in Marlborough or other regions around New Zealand. Central Otago winegrowers generate around $30 million in revenue at the vineyard gate (based on the tonnage of grapes produced annually and average grape prices per tonne), which then generates $113.5 million in wine sales as finished goods.

In 2018, it was estimated that 820 people were permanently employed in the industry (Deloitte and ANZ, 2018) and this workforce grew to over 1,000 during harvest. Additionally, the ancillary industry workforce that supports the viticulture and winery industry is sizeable and includes transportation, warehousing, irrigation, earthworks, trade industries and professional services (accounting, legal, surveying etc.). In 2020, the industry held an estimated $650+ million in tangible assets (predominantly land) and the price premium for Central Otago wines, over other New Zealand wine producing regions, added $36 million per year to revenues (COWA Strategic Review, 2020).

Wine tourism is an important contributor to the Otago economy and the region's international identity and reputation. In research on *Market Perceptions: Central Otago,* wine and wineries is one of the first things that come to mind for tourists when Central Otago is mentioned (Tourism Central Otago, 2021). The viticulture sector contributes to community trusts and charities and has invested in habitat restoration and regeneration, as well as the maintenance of historic places on behalf of the community. Examples include Project Gold[255] as well as the extensive native vegetation restoration by Te Kano wines on Northburn, the riparian planting on Felton Road Wines in Bannockburn, and native planting on Mishas' Vineyard.

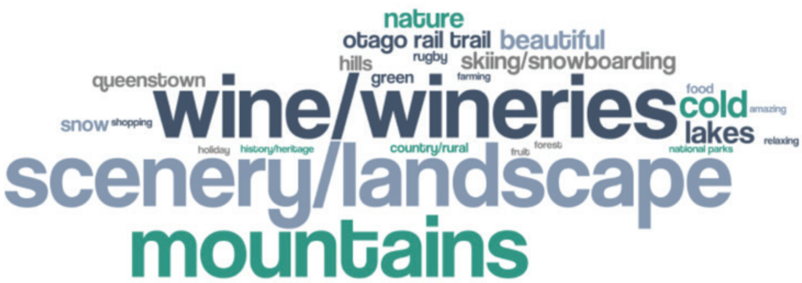

Image 43: Australian travellers responses to the question: "What is the first thing that comes to mind when you think about Central Otago?" Source: https://centralotagonz.com/assets/PDFs/Central-Otago-Market-Perceptions-Q4-2021.pdf

7.3 Methodology

This research involved collecting production, environmental and financial performance data from a sample of seven vineyards. These vineyards were specifically selected by Central Otago Winegrowers Association (COWA) to represent a cross section of vineyards in the winegrowing region, including planted area (i.e., size). All the vineyards sampled use some or all of their grapes to produce their own finished wine.

The environmental data was used to construct Overseer models of each vineyard, which reported nitrogen (N) and phosphorus (P) losses to the soil and greenhouse gas (GHG) losses to the atmosphere. The production and financial data collected was used to populate a standard financial model in Excel. This standard financial model was then used to create three vineyard models based on planted area: small, medium, and large. These models are described in Section 7.4.

The division of vineyards by area was based on data from the 2022 Sustainable Winegrowing New Zealand questionnaire, which is completed by 98 per cent of New Zealand vineyards annually as a requirement

255 https://www.doc.govt.nz/our-work/project-gold/

of the Sustainable Winegrowing New Zealand certification process. However, the national industry size models are also used in this chapter when referring to Deloitte Wine Industry Benchmarking and Insights 2018[256], which is a source of useful information relevant to the economics of wine production.

7.3.1 Selection of environmental actions

Almost all viticultural land across New Zealand occurs under the Sustainable Winegrowing New Zealand regime of standards and audits. To be certified, all member vineyards must submit:

1. An annual submission that covers the effects of the vineyard over six focus areas (soil, water, plant protection, waste, people, and (more recently) climate change.
2. A full spray diary that documents all agrichemical applications made to the vineyard that season[257].
3. They must also undergo regular on-site audits conducted by an independent verification company.

Those standards are continually being reviewed and updated annually through Sustainable Winegrowing New Zealand's audit process. Sustainable Winegrowing New Zealand, the Ministry for Primary Industries, and the Ministry for the Environment are currently undertaking a gap analysis to compare the viticulture sector's with the basic requirements of Freshwater Farm Plans. The on-vineyard environmental footprint of viticulture is low and consequently there were few additional environmental actions to test the impacts of for vineyards in this research.

In November 2022 a scoping exercise was undertaken to identify and prioritise relevant environmental actions for this research. This exercise highlighted the following points:

- Vineyards have low nutrient (nitrogen and phosphorus) losses for a rural land use activity. A similar situation exists for water takes where it is sufficient to keep vines in survival mode, used during the growing season, and for frost fighting over two months of year;
- There is diversity in circumstances because of multiple (and often interconnected) factors across the vineyards (e.g., water storage and frost fighting techniques). The diversity was used as the basis for the selection of vineyards to sample.
- Smaller growers are important to include in the analysis because there are a large number in Central Otago of between four and seven hectares in size. Both productive area and number of growers are relevant considerations.
- Data is less available for small growers because they are mostly looked after by contractors (cost / hectare basis). A description is needed of a small vineyard in terms of ownership and processing of grapes. A five hectare threshold was used to be consistent with Freshwater Farm Plans.

The scoping exercise prioritised water quantity as a topic, ahead of water quality, and identified two key aspects to consider in the analysis: the impacts of possible constraints on the management of water 1) for irrigation during growing season and 2) for frost fighting in spring and autumn. The use of water in viticulture tends to be seasonal rather than annual. However, the environmental effects of water use vary depending on minimum flows – and demand is usually higher when there is lower supply.

256 *https://www2.deloitte.com/nz/en/pages/primary/articles/vintage.html*

257 The spray diaries are processed for compliance to ensure that only approved products have been used and specific rules of use have been adhered to. In addition, Sustainable Wine New Zealand provides members with information on changes to agrichemical regulations and advises on best practices in viticulture.

7.4 Vineyard Models

In this section three vineyard models based on a sample of seven vineyards are presented for small, medium and large vineyards. These vineyard models are used in the next section to test the impacts of reducing consented water on grape yields.

> *Vineyard size has implications for employment, production, and profitability. Small (1 to 5 ha) vineyards tend to be family enterprises where they are managing the work themselves and have cellar door sales at full retail sufficient to earn an income. Small / medium-sized (5 to 15 ha) vineyards tend to not be large enough to have good wholesale distribution but face higher costs because they need help to operate the vineyard. Medium / large (15 to 35 ha) vineyards fit more of a small business model where they have staff to do most of the work but their production has to be of premium quality, and they have distribution in multiple markets. Very large vineyards (above 35 ha) are fully commercial scale with a company structure and staff across viticulture, winemaking, sales, and management.*
>
> *In 2022 (using the most recent data available) there were 235 vineyards in the Central Otago wine region and collectively they total 2,055 hectares of planted area. Smaller vineyards are the most common: 175 vineyards (74%) have an area planted in vines of less than ten hectares, and at the other end of the continuum three vineyards (~1%) have an area of more than 50 hectares. However, (using data from earlier in 2022) 164 smaller vineyards accounted for 581 hectares of land (31%) while ten large vineyards accounted for 554 hectares (29%) (i.e., a similar land area).*
>
> ***Excerpts from Chapter 8: Viticulture in Farmers and Growers in Otago (Wilkinson, 2022)***

For those winegrowers that reported the area of their vineyard under irrigation in the 2022 Sustainable Winegrowing New Zealand questionnaire, the total area was 1,662 hectares, the average area irrigated per vineyard was 10.9 hectares, and the average annual volume of nitrogen applied was 5.6 kg N/ha. In

Image 44: Vines being grown on sloping land, Misha's Vineyard near Cromwell.
Source: Central Otago Winegrowers Association

2022 average vineyard production in Central Otago ranged from around five tonnes of grapes per hectare on smaller vineyards (those below 15 hectares) to just over six tonnes of grapes per hectare on large vineyards. In general terms, the use of water for sprinkler frost protection is most common on medium-sized vineyards, although most of the sprinkler frost protection (by area) occurs on the large vineyards (Wilkinson, 2022). Many vineyards with water storage use the water for sprinkler frost protection and a few just use the water for irrigation.

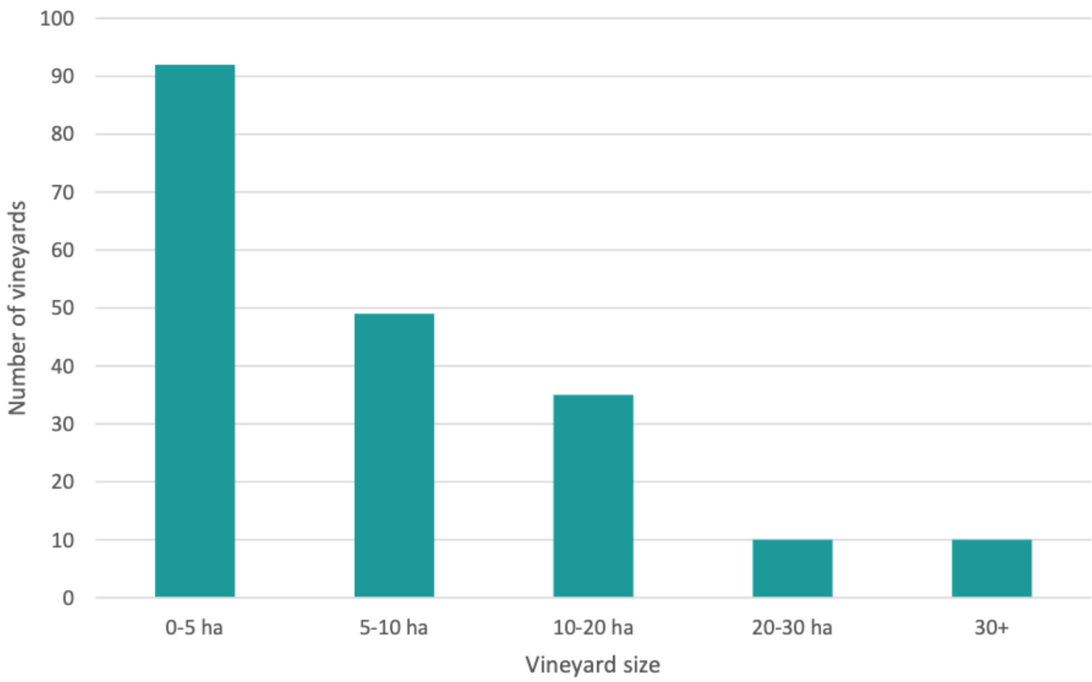

Figure 83: Distribution of vineyards in Otago by size
Source: Sustainable Winegrowers New Zealand Database

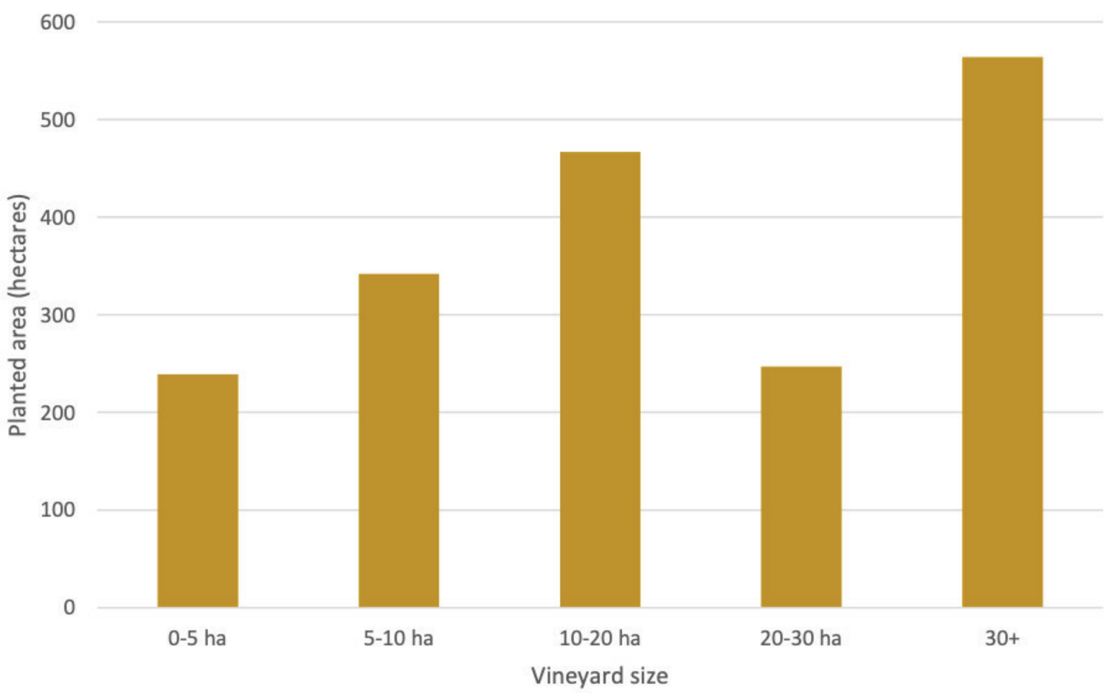

Figure 84: Distribution of vineyards in Otago by total area
Source: Sustainable Winegrowers New Zealand Database

The seven vineyards in the sample were chosen to illustrate a range of properties from small to large and with water consumption uses ranging from irrigation to overhead application for fighting frost. The vineyards included a mix of frost fighting techniques.

There was considerable diversity in how the vineyards sold their crop, from those that processed all their production into wine through to those that sold most of their grapes to other wine makers. As already noted, all the growers sampled produce their own finished wine (although some of their grape production may also be sold). There are some small vineyards (around 5 hectares) that are on a grower contract to solely supply a viticulture company, but none were included in the sample. These vineyards may be slightly more at risk than others because they only one revenue stream and less control over their value chain.

In general there are three basic business models in viticulture: there are vineyards that produce all (or substantially all) of their fruit into finished wine (i.e., are a vineyard and a winery), there are those vineyards that produce a small amount of finished wine but supply the majority of their fruit as contract to a winery, and then there are vineyards that only act as a grower for a winery. Predominately in Central Otago it is the first model, where vineyards produce to finished wine. By contrast, in Marlborough, even though there are a large number of vineyards that produce finished wine, the dominant model is vineyards that act as growers.

It is particularly challenging to separate the wine growing from the wine making and sales side of the business in Central Otago because the growing of the grapes is usually considered as a cost in the total value chain. In this case, expert opinion was used to choose the value that they would put on their grapes at the production stage. This value varies considerably and is consistent with Sustainable Winegrowing New Zealand wine sales data[258]. The values that were chosen usually related strongly to the relative value points of the final wine that they sold.

Three models were created, the small vineyard, the medium-sized vineyard, and the larger-sized vineyard, to reflect differences in scales within the Central Otago grape-growing production systems. In the following tables, the Gross Vineyard Revenue measure is the total revenue from all sources for the vineyard. Total Vineyard Operating Expenses is all the labour, working expenses and overhead expenses. Earnings Before Interest and Tax is the surplus (revenue less expenses) that is available to pay any interest, tax and provide sufficient value for management and ownership of the vineyard. A comparison of the distribution of expenses between the three models is shown in Figure 85 on page 301.

258 These reports are generated from the grape price data submitted in grape levy returns received by New Zealand Winegrowers from wineries each vintage. The average price per tonne and $50 incremental figures are then calculated. The tables of prices are not publicly available beyond members of New Zealand Winegrowers

7.4.1 Small vineyard model

Production information is shown in Table 70 and a summary of the financial performance of the model is shown in Table 71.

Table 70: Small vineyard model production and revenue data

Variety	Area (ha)	Yield (tonnes/ ha)	Total (tonnes)	Return ($/tonne)	Revenue ($)
Pinot Noir	3.3	6.4	21.1	4,650	98,668
Chardonnay	1.7	6.0	10.2	4,010	40,902
Total	**5.0**	**6.3**	**31.4**	**4,445**	**139,570**

Table 71: Summary data for the small vineyard (5 ha) model

	Whole Vineyard ($)	Per ha ($)
Income from grapes	139,570	27,914
Other direct vineyard income	2,555	511
Gross Vineyard Revenue	142,125	28,425
Labour	45,966	9,199
Total other working expenses	7,359	5,807
Total overhead expenses	16,221	3,244
Total Vineyard Operating Expenses	**91,275**	**18,255**
Earnings Before Interest and Tax	**50,851**	**10,170**

7.4.2 Medium-sized vineyard model

Production information is shown in Table 72 and a summary of the financial performance of the model is shown in Table 73.

Table 72: Medium-sized vineyard model production and revenue data

Variety	Area (ha)	Yield (tonnes/ ha)	Total (tonnes)	Return ($/tonne)	Revenue ($)
Sauvignon Blanc	1.6	6.2	9.9	2,950	29,170
Pinot Noir	13.2	6.4	84.9	4,650	394,673
Pinot Gris	2.0	7.1	14.2	3,050	43,310
Chardonnay	1.2	6.0	7.2	4,010	28,872
Riesling	2.0	5.6	11.2	3,380	37,856
Total	20.0	6.4	127.4	4,190	533,881

Table 73: Summary data for the medium-sized (20 ha) vineyard model

	Whole Vineyard ($)	Per ha ($)
Income from grapes	533,881	26,694
Other direct vineyard income	10,220	511
Gross Vineyard Revenue	544,101	27,205
Labour	324,585	16,229
Total other working expenses	89,096	4,455
Total overhead expenses	33,146	1,657
Total Vineyard Operating Expenses	**443,434**	**22,172**
Earnings Before Interest and Tax	**100,667**	**5,033**

7.4.3 Large vineyard model

Production information is shown in Table 74 and a summary of the financial performance of the model is shown in Table 75.

Table 74: Large vineyard model production and revenue data

Variety	Area (ha)	Yield (tonnes/ha)	Total (tonnes)	Return ($/tonnes)	Revenue ($)
Pinot Noir	35	7.4	259	3,450	893,550
Pinot Gris	10	6.5	65	2,900	188,500
Riesling	5	7.5	38	2,750	103,125
Total	**50**	**7.1**	**362**	**3,275**	**1,185,175**

Table 75: Summary data for the large vineyard (50 ha) mode

	Whole Vineyard ($)	Per ha ($)
Income from grapes	1,185,175	23,704
Other direct vineyard income	28,050	561
Gross Vineyard Revenue	1,213,225	24,265
Labour	649,177	12,984
Total other working expenses	266,519	5,330
Total overhead expenses	75,716	1,514
Total Vineyard Operating Expenses	**999,939**	**19,999**
Earnings Before Interest and Tax	**213,286**	**4,266**

7.4.4 Vineyard expenses

The expenses data from the vineyard sample shows that the majority of cost for viticulture is in labour. Central Otago has a vineyard model of hand tending vines and hand harvest, the steep and unforgiving terrain and the quality of wines dictate this regime to be the only viable method of farming. In the medium vineyard model the direct vineyard labour cost is more than 75 per cent of the overall cost.

While the small vineyard modelling shows the cost per hectare to be lower than either medium or large vineyards, much of the labour is not accounted for as a cost. Most of the work on small family vineyards is undertaken by family members or friends without wages and does not show on a 'Profit & Loss' statement. Larger vineyards have a nominally lower labour cost per hectare compared to medium-sized vineyards as scale contributes to efficiencies and larger vineyards are generally planted in less steep and more accessible locations.

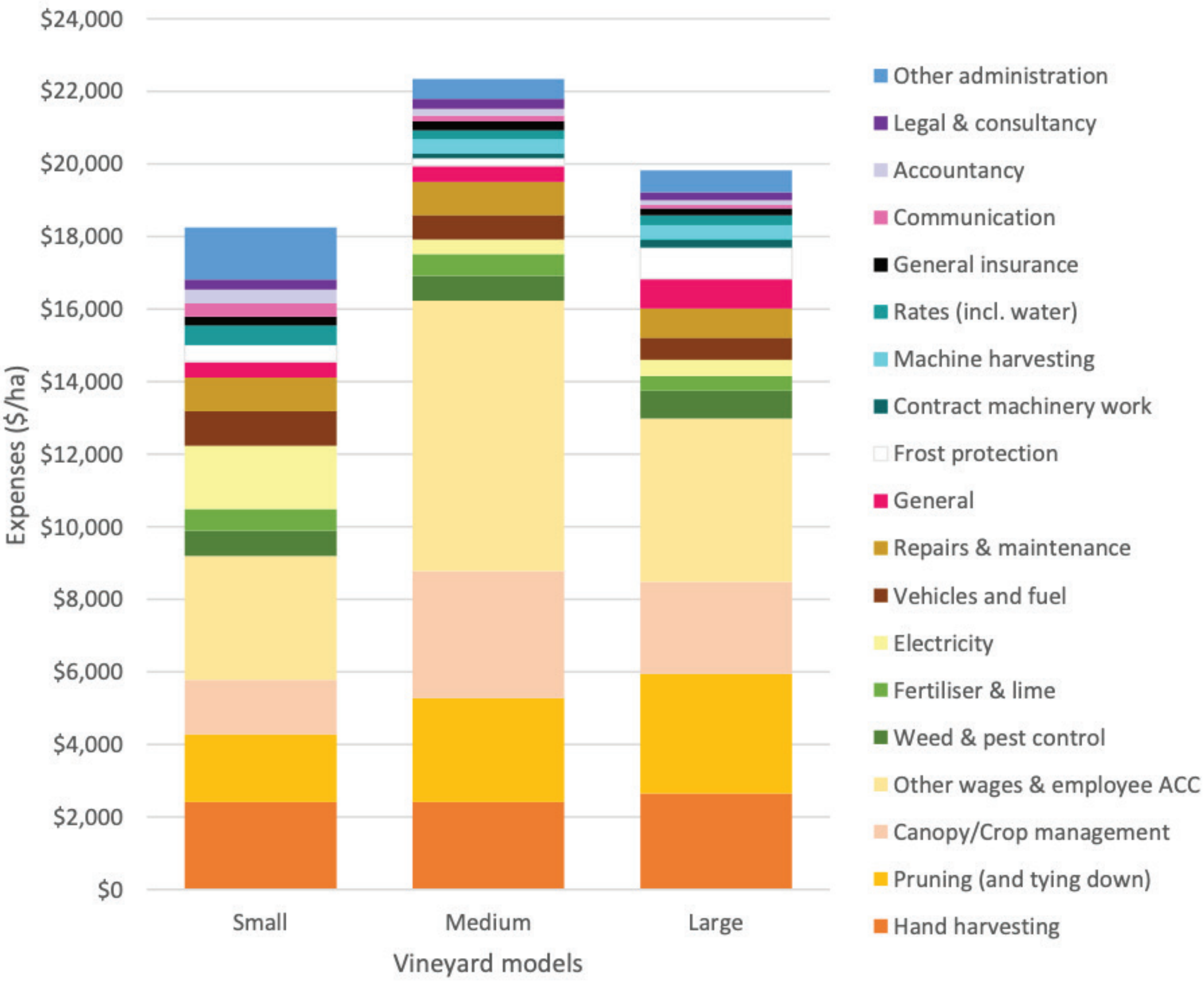

Figure 85: Distribution of expenses per hectare across three vineyard models

7.5 Environmental Actions

As noted in Section 7.3.1, vineyards generally have a low environmental footprint in terms of nutrients and water use and almost all vineyards operate under the Sustainable Winegrowing New Zealand regime of standards and audits. Consequently, there are few additional environmental actions available to test for viticulture in response to increased freshwater management.

This section starts by discussing 1) nutrient losses from vineyards in Central Otago and New Zealand as a whole and 2) the impacts of restrictions on access to water for frost fighting. It then investigates the impacts of reducing consented water on yields for the small, medium, and large vineyard models developed in Section 7.4, and investment in storage dams as a possible way of replacing this water. Finally, the impacts of surety of consent terms and conditions are discussed.

7.5.1 Nutrient losses

The nutrient requirements of vines are very low. Viticulture does not require an annual application of fertiliser and water is applied with a targeted and precision-based system, it is not a broadcast application (McArthur Ridge Vineyard Submission on the proposed Otago Regional Policy Statement, 2021). When nitrogen in the soil profile is not absorbed by plants it can wash through the soil profile, eventually resulting in a proportion of the nitrogen leaching into the waterways. Phosphorus is mainly lost through disturbance of the soil either through cultivation or through the movement of animals. Neither of these activities are prevalent in vineyards.

Nitrogen is introduced into the soil by several methods: fixation by plants, the application of nitrogenous fertilisers and in high concentrations in the urine of animals. There is a minimal proportion of the vineyard area, if any, that is planted in plants that fix nitrogen and although sheep are used to graze the vineyards in some cases, it occurs intermittently and at relatively low stocking rates. The application of nitrogen either through synthetic forms or through organic forms is normally very low in vineyards.

The Sustainable Winegrowing New Zealand data indicates that the average amount of nitrogen applied in Central Otago was 2.1 kg N/ha/yr in the 2021-22 season. Figure 86 shows that most vineyards apply either no nitrogen or less than 5 kg N/ha/yr.

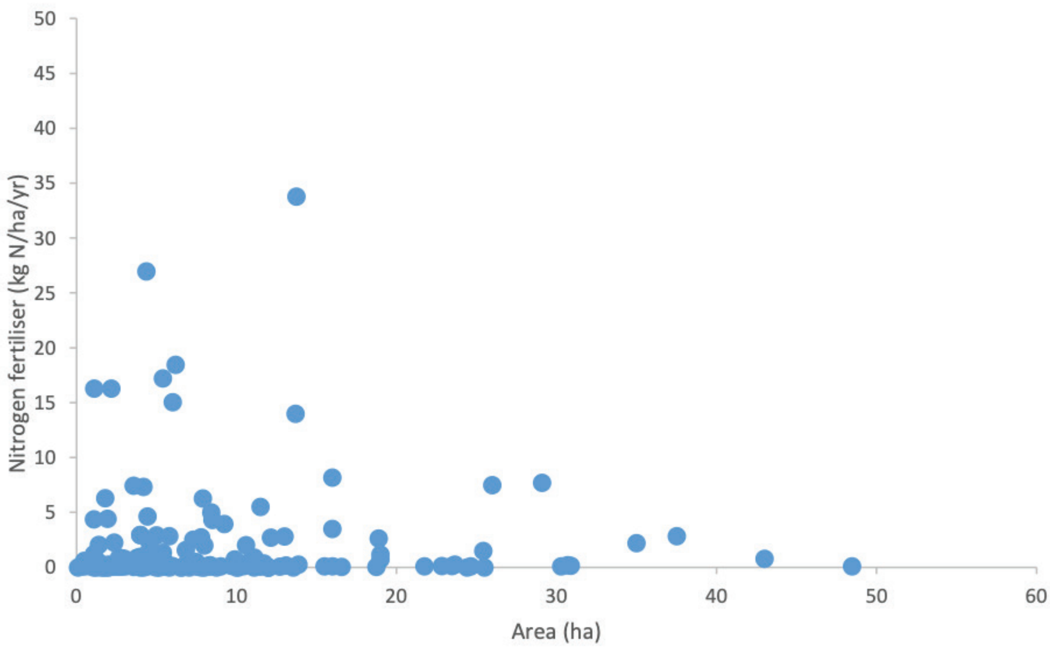

Figure 86: Applications of nitrogen fertiliser across Central Otago in 2021-22 season

This finding is supported by research for the New Zealand viticultural sector that was carried out by Clothier and Green (2017) using Plant and Food's model, SPASMO[259]. This research included modelling across the six main viticultural regions and consideration of 89 soils across these regions. The national average load of nitrate leaching beyond the rootzones of New Zealand's vineyards is just 8 kg N-NO_3 [260]/ha/y, and the average concentration is 7.9 mg/L. The soil-to-soil variation within and between regions was large.

Plant and Food also found that although irrigation regimes had only a minor effect on nitrate leaching, the role of the soil, and in particular its carbon to nitrogen ratio, is shown to play a dominant role in determining nitrate leaching[261].

The results of Clothier and Green (2017) modelling in Central Otago are given in Table 45. The results of modelling on 11 soil types shows that the average nitrogen load (leaching) was 1.2 kg N/ha/year with a variation from a high of 6.3 and a low of nil. Overseer files were created for each of the vineyards in the data collection phase for this research. The results of this are shown in Table 76.

Table 76: Summary findings of the regional arithmetic average loadings and concentrations of nitrate and phosphorus losses from vineyards in Central Otago in relation to soil types

Variety	Number of soils	Nitrate Load [1] kg NO3-N/ha/y	Nitrate Concentration mg/L	Phosphorus Load kg P/ha/y	Phosphorus Concentration mg/L
Central Otago	11	1.2 (6.3,0)	23.1 (107.1,0)	0.09 (1.0,0)	0.07 (0.45,0)
National[3]	89	8.0 (21.3,0)	7.94 (107.1,0)	0.25 (1.7,0)	0.16 (0.68,0)

1 Areally-weighted average by viticultural soil type (maximum, minimum)
2 Areally-weighted values for soils in all regions, except Gisborne, and the national average is weighted by the regional vineyard areas.
Source: Adapted from Clothier and Green (2017)

Table 77: Results of Overseer modelling for sample of seven Central Otago vineyards

Location	N Loss (kg N/ha/yr)	N Surplus	Plant Available Water to 150cm	Fertiliser N applied (kg N/ha/yr)	Stock Present
Otago 1	5	62	147	0	Sheep
Otago 2	9	65	288	11	Sheep
Otago 3	6	32	138	1	Sheep
Otago 4	6	26	117	12	No
Otago 5	2	26	225	3	Sheep
Otago 6	5	30	192	15	No
Otago 7	13	45	114	6	Sheep

Across the seven vineyards the average nitrogen loss was 6.5 kg N/ha/yr with a range from 2 kg N/ha/yr to 13 kg N/ha/yr. Vineyards usually have very low annual nitrogen and phosphorus losses. To date there has been no need for winegrowers to adopt specific environmental actions to reduce nitrogen and phosphorus losses.

259 SPASMO is the Soil Plant Atmosphere System Model which is owned by Plant and Food.
260 N-NO32 is the chemical description for Nitrate Nitrogen.
261 Carbon and no oxygen are the two requirements for denitrification. Carbon is the food source that microbes are trying to breakdown and nitrate is the first electron acceptor in the chain of redox processes that they use to do so – nitrate gains an electron and is removed as dinitrogen gas. As most irrigation wets the soil for short periods there may be opportunities for microbes to denitrify nitrogen provided there is sufficient carbon. https://landscapedna.org/science/chemical-processes/

7.5.2 Restrictions on access to water for frost fighting

The protection of grapevines from frost is a complex topic. Frost fans, which use diesel, are less effective for heavier frosts or snow while water for frost fighting needs harvesting and storage. The location of vineyards is important. Some vineyards are more vulnerable to frost because they have a high inversion layer that frost fans cannot access, and water is the only option. Other vineyards have natural drainage of cold air[262], which means they are less frost-prone. The impacts of restricting water used for frost fighting on a large vineyard will be more impactful to industry as a whole.

The impact of a frost event depends on both the severity of the frost event and its timing. At the early shoot development stage (November) or flowering stage, (December) a severe frost event could mean the total loss of that year's production. Later, it could reduce both the volume and quality of the grapes produced in that season and have an impact on the vines' ability to form buds in the subsequent year.

The Central Otago vineyard growing area has a diverse range of geographical sites that vineyards are situated on, which means that their potential for frost events varies considerably in both frequency and severity. This ranges from vineyards on the slopes that have sufficient katabatic drift air movement, which means that they are not affected by frosts, to those that are situated on flat land below high peaks, that are prone to frequent and severe frosts.

The severity of the frosts is highly relevant to the methods used to protect the vines from damage. The research shows that in a frost of up to -2.5° the use of fans can be a successful means of protecting the vines. Above that the spraying of water onto the vines or the use of helicopters are the most appropriate means of protection against frosts.

Image 45: Vineyard at dawn during a heavy frost with water being used for frost protection, October 2022. Source: McArthur Ridge.

262 Katabatic drift (or cold air drainage) is a drainage wind that carries high-density air from a higher elevation down a slope under the force of gravity. Even in very flat areas, the drift is influenced by sloping land many kilometres away and will also follow rivers and water courses. https://www.nzfrostfans.com/wp-content/uploads/2021/11/Fact-Sheet-katabatic-drift-ENGLISH.pdf

Image 46: Frozen frost protection water after a heavy frost in October 2022.
Source: McArthur Ridge.

The Sustainable Winegrowing New Zealand questionnaire indicates that one-quarter of vineyards utilised overhead sprinklers, which it was presumed are for frost fighting. These systems were assumed to be either fed direct from their water source or from stored water. Frost fighting is the main reason that vineyards have water storage, but it can be drained quickly when there are multiple days of frost. Actions such as the use of header tanks can make a difference, so a grower is not starting a pump at low flows.

Waterforce[263] indicated that most frost fighting systems deliver one mm of water per hour and that the average use per frost event is for six hours. These systems are designed with water storage that allows for sufficient storage to apply frost protection water for five events. This means that access is needed to sufficient water to either apply water at a faster rate than that of irrigation or at a rate that is able to replenish the storage.

If sufficient access to water storage is not available, the next alternative option for vineyards depends on the likely frequency and severity of the frost risk. For those vineyards that have a high frequency of less than -2.5° frosts the use of frost fans is likely to be appropriate. During more extreme events helicopters can be used to force warm air down through the inversion layer would be the only alternative method. Where water storage is both viable and affordable, it is the most desirable form of frost fighting with lower costs for operating the system of overhead sprinklers than the costs of operating diesel-powered frost fans or the high costs of helicopter operations. The reduction of diesel engines, helicopter noise, carbon emissions and visual impacts are also considerations. Frost fighting is needed in the spring when many river systems tend to have more plentiful amounts of water and there is less demand overall for water for irrigation.

263 Waterforce is a New Zealand company that provides water management technologies and systems across a wide range of industries *https://www.waterforce.co.nz/*

7.5.3 Reducing consented water takes

Access to water is the single most important consideration for viticulture in Otago – one of New Zealand's driest regions. Irrigation is essential for the establishment of vines, ongoing survival of vines, and to produce fruit for winemaking.

Viticultural operations are highly efficient users of irrigation water. The amount of water used must be precisely determined to optimise vine health: underwatering plants results in reduced yields and potentially loss of plants, while overwatering can cause excessive leaf growth, more expensive management practices, poorer grape quality and unnecessary pumping costs ((McArthur Ridge Vineyard Submission on the proposed Otago Regional Policy Statement, 2021).There is almost no sub-region in Otago that can dry-farm grapes successfully: the Otago soils, climate, and terrain demand water for irrigation to produce crops. Vineyards that have been established for more than 30 years still rely on irrigation for grape production each season. Further, as the worlds' southern-most winegrowing region in a continental climate, additional short-term access to high volumes of water is required to fight early season and late season frost.

To test the impact of potential reductions for consented water a literature review was carried out to establish relevant parameters to use in the analysis. Those parameters were then applied to test the impacts of water quantity restrictions on the yields of three vineyard models. Second, the cost was calculated of continuing to supply current levels of water through the construction of a storage dam. However, any in-depth analysis of water storage needs to be case by case basis.

7.5.3.1 Literature review

Three papers were identified in the literature and relied on to understand the relationship between irrigation management strategies and the grapevine response. Each paper is briefly discussed here in turn and informed the analysis of the impacts of reducing consented water takes (Section 7.5.3.2).

1. *Chalmers, Y. (2012). "Insights into the relationships between yield and water in wine grapes." Grape and Wine Research and Development Corporation; Department of Agriculture, Fisheries and Forestry of the Government of Australia; Canberra, Australia.*

The aim of this research was to:

> *consolidate current thinking around the relationships between yield and water across the key growing regions within the Murray Darling Basin. There are many other variables, including varieties, climate, soils, management practices and their complex interactions that could be discussed, however this module has been designed to provide guiding information to the winegrape growing community about the management of irrigation water, particularly deficit irrigation, and the possible impact on production (yield and quality).*
>
> *The amount of water required at different stages of grapevine growth will depend on the variety, rootstock-to-scion interaction, climate (rainfall and evaporation), soil type/depth and crop load. Figure 87 illustrates the approximate annual percentage of water required by vines at each stage of the growth cycles.*

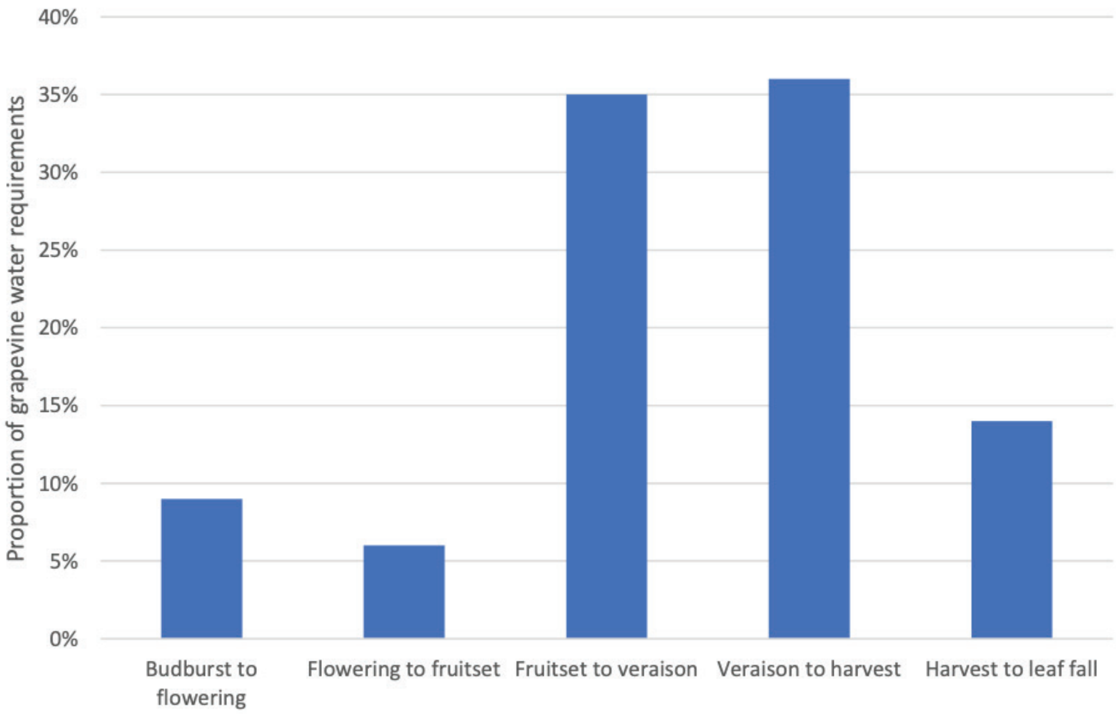

Figure 87: Grapevine growth stages and the approximate water requirement at each stage as a proportion of the annual requirement from Chalmers (2012)[264]

It is widely known that water deficit can influence grapevine canopy structure, yield components and berry composition. The effect of water deficit on grapevine production differs depending on the stage of canopy growth and berry development when the water deficit is applied. Various studies have used different irrigation regimes to manipulate canopy vigour and have noted that yield and quality at harvest are dependent on when the irrigation is applied in relation to the stage of berry growth.

With the realisation that some form of deficit irrigation management will be necessary to produce sustainable wine grape production into the future, there needs to be greater understanding as to how a managed soil water deficit will affect yield, quality and long-term vineyard sustainability. Currently, the Australian wine industry has widely adopted various irrigation management strategies such as regulated deficit irrigation, partial rootzone drying and sustained deficit irrigation to improve and sustain water use efficiency, which is calculated as tonnes of fruit per megalitre of water. A common feature of these irrigation techniques is the reduction in available soil water but how the water is applied is fundamentally different.

In the case of regulated deficit irrigation, a controlled application of irrigation water at less than the crop water use is applied at a specific vine growth stage (temporal deficit). By contrast with PRD, the irrigation water is manipulated over the soil area (spatial deficit) by applying alternate irrigations to each side of the grapevine, thus creating discrete wet and dry zones around the root system. Conversely, for a sustained deficit irrigation the water deficit is not created by withholding water but by applying less water than the optimum required at each irrigation event for the entire irrigation season.

264 Chalmers (2012) adapted this graph from NSW Agriculture (2004) 'Irrigating grapevines with limited water supplies.' Agricultural Note. In Central Otago the timing of the growth stages in Figure 87 are: budburst to flowering (October-December), flowering to fruit set (December), fruit set to veraison (December-February), veraison to harvest (February-March/April), and harvest to leaf fall (March/April-May). Note 'veraison' is the onset of the ripening of the grapes (indicated by a change in colour of the fruit).

Image 47: Chardonnay grapes.
Source: Central Otago Winegrowers Association

Image 48: Pinot noir grapes ready for harvest.
Source: Central Otago Winegrowers Association

2. *Krasnow, M., Haywood, A., and McMillan, D. (2018) Optimising irrigation in New Zealand vineyards. Bragato Research. Bragato Research Institute.*

This research was designed to test the theory that it is possible to schedule irrigation so that the vines receive adequate, but not excessive, water. The study sought to compare the vineyard's normal irrigation regime (control), which for most was soil moisture probe-based, to irrigation based on measuring the vines' water potential.

> *Water potential can be thought of as the blood pressure of the vine. It measures how hard leaves must pull on water to remain hydrated. Water potential irrigation thresholds were set up that were specific to each variety, and no water was applied to the "deficit" side of the trial until the vines reached these values, indicating that they needed water. These thresholds changed based on the phenology[265] of the vines (refer to Table 78.*

This regulated deficit irrigation treatment employed infrequent, but long irrigations (8-12 hours per irrigation), compared with the standard of frequent, short waterings (1-2 hours per irrigation). Two Pinot Noir vineyards in Central Otago were included in the trial in 2017-18 season and the results are reproduced in Table 79.

Table 78: Stem water potential irrigation thresholds for the deficit treatment

Variety	Budburst to Set	Set to Veraison	Veraison to Harvest
Chardonnay	-0.8 MPa	-0.8 MPa	-1.0 MPa
Sauvignon Blanc	-0.5 MPa	-0.5 MPa	-0.9 MPa
Merlot and Pinot Noir	-0.8 MPa	-1.2 MPa	-1.2 MPa

Source: Krasnow et al. (2018)

Table 79: Seasonal irrigation use and yield of two irrigation scheduling methods.

Trial	Treatment	Seasonal Irrigation (L/ vine)	Yield (T/ha)
Pinot Noir 1	Control	292	13.5
	Regulated deficit irrigation	0	17.9
Pinot Noir 2	Control	63	8.8
	Regulated deficit irrigation	19	10.3

Data Source: Krasnow et al. (2018)

Although these are only one year's results, they point towards the regulated deficit irrigation method of irrigation scheduling as possibly reducing the amount of water used at the same time as at least maintaining both quantity and quality of production. However, with the different soils across Otago and underlying sub-soil structures there is insufficient research to definitively state that the regulated deficit irrigation method can be used in all or even in substantial areas of viticulture in the region. The current irrigation practices support the direct relationship in yield to optimum irrigation in the data below.

265 Phenology is the study of the events or growth stages that recur seasonally and relative to climatic factors (e.g., for grapevines it is budburst, bloom and set, veraison, ripening, leaf drop, dormancy).

3. *Mercer, J., Dryden, G., Neal, M., and Green, S. (2016) Maximising irrigation savings in grape vines and the effect on yield and wine quality. Sustainable Farming Fund.*

This research was designed to test how far a vineyard could go in terms of reduced irrigation without negatively affecting output in both wine quantity and quality. The trial was carried out on the Nautilus Estate in Marlborough, which is a relatively dry block planted in Sauvignon Blanc grapes. The trial was run for three years (production seasons) under reduced application treatments but was then fully irrigated in the fourth year and, as a result, it found that production reverted to its normal level.

The treatments used the following irrigation strategies:

- *Treatment 1: Control – standard irrigation strategy (evapotranspiration) less effective rainfall*
- *Treatment 2: 50% evapotranspiration less effective rainfall*
- *Treatment 3: 40% evapotranspiration less effective rainfall*
- *Treatment 4: 30% evapotranspiration less effective rainfall*
- *Treatment 5: Partial Rootzone Drying*[266] *and 60% evapotranspiration less effective rainfall*
- *Treatment 6: Mulch and 30% evapotranspiration less effective rainfall*

> *The major difference between this trial and others previously or currently being carried out is the desire to manage irrigation application under these regimes. This project won't just look at reducing dripper output to, say, 40 per cent of the control, but will look at the best use of the total 40 per cent of ET available to the vine over the whole season. In effect, there could be times when the 40 per cent treatment receives more than the control and times when it receives nothing. The important part of this approach is practicality. This is the approach that a grape grower would take in a real situation. They would not merely go from say a 4 ltr/hr dripper to a 1 ltr/hr dripper but rather continue to use 4 ltr/hr drippers but manage the irrigation.*

Averages of results for the first three years of the trial are given in Table 80. In year four all the treatments had virtually the same amount of irrigation.

> *As irrigation application decreased actual crop water use also declined across all three seasons. However, while the vines adapted to the reduced irrigation and produced a crop there were serious consequences on the vines and fruit.*

Image 49: Vineyard in Earnscleugh, Central Otago.
Source: Simon Moran

266 The authors described Partial Rootzone Drying as a technique where there are two irrigation lines per row and one side of the vine is kept dry, the other irrigated and then alternated several times during the season to "trick" the vine into thinking it is receiving more water than it actually is.

Table 80: Average results from the three-year trial (2003/4 to 2005/6)

Treatment (irrigation strategy)	Proportion of crop water use less effective rainfall	Irrigation (mm)	Yield (T/ha)	Share of the yield in Control
T1: Control	72%	110	16.4	100%
T2: 50% evapotranspiration less effective rainfall	57%	58	12.7	77%
T3: 50% evapotranspiration less effective rainfall	40%	32	11.0	67%
T4: 50% evapotranspiration less effective rainfall	35%	20	9.8	60%
T5: Partial Rootzone Drying[267] and 60% evapotranspiration less effective rainfall	90%	116	16.1	98%
T6: Mulch and 30% evapotranspiration less effective rainfall	35%	29	9.6	59%

Data source: Mercer et al. (2016)

The results of the reduction in irrigation application impact on yield are shown in Figure 88. It suggests the yield response is relatively linear, which indicates a strong relationship between water availability and the production of wine grapes.

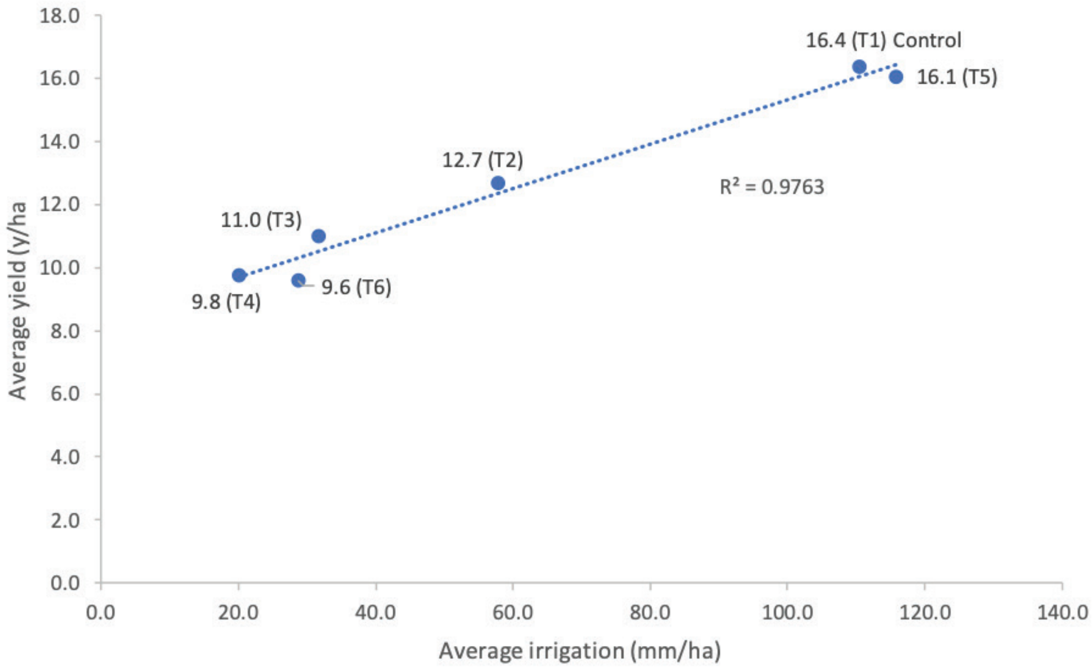

Figure 88: Relationship between irrigation and grape yields using results from Mercer et al., (2016)
Note: T1 = Control, T2 = Treatment 2, T3 = Treatment 3 etc. (refer to Table 80)

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267 The authors described Partial Rootzone Drying as a technique where there are two irrigation lines per row and one side of the vine is kept dry, the other irrigated and then alternated several times during the season to 'trick' the vine into thinking it is receiving more water than it actually is.

There was a belief that the negative effects of the low irrigation treatments may be able to be compensated for by an improvement in wine quality. Small batches of wine were made (around 500 litres per treatment) to establish the effect on wine quality. A number of objective and subjective measures of wine quality were used. The results showed that there was certainly an effect on wine composition. Generally, the very low yields, while producing wines of an acceptable standard, were not up to the traditional 'Marlborough Sauvignon Blanc' that can be grown in the district. Comments from winemakers were that they were of a standard that they would use in the blending process rather than as a selection in its own right. The lower irrigation wines tended to exhibit flavours more at the tropical end of the spectrum.

During the project it also became clear as to how important the timing of irrigation application is to berry size, it is not just how much water is applied but when it is applied that also counts. Irrigation at flowering is critical to ensuring adequate fruit set and reduced irrigation and or rainfall in the weeks following set will reduce berry size. This is an important consideration for growers wishing to maximise yield with reduced irrigation availability.

Using the results of the research, in the next section the yields from each of the vineyard models were modelled in ten per cent reductions in irrigation water available from 100 per cent (i.e., the optimum) to 60 per cent.

Image 50: Mondillo vineyard with frost fans, Bendigo.
Source: Central Otago Winegrowers Association

7.5.3.2 The impacts of water restrictions on the vineyard models

The impact on the financial performance of each vineyard of the yields resulting from restrictions in access to irrigation water are shown in Figure 89 to Figure 91 (on the following pages). In these graphs 100 per cent is the optimum level of irrigation to the vines in any particular season. The reductions were modelled to reflect the impact on gross revenue at the vineyard gate (tonnage of grapes at revenue or tonne) for water restrictions to the vines in ten per cent steps from 60 per cent through to 100 per cent (with 100 per cent being the optimum).

While percentage reductions in water use are used in this analysis it is important to consider each vineyard's starting point for how far the restrictions may go. If there is not sufficient water then it is not just a matter of reduced yield as the vines will not survive. Where vines fail then need replanting and four to five years to return to full production.

Noticeable in the small vineyard analysis is the apparent lower cost per hectare for operating the vineyard. The anomaly is attributed to the mostly family owned and operated nature of small vineyards where much of the labour is not accounted for in the financial models. Family and friends make up a large part of the workforce with no wages being attributed to the operating costs. Vineyards are pruned over several months by owners, harvest is often done in a few days of family and friends picking grapes with the only reward being meals and social activities. Some contractor costs may be incurred for spraying, trimming and other machine related work, however even some of these are vineyard tasks are done with shared resources between families. This circumstance is not completely unique to rural industries and viticulture has traditionally relied on family and friends for its workforce.

The sale of finished wines by small producers is also quite different to the medium or large producers with 69 per cent of wines sold domestically (NZ wide producer statistic from Deloitte 2018 benchmarking survey) compared to just 18 per cent for the very large New Zealand wine producers. Much of the domestic sales for small producers is to local cafes, restaurants, and retailers at trade pricing, and through cellar door sales at full retail, while only a small number have national distributors where wines are sold at wholesale. Three pricing tiers generally exist in the wine distribution model:

1. Wholesale price to national distributors;
2. Export pricing where the distributor or importer marks up to trade price for sales to restaurants and wine retailers; and
3. Retail price is the final price to the consumer.

The most at-risk operations in Otago are the medium-sized vineyards. The two most common systems are those who fully use viticulture contractors for all the operations on the vineyard, and those who are more self-sufficient and have a vineyard manager/viticulturist, some permanent staff and hire casual seasonal workers during the growing season and harvest. These operations are often financially at risk because of the higher operating cost per hectare when using a contract viticulture company, or when employing a full-time team, they do not have the scale to fully utilise equipment and resources.

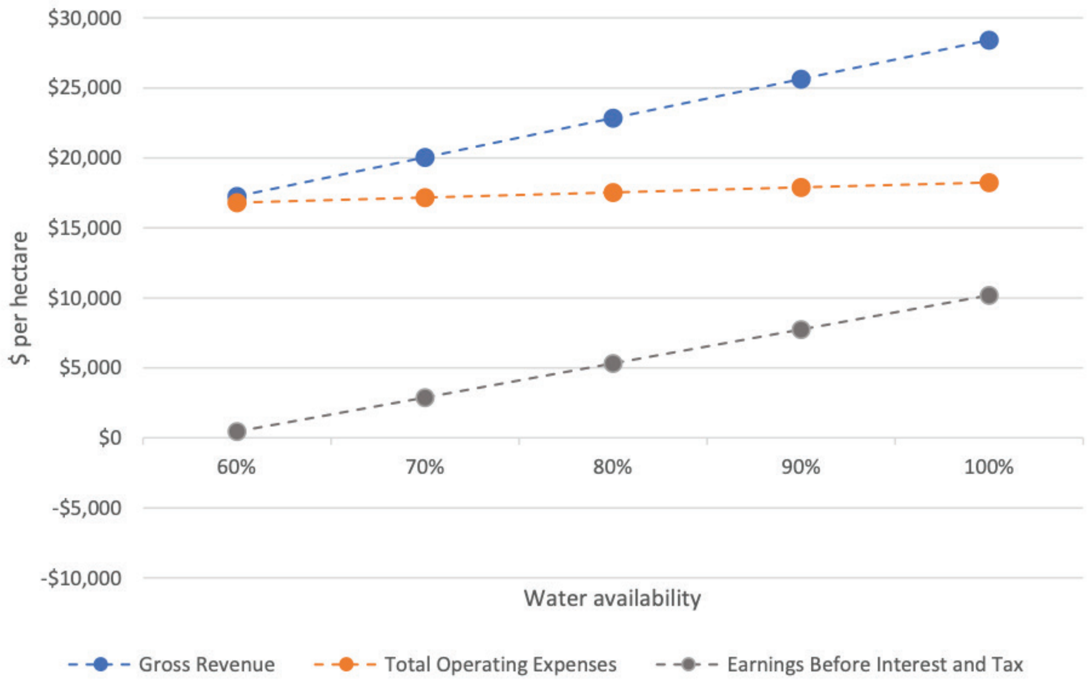

Figure 89: The impact of a range of restrictions on irrigation water on the small vineyard model

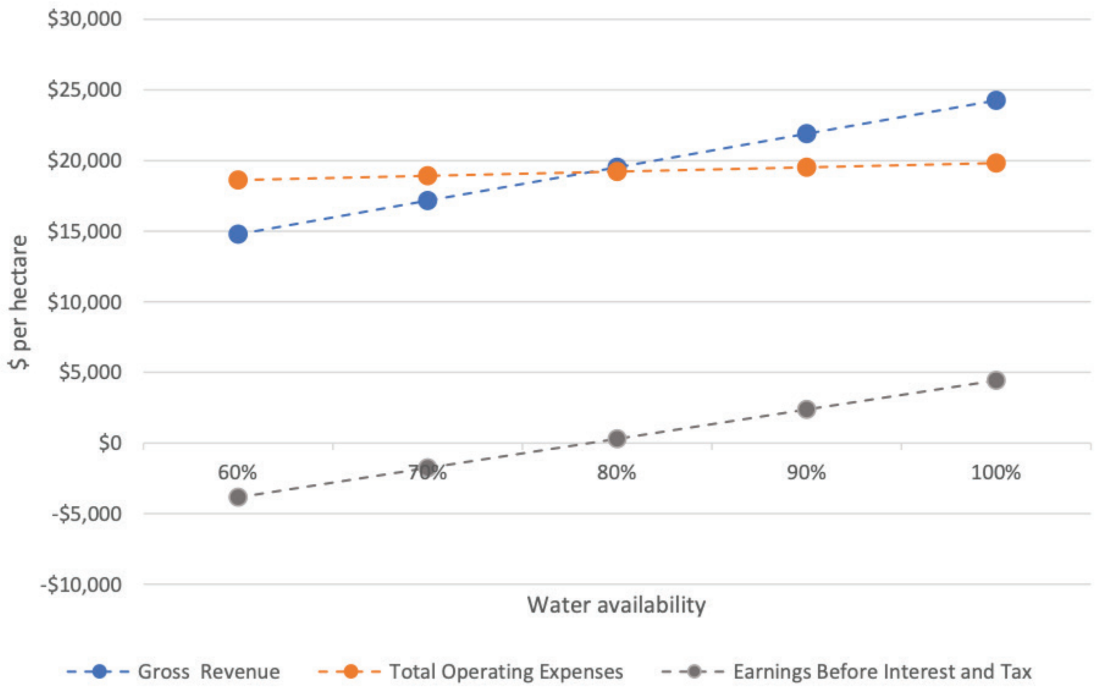

Figure 90: The impact of a range of restrictions on irrigation water on the medium-sized vineyard model

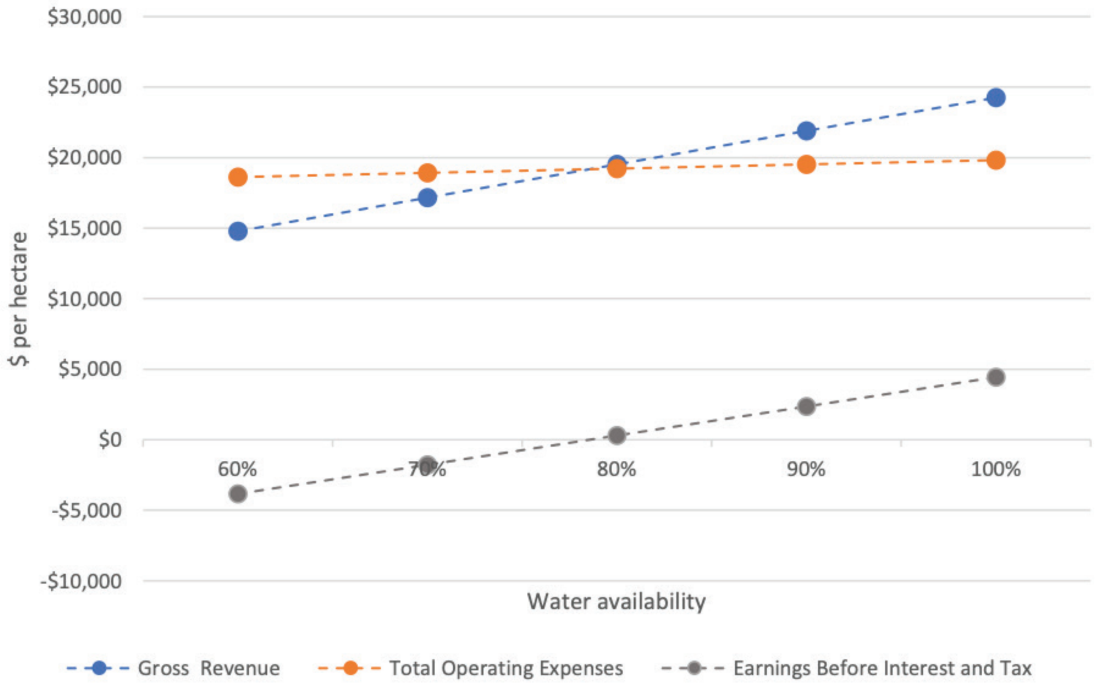

Figure 91: The impact of a range of restrictions on irrigation water on the large vineyard model

The Deloitte Wine Industry Benchmarking and Insights 2018 report referenced earlier identified the return on assets (earnings before interest and tax/assets) varied across the different tiers in the survey from 2.4 per cent ($1.5 to $5 million turnover) to 8.4 per cent ($20+ million turnover) showing the low return on these medium-sized operations. The report noted that these came in a particularly good year (2018) when *"All tiers reported positive profit for only the third time in the history of the survey"*. By averaging the results for each 'turnover' category, it was found that they all recorded a positive profit before tax result for only the third time in the twelve-year history of the survey (2014, 2016 and 2018).

While no further Deloitte surveys have been undertaken, subsequent years have been challenging for wine producers with Covid-19 impacts, increased excise taxes and operating costs, and supply chain challenges. Also noted in the Deloitte report is the working capital (being current assets less current liabilities) peaking at the $1.5 to $5 million revenue tier (aligned to the medium-sized vineyard model in this chapter) at 50 per cent of assets. With such a large proportion of the current assets deployed as working capital – much of it held in inventories – the financial stability at this tier is more fragile than tiers below or above it.

While there are a few large vineyards in Otago they account for around 44 per cent of the total vineyard planted land. Their scale of production provides more financial stability and the ability to withstand variation in the yields from the seasonal influences. The operating costs per hectare are noticeably lower than the medium-sized vineyards as scale provides a better return on working capital. However, they are no less dependent on surety of fresh water and are more likely to depend on access to water for frost fighting as well as for irrigation. The location of large vineyards is likely to be on a valley floor rather than the steeper slopes. The valley floor gives the ability to use machinery for viticulture activities, including for harvest, but the lower level and flat terrain increases the frost risk.

7.5.3.3 The cost of replacing the restricted water with stored water.

Data from the Sustainable Winegrowing New Zealand questionnaire was used to calculate the cost of providing for the restricted water from water storage. It suggests that the medium-sized vineyard uses 130 mm of irrigation annually (with variation from 107 mm to 174 mm). The restrictions were then calculated as ten per cent of average annual water use (13 mm). The cubic metres needed to store that water was multiplied by 1.2 to allow for the footprint of the dam and the product (i.e., a lined dam[268]) was then multiplied by $16/m^3 to estimate the cost of construction. The cost of the land was then added at $70,000/ha[269] to calculate the total cost of the dam and an interest rate of eight per cent applied for the annual cost of the dam. The following tables give the estimated cost of each water restriction, compared to current or 100% (i.e., 90% is a 10% restriction). The total cost of the dam, the cost of the dam over a ten-year period. The results of this calculation are shown in Tables 81 to 83.

Table 81: The costs of a storage dam on the small vineyard model for differing water availability percentages

Costs ($)	**90%**	**80%**	**70%**	**60%**
Restriction in EBIT	12,150	24,301	36,451	48,602
Dam	26,130	52,260	78,390	104,520
Dam over 10 years	20,904	41,808	62,712	83,616

Table 82: The costs of a storage dam on the medium-sized vineyard model for differing water availability percentages

Costs ($)	**90%**	**80%**	**70%**	**60%**
Restriction in EBIT	$48,548	$97,097	$145,645	$194,193
Dam	$104,520	$209,040	$313,560	$418,080
Dam over 10 years	$83,616	$167,232	$250,848	$334,464

Table 83: The costs of a storage dam on the large vineyard model for differing water availability percentages

Costs ($)	**90%**	**80%**	**70%**	**60%**
Restriction in EBIT	$103,479	$221,516	$310,437	$413,916
Dam	$261,300	$522,600	$ 783,900	$1,045,200
Dam over 10 years	$209,040	$418,080	$627,120	$836,160

The question then becomes what frequency of restrictions would mean that the storage dam was able to at least pay for itself. Based on these calculations, a dam may pay for itself:

- On a small vineyard if there are 1.7 water restriction events every ten years;
- On a medium-sized vineyard if there are 1.7 water restriction events every ten years; and
- On a large vineyard if there are 2.0 water restrictions events every ten years.

In reality, the proportion of vineyards that have their own water storage remains fairly constant and new vineyard developments are not usually adding much water storage. As a result of the seasonality of water use, water is lost by storage through evapotranspiration during the periods where water is not in high demand.

268 Waterforce Wanaka
269 Colliers Otago

7.5.4 Surety of consent term and conditions

Viticulture is a capital-intensive sector. Large investments are needed to develop or purchase vineyards as well as in the making and marketing of wine. There is also a sizeable annual cost in the maintenance of that investment, meaning producer confidence is necessary to access finance. When producers face uncertainty the viability of investing in new vineyards or continuing to produce in existing vineyards can be called into question. Reducing uncertainty is a key to producer confidence.

Longer-term consents for the use of fresh water gives producers greater confidence in decision-making around investments. It also encourages long-term planning, and research and development into production methods, including new technologies and innovations around environment actions (e.g., sub-surface drip line irrigation). With longer-term consents, the costs of research and development can be spread over a longer period, reducing the investment risk that comes from variability between production seasons. Longer-term consents also allow for external parties, such as lenders and purchasers, to have greater confidence in the producer's performance, which is necessary for the value chain and succession.

Conversely, short-term consents reduce producer confidence and create risk aversion in the sector. Uncertainty can impact investments in land and infrastructure, and all aspects of production down to total yield and quality of produce. It is likely to result in more of a focus on the present rather than planning for the future, impacting on willingness to invest in further development. Lenders, purchasers and others in the value chain are likely to have less confidence in the producer's long-term viability. There is also a risk of trapped assets – land that has been prepared for viticulture but is not yet planted – means it is likely to be more challenging to gain funding for such projects (Wilkinson, 2022).

In 2023, the development costs for a producing vineyard range from $80,000 to $120,000 per hectare. When added to the market price of land, which in Central Otago is roughly $70,000 to $80,000 per hectare, it means a new vineyard development may need investment in the vicinity of between $150,000 and $200,000 per hectare. In autumn of 2023, Colliers Otago indicated that, depending on the area and the size of the vineyard, established vineyards are usually selling for between $150,000 and $250,000 per hectare.

Further scientific research may reduce uncertainties around both the supply and demand aspects of water allocation across catchments. An additional consideration is how water restrictions may impact shared water schemes (some are mixed use), rather than a single vineyard. Some wine-growing sub-regions may be more at risk than others, particularly because of existing water over-allocation issues, and the allocation of water downstream of the Clutha dam compared with upstream (Wilkinson, 2022).

7.6 Research Findings

Seven vineyards were surveyed in this research. They ranged in scale from small to large operations and across various water consumption uses for irrigation and fighting frost. There was considerable diversity in how the vineyards sold their crop, but all the growers used some or all of it to produce their own finished wine. Small vineyards on a grower contract to solely supply a viticulture company were not included in the sample.

Vineyards generally have a low environmental footprint in terms of nutrients and water use, and almost all vineyards operate under the Sustainable Winegrowing New Zealand regime of standards and audits. Consequently, few environmental actions were available to test for viticulture in response to increased freshwater management. The two actions tested were: 1) the impacts of changes in yield from restrictions in water available to the vine, and 2) the cost of replacing this water with stored water. Each vineyard's existing water use is an important consideration because it may be more of a question of rootstock survival than changes in yield. Where vines fail and need replanting it can take four to five years to return to full production, assuming new rootstock is available. An in-depth analysis of water storage needs to be case by case basis.

Within a catchment, the small vineyards and small-medium vineyards tend to be more vulnerable to impacts of environmental actions than the larger vineyards. The small-medium vineyards often need, but cannot afford, extra labour so are already under pressure. Smaller growers are important to industry because most contribute their grapes into other wine labels. Larger vineyards tend to have lower operating costs per hectare but they are more likely to be located on the valley floors, where vineyards are particularly dependent on access to water for frost fighting. Yield reductions caused by water restrictions impact all parts of the value chain, including wine processing, bottling, freight, storage, tourism, and hospitality.

If a vineyard is no longer able to operate then the vines tend to be leased – so production is not necessarily lost from industry even through the growers may be. However, there are examples of the removal of vines and conversion back to grazing land. The response may depend on the value of the grapes.

These findings reflect a main point made in the McArthur Ridge Vineyard Submission to the proposed Otago Regional Policy Statement:

> *Viticulture has limited ability to respond to water rationing in dry years and no ability to respond to restricted access to water for frost fighting when this is required (if water is the chosen means to frost fight). Reliability of water supply is therefore critical to the industry and its commercial viability.*

Image 51: Harvested pinot noir grapes.
Source: Central Otago Winegrowers Association

8 References

Anon (2013). *On efficiency and effectiveness: some definitions*. Productivity Commission Staff Research Note, Australian Productivity Commission Canberra.

Baars, J. A., Jagusch, K. T., Littler, R. A., & Farquhar, P. A. (1984). Effects of rotational grazing and set stocking on pasture production under sheep grazing. *Proceedings of the Agronomy Society of New Zealand,* 14, 131-134.

Barling, R. D. & Moore, I. D. (1994), Role of buffer strips in management of waterway pollution: A review. *Environmental Management,* 18(4), 543-558.

Chalmers, Y. (2012). *Insights into the relationships between yield and water in wine grapes.* Department of Agriculture, Fisheries and Forestry of the Government of Australia, Grape and Wine Research and Development Corporation, Canberra, Australia. https://www.wineaustralia.com/getmedia/79a5bc97-bf38-40a3-a867-8898b983ed82/Yield-and-water-notes.pdf

Clothier, B. E. & Green, S. R. (2017). The leaching and runoff of nutrients from vineyards. In L. D. Currie and M. J. Hedley (Eds.), *Science and policy: nutrient management challenges for the next generation.* (Occasional Report No. 30). Fertilizer and Lime Research Centre, Massey University, Palmerston North. https://www.massey.ac.nz/~flrc/workshops/17/Manuscripts/Paper_Clothier_2017.pdf

Dasgupta, P. (2021). *The Economics of Biodiversity: The Dasgupta Review.* HM Treasury, London.

Davey, T., Fahey, B., & Stewart, M. (2006). Tussock grasslands and high water yield: A review of the evidence. Journal of Hydrology (NZ) *45*(2): 83-94.

Deloitte & ANZ. (2018). Growing Smarter: *Wine industry benchmarking and insights 2018.* New Zealand. A report produced in conjunction with Deloitte; ANZ; & New Zealand Winegrowers.

Doole, G. J. (2013). *Evaluation of policies for water quality improvement in the Upper Waikato catchment.* University of Waikato, Hamilton. https://environment.govt.nz/publications/evaluation-of-policies-for-water-quality-improvement-in-the-upper-waikato-catchment/

Dosskey, M. G., Helmers, M. J., Eisenhauer, D. E., Franti, T. G., & Hoagland, K. D. (2002). Assessment of concentrated flow through riparian buffers. *Soil and Water Conservation Society* 57(6), 336-343.

Drewry, J. J., Cameron, K. C., and Buchan, G. D. (2008). Pasture yield and soil physical property responses to soil compaction from treading and grazing — a review. *Soil Research,* 46(3), 237-256. http://www.publish.csiro.au/paper/SR07125

Fastellini, G. & Schillaci, C. (2020). Chapter 7. Precision farming and IoT case studies across the world. In A. Castrignanò (Ed.), *Agricultural Internet of Things and Decision Support for Precision Smart Farming* (pp. 331-415). https://doi.org/10.1016/B978-0-12-818373-1.00007-X

Easton, B. (2023). *Learnings from The New Zealand Economic History of Shocks.* Working paper. The New Zealand Productivity Commission, Wellington. https://www.productivity.govt.nz/assets/Inquiries/resilience/Brian-Easton-2022-Learnings-from-The-New-Zealand-Economic-History-of-Shocks.pdf

Edmeades, D., Watkinson, J., Perrott, K., Sinclair, A., Ledgard, S., Rajan, S., Brown, M., Roberts, A., Thorrold, B.. O'Connor, M., Floate, M., Risk, W., & Morton, J. (1991). Comparing the agronomic performance of soluble and slow release fertilisers: the experimental basis for RPR recommendations. *Proceedings of the New Zealand Grassland Association,* 53, 181-190.

Fisher, A. & Burtt, A. (2022). Sheep and Beef Cattle Farming. In E. Moran (Ed.) *Farmers and Growers in Otago* (p. 29). EM Consulting for Otago Regional Council (LWRP Economic Work Programme), Dunedin.

Fleming, P. H. (2003). *Farm Technical Manual.* Farm Management Group, Lincoln University, Lincoln.

Gregory, J. (2018). *The Deer Industry Environmental Management Code of Practice.* Deer Industry New Zealand, Wellington.

Harrington, K. C., & Ghanizadeh, H. (2023). Comparing herbicide resistance in New Zealand and Australia. *New Zealand Journal of Agricultural Research,* DOI: 10.1080/00288233.2023.2180759

Haynes, R. J., & Williams, P. H. (1993). Nutrient Cycling and Soil Fertility in the Grazed Pasture Ecosystem. In L. S. Donald (Ed.), *Advances in Agronomy* (Volume 49, pp. 119-199). Academic Press. https://doi.org/10.1016/S0065-2113(08)60794-4

Horrocks, A., (2022). Arable Cropping. In E. Moran (Ed.), *Farmers and Growers in Otago* (p. 91). EM Consulting for Otago Regional Council (LWRP Economic Work Programme), Dunedin.

Kaine, G. & Wright, V. (2015). *Towards predicting rates of adoption and compliance in farming: motivation, complexity and stickiness.* Report to the Waikato Regional Council, Hamilton. https://www.waikatoregion.govt.nz/assets/WRC/WRC-2019/tr201705.pdf

Kaine, G. & Wright, V. (2016). *Rates of adoption and compliance in dairy farming.* Report to the Waikato Regional Council, Hamilton. https://www.waikatoregion.govt.nz/assets/WRC/WRC-2019/tr201706.pdf

Kirk, N., Robson-Williams, M., Fenemor, A., & Heath, N. (2020). Exploring the barriers to freshwater policy implementation policy in New Zealand. *Australasian Journal of Water Resources,* 24(2), 91-104.

Knight, C. (2017). New Zealand’s Rivers: *An Environmental History.* Canterbury University Press, Christchurch.

Krasnow, M., Haywood, A., and McMillan, D. (2018). Optimising irrigation in New Zealand vineyards. *Bragato Research Institute,* October 1, 2018. https://bri.co.nz/2018/10/01/optimising-irrigation-in-new-zealand-vineyards/

Krugman, P. (22 May 2023) Working from home and realizing what matters. Opinion Column, New York Times, New York.

Lynn, I., Manderson, A., Page, M., Harmsworth, G., Eyles, G., Douglas, G., MacKay, A., & Newsome, P. (2009). *Land Use Capability Survey Handbook: A New Zealand Handbook for the Classification of Land. AgResearch,* Hamilton. https://www.tupu.nz/media/jzbjrpy4/land-use-capability-luc-survey-handbook-3rd-edition.pdf

Manaaki Whenua Landcare Research. (2023). The digital soil map for New Zealand. https://smap.landcareresearch.co.nz/

Makhlouf, G. (7 March 2018). *Natural Capital and the Living Standards Framework.* Speech delivered by the Secretary to the Treasury. https://www.treasury.govt.nz/publications/speech/natural-capital-and-living-standards-framework

McArthur Ridge Vineyard Submission on the proposed Otago Regional Policy Statement. (2021). https://www.orc.govt.nz/media/10769/mcarthur-ridge-vineyard-ltd-rps21_0403.pdf

McDowell, R. W., Monaghan, R. M., Close, M. E., & Tanner, C. C. (2016). Agricultural Catchment Restoration. In D. Hamilton, K. Collier, J. Quinn, C. Howard-Williams (Eds.), *Lake Restoration Handbook.* Springer, Cham, Switzerland.

Mercer, J., Dryden, G., Neal, M., & Green, S. (2016). *Maximising irrigation savings in grape vines and the effect on yield and wine quality.* Sustainable Farming Fund, Wellington. https://www.fruition.net.nz/wp-content/uploads/2016/08/Maximising-irrigation-savings-in-grape-vines-and-the-effect-on-yield-and-wine-quality.pdf

Ministry for the Environment. (2013). *Freshwater reform 2013 and beyond.* Wellington: Ministry for the Environment. https://environment.govt.nz/assets/Publications/Files/freshwater-reform-2013.pdf

Ministry for the Environment. (2017). Irrigated land in New Zealand. https://environment.govt.nz/facts-and-science/land/irrigated-land-in-new-zealand/

Moran, E. (2017, re-edited 2019). *The Southland Economic Project: Agriculture and Forestry Report.* (Technical Report No. 2019-04). Environment Southland, Invercargill.

Moran, E. (2019). "Introduction: Avoided Costs." In *Regional Case Studies for Essential Freshwater: Action for Healthy Waterways*, a report produced by the Regional Sector Water Subgroup for Local Government New Zealand, Wellington.

Moran, E. (Ed.). (2022). *Farmers and Growers in Otago.* EM Consulting for Otago Regional Council (LWRP Economic Work Programme), Dunedin.

Moran, E. (2023). "The nature of economic analysis for resource management." *In Economic methods and impact assessment*, NZAIA Impact Connector 15.

Moran, E., McDonald, N., & McKay, D. (2022). Farm Debt, *Farm Viability and Freshwater Management in Pastoral Southland: A Report from The Farm Debt Working Group.* Environment Southland, Invercargill.

Morton, J. D., & Roberts, A. H. C. (2018). Fertiliser Use on New Zealand Sheep and Beef Farms (5th Edition ed.). *Fertiliser Association of New Zealand.* https://www.fertiliser.org.nz/Site/resources/booklets.aspx

Muller, C. F. & Neal, M. B. (2019). The impact of nutrient regulations on dairy farm land values in Southland. *New Zealand Journal of Agricultural Research,* 62(4), 457-475. https://doi.org/10.1080/00288233.2018.1509876

New Zealand Government. (1949). *Royal Commission to Inquire Into and Report Upon the Sheep-Farming Industry in New Zealand* (Report, March, 1949. Session I, H-46a) [Appendix to the Journals of the House of Representatives, 1949]. R. E. Owen, Government Printer, Wellington. https://atojs.natlib.govt.nz/cgi-bin/atojs?a=d&d=AJHR1949-I.2.4.2.12&e=-------10--1------0--

Ministry for the Environment. (2020, p50). National Policy Statement for Freshwater Management. Welilington. https://environment.govt.nz/publications/national-policy-statement-for-freshwater-management-2020-amended-february-2023/

Pearce, T., Norton, S., & Fung, L. (2022). Deer Farming. In E. Moran (Ed.), *Famers and Growers in Otago* (p. 70). EM Consulting for Otago Regional Council (LWRP Economic Work Programme), Dunedin.

Quin, B. F., & Zaman, M. (2012). RPR revisited (1): Research, recommendations, promotion and use in New Zealand. *Proceedings of the New Zealand Grassland Association,* 74, 255-268.

Reilly, K. (2023). *Otago Catchment Stories Summary Report.* Landpro Limited for Otago Regional Council (LWRP Economic Work Programme), Dunedin.

Ribaudo, M. O., Horan, R.D., & Smith, M.E. (1999). *Economics of Water Quality Protection From Nonpoint Sources: Theory and Practice.* (Agricultural Economic Report No. 782). Resource Economics Division, Economic Research Service, U.S. Department of Agriculture.

Ross, C. (2022) Dairy Farming. In E. Moran (Ed.), *Famers and Growers in Otago (p. 115).* EM Consulting for Otago Regional Council (LWRP Economic Work Programme), Dunedin.

Smith, L. C., & Muirhead, R. W. (2023). A review of the effectiveness of sediment traps for New Zealand agriculture. *New Zealand Journal of Agricultural Research.* https://doi.org/10.1080/00288233.2023.2184838

Tanner, C. C., Depree, C. V., Sukias, J. P. S., Wright-Stow, A. E., Burger, D. F., & Goeller, B. C. (2022). *Constructed Wetland Practitioners Guide: Design and Performance Estimates.* DairyNZ and NIWA, Hamilton.

Tourism Central Otago. (2021). *Market Perceptions: Central Otago.* Visitor Insights Programme. Angus & Associates for Tourism Central Otago. https://centralotagonz.com/assets/PDFs/Central-Otago-Market-Perceptions-Q4-2021.pdf

Wilkinson, A. (2022). Viticulture. In E. Moran (Ed.) *Farmers and Growers in Otago* (p. 163). EM Consulting for Otago Regional Council (LWRP Economic Work Programme), Dunedin.

Yang, A. & Cardwell, R. (2023). Otago Economic Profile for Land and Water. Otago Regional Council LWRP Economic Work Programme), Dunedin.

Yao, F., Livneh, B., Rajagopalan, B., Wang, J., Crétaux, J., Wada, Y., & Berge-Nguyen, M. (2023). Satellites reveal widespread decline in global lake water storage. *Science, 380*(6466) 743-749. https://www.science.org/doi/10.1126/science.abo2812

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